Water Sensitive Urban Design Technical Manual

Contents

Chapter 1 Introduction

Chapter 2 WSUD Measures for Different Types and Scale of Development

Tables

Figures

Chapter 3 Designing a WSUD Strategy for Your Development

Tables

Figures

Appendices

Chapter 4 Demand Reduction

Tables

Figures

Appendices

Chapter 5 Rainwater Tanks

Tables

Figures

Appendices

Chapter 6 Rain Gardens, Green Roofs and Infiltration Systems

Tables

Figures

Appendices

Chapter 7 Pervious Pavements

Tables

Figures

Appendices

Chapter 8 Urban Water Harvesting and Reuse

Tables

Figures

Chapter 9 Gross Pollutant Traps

Tables

Figures

Appendices

Chapter 10 Bioretention Systems for Streetscapes

Tables

Figures

Appendices

Chapter 11 Swales and Buffer Strips

Tables

Figures

Appendices

Chapter 12 Sedimentation Basins

Figures

Appendices

Chapter 13 Constructed Wetlands

Tables

Figures

Appendices

Chapter 14 Wastewater Management

Tables

Figures

Appendices

Chapter 15 Modelling Process and Tools

Tables

Figures

Appendices

Glossary

Term	Explanation
Aquifers	Underground sediments or fractured rock that hold water and allow water to flow through them. Aquifers include confined, unconfined and artesian types
Average recurrence interval (ARI)	The average or expected value of the period between exceedances of a given discharge
Bioretention swale	A grassed or landscaped swale promoting infiltration into the underlying medium. A perforated pipe collects the infiltrated water and conveys it downstream. Flows are also conveyed along the surface of the swale prior to being infiltrated
Brownfield sites	Sites where there are opportunities to recycle redundant, surplus and in some cases inappropriately located facilities. Development on sites that have previously been used for urban land uses
Catchment	Area of land that collects rainfall and contributes to surface water (streams, rivers wetlands) or to groundwater
Class 1 buildings	(a) Class 1a – a single dwelling being – (i) a detached house; or (ii) one of a group of two or more attached dwellings, each being a building, separated by a fire-resisting wall, including a row house, terrace house, town house or villa unit; or (b) Class 1b – a boarding house, guest house, hostel or the like - (i) with a total area of all floors not exceeding 300 sqm measured over the enclosing walls of the Class 1b building; and (ii) in which not more than 12 persons would ordinarily be resident
Class 10 buildings	(a) Class 10a – a non habitable building being a private garage, carport, shed, or the like: or (b) Class 10b – a structure being a fence, mast, antennae, retaining or free-standing wall, swimming pool or the like
Commercial	Commercial uses can include, but are not limited to, automotive/equipment showrooms, food outlets, restaurants, hotels, garden centres, motels, offices, supermarkets and shops
Demand management	An approach that is used to reduce the consumption of water (also called water conservation)
Detention	Short term storage of runoff. The objective of a detention facility is to regulate the runoff from a given rainfall event and to control discharge rates to reduce the impact on downstream stormwater systems

Term	Explanation
Development	As defined by the *Development Act 1993*
Ecological footprint	Ecological footprinting seeks to determine what total area of land and/or water is required, regardless of where that land and/or water is located, to sustain a given population, organisation or activity. When used as a resource accounting tool, ecological footprinting can indicate when human demand for renewable resources exceeds nature's supply on a local, national or global scale
Ecologically sustainable development	Comprises the use, conservation, development and enhancement of natural resources in a way, and at a rate, that should enable people and communities to provide for their economic, social and physical wellbeing while sustaining the potential for natural resources to meet the reasonable foreseeable needs of future generations; safeguarding the life-supporting capacities of natural resources; avoiding, remedying or mitigating any adverse effects of activities on natural resources
Effluent	The outflow of water or wastewater from any water processing system or device
Environmental water requirement	The water regime needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk. Basically, this means what these ecosystems – including watercourses, riparian zones, wetlands, floodplains, estuaries, cave aquifer ecosystems – need
Eutrophication	The ecological changes that result from excess levels of nutrients in waterways and wetlands, often resulting in prolific aquatic plant growth and algal blooms. These conditions can cause a simplification of an ecosystem and a loss of biodiversity.
Evapotranspiration	Refers to the total loss of moisture from the soil to the atmosphere through the processes of evaporation and transpiration from growing plants
Greenfield sites	Development on broadacre/broadhectare (usually greater than 4000 square metres) land that has not previously been developed for urban land uses
Greywater	Wastewater from the hand basin, shower, bath, spa bath, washing machine, laundry tub, kitchen sink and dishwasher. Water from the kitchen is generally too high in grease and oil to be reused successfully without significant treatment
Groundwater	Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground

Term	Explanation
ICLEI	International association of local governments and national and regional local government organisations that have made a commitment to sustainable development
Impervious surfaces	Surfaces that do not allow natural infiltration of rainfall to the underlying soil, thereby increasing the volume and peak flow rate of surface runoff
Industrial	Relating to, derived from, or characteristic of industry. Means premises used for the manufacture, production, processing, altering, cleaning or repair of any article, material or thing whether solid, liquid or gaseous
Infill development	Additional development or redevelopment of land within existing urban areas
Macrophyte zone	Corresponds to the wet areas of a wetland that are covered with plants such as reeds and rushes. It is sometimes divided into a submerged macrophyte zone where the plants are fully underwater and usually need to stay underwater and an emergent macrophyte zone where plants, while living in the water, extend out above the water surface. Often also called a reed bed.
Managed aquifer recharge (MAR)	Managed aquifer recharge is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit
Nitrogen	An important nutrient found in high concentrations in recycled waters, originating from human and domestic wastes. A useful plant nutrient that can also cause off-site problems or eutrophication in lakes, rivers and estuaries. It can also contaminate groundwaters
Objectives	Statements of value that are to be pursued in the long term
Peak flow	The estimated maximum flow at a given location in a catchment, for a selected Average Recurrence Interval
Phosphorus	An important nutrient found in high concentrations in recycled waters, originating principally from detergents but also from other domestic wastes. A useful plant nutrient that can also cause off-site problems of eutrophication in water bodies. It may also be harmful to some native species
Pervious pavement	A type of pavement that does not contain fine particles, and which is designed to allow the infiltration of water to an underlying sub-base, thereby producing less runoff than conventional pavements
Potable water	Water suitable on the basis of both health and aesthetic consideration for drinking or culinary purposes (otherwise known as drinking water)

Term	Explanation
Pre-development	Pre-development refers to the situation where there is no development on the site which is considered to constitute the following scenarios: 1. If the site is currently developed, then the no development case is where runoff from the site assumes a cleared but grassed state 2. If the site is currently vegetated, then the no development case is where runoff from the site assumes the uncleared vegetated state
Prescription	Establishes a system for water resource planning and the sustainable allocation and management of water
Principles	Rules of conduct that are applied when implementing management actions or making decisions. They provide guidance on how decisions should be made
Retention	Permanent storing of runoff indefinitely. Water is stored until it is lost through percolation, taken in by plants, through evaporation or reuse
Runoff	Occurs as a result of rainfall and includes roof runoff (i.e. rainwater) and stormwater
Sediment	Small-grained material (such as sand, silt and clay) that is carried by water and is deposited on the surface of the land. Sediment is capable of choking and destroying natural aquatic ecosystems
Stormwater	Runoff from an area as a result of rainfall which is discharged to drainage infrastructure
Swale	Vegetated open channels that capture and treat stormwater runoff by means of filtering and conveyance during regular rainfall events with an average recurrence interval in the range of 3 to 6 months
Target	Detailed statements of outcomes against which the success of a plan or strategy can be measured and evaluated. They comprise a quantitative value of some condition or parameter that should be achieved
Treatment train	A series of treatment measures that collectively address all stormwater pollutants. A treatment train employs a range of processes to achieve pollutant reduction targets
Wastewater	Water that has been used for domestic or industrial purposes and is then discharged as waste. The water may be contaminated with solids, chemicals or changes in temperature

Abbreviations

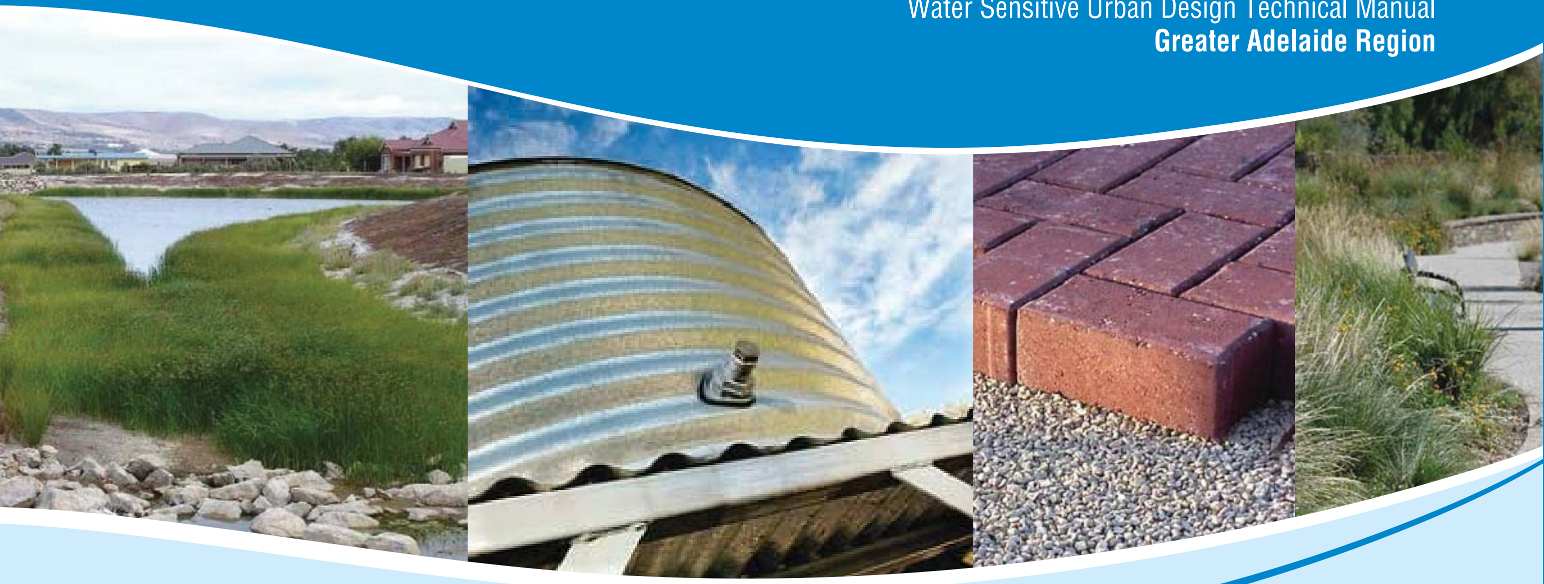
Abbreviation	Meaning
ARI	Average recurrence interval
ASR	Aquifer storage and recovery
BDP	Department of Planning and Local Government's Better Development Plans project
DAC	Development Assessment Commission
DEH	Department for Environment and Heritage
DPA	Development Plan Amendment (previously Plan Amendment Report (PAR))
DTEI	Department for Transport, Energy and Infrastructure
DWLBC	Department of Water, Land and Biodiversity Conservation
EDALA	Electronic land division lodgement
EPA	Environment Protection Authority
EPPs	Environment Protection Policies
ESD	Ecologically sustainable development
ICLEI	See Glossary
MAR	Managed aquifer recovery
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NRM	Natural Resources Management
PAR	Plan Amendment Report (now referred to as DPA)
PIRSA	Primary Industries and Resources South Australia
SA Water	SA Water Corporation
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
WSUD	Water Sensitive Urban Design
WTP	Water treatment plant
WWTP	Wastewater treatment plant

July 2009

Chapter 1

Introduction

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Chapter 1 Introduction

1.1 What is Water Sensitive Urban Design?

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- The use of vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- The utilisation of water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non-drinking water supplies.

WSUD recognises all water streams in the total water cycle as valuable resources:

- Rainwater (collected from the roof);
- Runoff (including stormwater, collected from all impervious surfaces);
- Potable mains water (drinking water);
- Groundwater;
- Greywater (from bathroom taps, showers and laundries); and
- Blackwater (from kitchen sinks and toilets).

By applying appropriate measures in the design and operation of development, it is possible to:

- Maintain and restore the natural water balance;
- Reduce flood risk in urban areas;
- Reduce erosion of waterways, slopes and banks;
- Improve and protect water quality of surface and groundwater;
- Make more efficient use of water resources;
- Reduce the cost of providing and maintaining water infrastructure;

- Minimise demand on the reticulated water supply system;
- Protect and restore aquatic and riparian ecosystems and habitats;
- Protect the scenic, landscape and recreational values of streams;
- Minimise treated wastewater discharges to the natural environment;
- Integrate water into the landscape to enhance visual, social, cultural, biodiversity and ecological values; and

- Reduce greenhouse gas emissions by reducing water consumption, increasing rainwater harvesting and 'natural' treatment alternatives.

1.2 Water Sensitive Urban Design Objectives and Principles

Objectives

The overarching objective (or vision) of WSUD in the Greater Adelaide Region is to stabilise and improve the health of the Greater Adelaide Region's coastal waters, inland watercourses and groundwater systems, while maintaining and enhancing human health and reducing the ecological footprint of the Greater Adelaide Region.

Other key objectives of implementing WSUD are to:

- Move towards a natural flow regime (for example, lower flows to reduce erosion of creeks and improve or maintain ecological value);
- Manage risk in relation to drought, flood, climate change and public health;
- Protect, enhance, value and conserve water resources;
- Encourage leading practice in the use and management of water resources so as to increase water efficiency, reduce reliance on imported water and apply at-source reduction of impacts on water quality, flooding, erosion and sedimentation;
- Raise awareness and catalyse change in the design, construction and management of urban development and urban infrastructure; and
- Recognise and foster the significant environmental, social and economic benefits that result from sustainable and efficient use of water resources.

Further information about objectives is contained in **Appendix C** of **Chapter 3**.

Principles

There are a number of guiding principles that underpin the objectives for water management and the implementation of WSUD in the Greater Adelaide Region. These principles should be addressed when undertaking the planning and implementation of water management on a site, catchment or regional scale.

The guiding principles include to:

- Incorporate water resources as early as possible in the land use planning process;
- Address water resource issues at the catchment and sub-catchment level;
- Ensure water management planning is precautionary, and recognises inter-generational equity, conservation of biodiversity and ecological integrity;
- Recognise water as a valuable resource and ensure its protection, conservation and reuse;

- Recognise the need for site-specific solutions and implement appropriate non-structural and structural solutions;
- Protect ecological and hydrological integrity;
- Integrate good science and community values in decision making; and
- Ensure equitable cost sharing.

Further information about principles is contained in **Appendix D** of **Chapter 3.**

1.3 Purpose, Target Audience and Scope of the Technical Manual

Purpose

WSUD promotes innovative integration of urban water management technologies into an urban environment.

The aim of the Technical Manual is to:

- Demonstrate how WSUD can be successfully incorporated into a range of projects, illustrating example measures;
- Provide a consistent approach to the planning and design of WSUD measures for urban developments across the Greater Adelaide Region;
- Inform and guide urban management decision making processes;
- Help increase awareness and appreciation of WSUD; and
- Encourage the consideration of factors including landscaping, biodiversity and greenhouse gas emissions early in the design process.

The Technical Manual outlines a WSUD planning process, design procedures, simplified design tools and checklists for individual WSUD measures that can be used by a range of audiences.

The Manual is not meant to be prescriptive, rather it provides a range of opportunities and techniques that can be employed to achieve the consenting authority's primary objective(s) and also assist in achieving regional and state targets.

Target Audience

The successful incorporation of WSUD into urban activities and development requires a multi-disciplinary approach to ensure a sustainable design and layout of a development. Typically this would involve all, or a combination, of a range of the following professions:

- Engineers;
- Planners;
- Urban designers;
- Architects;
- Landscape architects; and
- Environmental scientists/ecologists.

The target audience for the Technical Manual is therefore wide ranging and includes the above professions as well as:

- Applicants (or developers);
- Development assessment staff involved in the formulation and evaluation of WSUD strategies;
- Local government staff and those from the professions listed above; and
- South Australian Government agency staff.

It has been assumed that the reader is familiar with the land development process, the planning framework for land rezoning and the development approval process in their local area. Further information on the planning and development system in South Australia can be obtained from the Department of Planning and Local Government website, www.planning.sa.gov.au

Use of the Technical Manual by Applicants

The purpose of the Technical Manual for applicants is to:

- Provide a tool for developing design responses that incorporate better water management and biodiversity practices and which meet defined performance standards; and
- Help in the preparation of conceptual and detailed designs for WSUD systems as part of a development proposal.

Chapter 2 should be used in the selection, location and conceptual design of WSUD measures. This section should be applied as early as possible to the development design process to ensure:

- Impacts on the water cycle are minimised;
- WSUD is considered in the initial development design and layout; and
- Suitable WSUD measures are identified to adequately address and meet applicable water quality and quantity objectives and targets.

Chapter 3 should be used to assist in determining the requirements of councils for documentation of conceptual and detailed options.

Use of the Technical Manual by Local Government

Local government can use the Technical Manual to provide:

- Better advice to actively guide WSUD planning, design and installation in the Greater Adelaide Region in a consistent manner; and
- A clear and transparent development assessment process for WSUD measures and promotion of the achievement of water quality and quantity objectives and targets.

Specifically councils can use:

- Design Assessment Checklists which provide a template for checking development submissions, ensuring a sufficient level of detail is presented for assessment; and

- Inspection Forms and Maintenance Checklists to help ensure WSUD measures are built as designed, are maintained and are in good operating condition prior to asset handover to council.

Scope of the Technical Manual

This Manual aims to provide WSUD leading management practice information for a range of WSUD measures suitable for application at different scales. In particular the WSUD measures outlined in this document are based upon innovative WSUD methods which have proven environmental, aesthetic and economic outcomes and are applicable to the local environment of the Greater Adelaide Region. However, it should be noted that the WSUD measures outlined is not an exhaustive list of all possible WSUD components that could be used in urban areas. Nonetheless, the documents do include those measures that are most likely to be used in the Greater Adelaide Region.

Managing urban runoff as a resource, for the protection of receiving ecosystems and for flood prevention are key elements of WSUD, and in this first version of the Technical Manual, urban runoff (including rainwater and stormwater) is the main focus of the tools presented. However, opportunities for on-site and community treated wastewater reuse should also be encouraged, so general information has also been included. It is envisaged that future editions of the Technical Manual will include more comprehensive coverage of treated wastewater reuse as this becomes more widely accepted and practical for general application.

1.4 Structure of the Technical Manual

This Technical Manual is comprised of 15 chapters.

- **Chapter 1 – Introduction and Snapshot of WSUD Measures (the 'WSUD Toolkit')**

Introduces WSUD and provides an introductory overview of 11 WSUD management strategies, including technologies and design features, detailed in this Manual.

- **Chapter 2 – WSUD Measures for Different Types and Scales of Development**

Presents various WSUD options for different types and scales of development, ranging from single residential houses through to residential subdivisions, multi-unit developments, open space and commercial and industrial sites.

Research and experience demonstrates that WSUD measures can be designed for all types of development, including in the inner city where limited space is available. A design response may utilise a single WSUD measure or it may combine several to achieve the necessary outcomes.

- **Chapter 3 – Designing a WSUD Strategy for Your Development**

Outlines a 12 step design process required to successfully incorporate WSUD measures into a development or redevelopment.

- **Chapters 4 to 14**

Outline in detail the 11 WSUD tools contained within this Technical Manual.

These are:

- Demand Reduction – **Chapter 4**
- Rainwater Tanks – **Chapter 5**
- Rain Gardens, Green Roofs and Infiltration Systems – **Chapter 6**
- Pervious Pavements – **Chapter 7**
- Urban Water Harvesting and Reuse – **Chapter 8**
- Gross Pollutant Traps – **Chapter 9**
- Bioretention Systems for Streetscapes – **Chapter 10**
- Swales and Buffer Strips – **Chapter 11**
- Sedimentation Basins – **Chapter 12**
- Constructed Wetlands – **Chapter 13**
- Wastewater Management – **Chapter 14**

- **Chapter 15 - Modelling Process and Tools**

Provides an overview of the modelling process and the modelling tools that are available and applicable to the Greater Adelaide Region.

The Technical Manual will be a 'living document' and will be reviewed and updated regularly.

The Technical Manual complements existing local and interstate resources, in particular the *WSUD: Basic Procedures for 'Source Control' of Stormwater* (Allen et al. 2005).

1.5 Snapshot of 11 WSUD Measures

This section introduces the 11 WSUD measures described in **Chapters 4 to 14** of the WSUD Technical Manual for the Greater Adelaide Region.

Included is a table summarising the focus and suitability of each measure to certain circumstances.

1.5.1 Demand Reduction

(See **Chapter 4** of the WSUD Technical Manual.)

Description

New development, redevelopment and alterations to existing buildings can contribute to environmental sustainability by incorporating a variety of water efficiency (or demand reduction) measures.

Purpose

The purpose of demand reduction is to conserve water supplies.

Application / Scale

Demand reduction applies to residential, commercial, industrial, community service and recreational developments, redevelopments and retrofitting. Demand reduction is applicable at the allotment level.

Example Measures

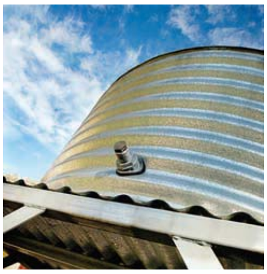
The following measures can be applied:

- Water-efficient fixtures and appliances;
- Rainwater tanks;
- Landscape practices;
- Treated runoff and wastewater reuse; and
- Education and incentives.

1.5.2 Rainwater Tanks

(See **Chapter 5** of the WSUD Technical Manual.)

Description



A rainwater tank is designed to capture and store roof runoff (i.e. rainwater) from gutters or downpipes on a building and does not generally collect water other than roof runoff or mains water. Harvested water is then available for toilet flushing, laundry uses, hot water uses, outdoor irrigation or drinking (following filtration).

Purpose

Rainwater tanks provide a simple means of achieving several environmental benefits, including:

- Potential reduction in peak runoff rates and volumes and the consequent negative environmental impacts (including flooding, pollution and erosion);
- Reduction in importation of water from distant catchments; and
- Reduction in drinking water (or mains water) consumption.

Application / Scale

Rainwater tanks are generally applied at the allotment scale, but can be applied at the street scale in larger development projects.

Rainwater tanks can be utilised on residential, commercial, recreational, institutional and industrial development sites. Adelaide currently has the highest adoption rate of rainwater tanks of any state capital city in Australia.

Example Measures

Rainwater tanks come in a variety of shapes and sizes including standard exterior tanks made from galvanized steel (or similar), plastic or fibreglass and wall-cavity tanks, subsurface tanks, special rainwater storage guttering and under-floor water storage pillows. In addition, indoor modular tanks and underground storage systems are now readily available. Slimline tanks and integrated fence systems that incorporate rainwater storage are also useful in restricted spaces.

1.5.3 Rain Gardens, Green Roofs and Infiltration Systems

(See **Chapter 6** of the WSUD Technical Manual.)

Overview

Source control is one of the most effective ways of managing runoff in an urban catchment. Managing runoff at the source provides more opportunities to achieve a hydrological cycle that is closer to the predevelopment (natural) regime. WSUD measures that can be implemented at the site level include rain gardens, green roofs and infiltration systems. They have the ability to intercept runoff, treat it and promote infiltration to the soil with subsequent recharge of the groundwater system.

Rain gardens, green roofs and infiltration systems are discussed in the same chapter of the Technical Documents as all on-site measures with similar functions.

Rain Gardens

Description

Rain gardens resemble a regular garden with one major difference – they have runoff directed into them from downpipes or paved areas. They assist in the infiltration of runoff into underlying soils.

Purpose

Rain gardens retain runoff for infiltration into the soil. In doing so, rain gardens reduce the amount of runoff that would otherwise wash pollutants quickly into the stormwater drainage system. Rain gardens also treat the runoff while providing habitat for native fauna.

Application / Scale

Rain gardens can be applied at the allotment scale as well as being incorporated into landscaping within major developments. They are appropriate for commercial, industrial, institutional, recreational and residential sites, and can be incorporated into new construction or added to existing gardens during renovation.

A wide range of native species are suitable for rain gardens.

Green Roofs

Description

Green roofs are also known as rooftop gardens, vegetated roof covers, living roofs, eco-roofs and nature roofs.

Green roofs are a series of layers consisting of living vegetation growing in substrate over a drainage layer on top of built structures, either new or retrofitted. Under the substrate is usually a range of protective barriers that prevent the penetration of water and roots.

There are four types of green roofs. The primary difference is the depth of the substrate, which has a direct relationship to runoff holding capacity.

Purpose

The benefits of green roofs include:

- Managing runoff;
- Improving water quality;
- Reducing impervious areas;
- Reducing the Heat Island Effect;
- Reducing air pollution;
- Increasing biodiversity;
- Improving insulation;
- Increasing carbon dioxide/oxygen exchange; and
- Additional living space.

Application / Scale

Green roofs are appropriate for commercial and industrial structures as well as residential buildings. They can be installed on flat roofs but also can be built on roofs with slopes up to 30 degrees. Green roofs can be incorporated into the design of new construction or retrofitted into existing buildings.

Infiltration Systems

Description

Infiltration systems generally consist of a shallow excavated trench or 'tank', designed to detain (and retain) a certain volume of runoff and subsequently infiltrate the stored water to the surrounding soils. They reduce runoff volumes by providing a pathway for treated runoff to recharge local groundwater aquifers.

Purpose

The main purpose of infiltration systems is to facilitate infiltration of surface waters to groundwater.

Application / Scale

Infiltration systems are highly dependent on local soil characteristics and are best suited to sandy soils with deep groundwater. Infiltration measures generally require pre-treatment of runoff before infiltration to avoid clogging of the surrounding soils and to protect groundwater quality.

Infiltration systems are required to have sufficient setback distances from structures to avoid any structural damage from the wetting and drying of soils (e.g. from soil shrinkage). These setback distances depend on local soil conditions.

1.5.4 Pervious Pavements

(See **Chapter 7** of the WSUD Technical Manual.)

Description

Pervious pavements (also known as porous and permeable pavements) are pavements that allow the ingress of water and flow through to the paving substrate and eventually into the underlying subsoil.

More recent developments have seen storage systems being incorporated underneath pervious pavements so that the filtered water can be recovered and reused.

Purpose

The purpose of pervious pavements is to:

- Provide for on-site retention of runoff, thereby reducing peak flows;
- Reduce the overall volume of runoff from a site; and
- Minimise the export of sediments and pollutants from a site.

When coupled with underlying or offline storages (and associated reuse) their effectiveness can be significant.

Application / Scale

Pervious paving can be used as an alternative to conventional paving and hardstand surfaces within urban developments to reduce runoff velocity and volume. They are most appropriately used in residential situations where vehicle traffic is low and where there are low sediment loads.

Example Measures

A number of pervious paving types are available, each with advantages and disadvantages for various applications, including:

- Porous asphalt or concrete (monolithic structures) – open graded asphalt or concrete with reduced or no fines and a special binder that allows water to pass through the pavement by flowing through voids between the aggregate.
- Modular pavers – these pavers may be made from porous material or from non-porous clay or concrete. They are usually installed with gaps between the pavers to allow water to penetrate into the subsurface.
- Grid or lattice systems – these are made of concrete or plastic grids filled with soil or aggregate through which water can percolate. These systems may also be vegetated (usually with grass).

1.5.5 Urban Water Harvesting and Reuse

(See **Chapter 8** of the WSUD Technical Manual.)

Description

Urban water harvesting and reuse refers to the collection and reuse of various water sources for drinking and non-drinking water substitution purposes.

Purpose

The purpose of urban water harvesting and reuse schemes is to:

- Conserve water;
- Prevent increased stream erosion;
- Maintain water balance;
- Provide on-site detention (and retention) and therefore reduce peak runoff rates and volume; and
- Improve water quality.

An integrated urban water harvesting and reuse scheme should provide at least five core functions: (a) collection; (b) treatment; (c) storage; (d) flood and environmental flow protection; and (e) distribution to the end user.

Figure 1.1 Grange Golf Course, Stormwater Harvesting and Reuse

Source: Courtesy of Adelaide and Mt Lofty Ranges Natural Resources Management Board

Application / Scale

Urban water harvesting and reuse schemes can be applied at the street, precinct or catchment scale and can utilise various sources of water including rainwater, stormwater and, at the subdivision scale, occasionally treated wastewater.

One of the greatest challenges facing water harvesting and reuse is the storage of water for subsequent use. Water harvested can be stored using, for example, underground or above ground storage tanks, in a basin or in an aquifer.

Example Measures

Typical measures include:

- Wetlands;
- Managed aquifer recharge (otherwise known as aquifer storage and recovery);
- Rainwater tanks;
- Ponds and lakes;
- Pervious pavement systems with underlying or offline storages; and
- Underground or subsurface tanks.

1.5.6 Gross Pollutant Traps

(See **Chapter 9** of the WSUD Technical Manual.)

Description

Gross pollutant traps (GPTs) are constructed devices designed to remove solids (usually greater than 5 millimetres in diameter) from the stormwater drainage system. They remove the large debris washed into the stormwater system before the stormwater enters the receiving waters. GPTs are also known as litter traps or trash racks. It should be noted that trash racks often target solids greater than 60 millimetres in diameter.

Purpose

The use of GPTs for pre-treatment can be for either improved aesthetics in receiving waters or to maintain the integrity of additional treatment devices located further downstream within an integrated treatment train.

Application / Scale

GPTs are generally applied on the catchment scale.

Example Measures

There are many differing types of GPTs that are commercially available. They can range from simple to complex constructions including:

- Simple grated entry pits, suited to preventing large litter items from entering the drainage system;
- Side entry pit inserts, formed by simple baskets or screens placed at, or close after, the throat entry. They typically have screen sizes between 5 and 20 millimetres;
- Proprietary manufactured traps which fall into three broad types:
  - Boom diversion systems (e.g. CSR Humes);
  - Return flow litter baskets (e.g. Ecosol);
  - Continuous deflection separation (e.g. CDS Technologies).

These devices vary greatly, though in general GPTs should be designed to capture gross pollutants and coarse sediment up to a three month average recurrence interval (ARI) flow.

1.5.7 Bioretention Systems

(See **Chapter 10** of the WSUD Technical Manual.)

Bioretention systems refer to both bioretention swales and bioretention basins, which are both vegetated WSUD systems. A particular challenge in Adelaide is to provide sufficient water to maintain the vegetation during the long interstorm dry periods commonly experienced in South Australia. In summer, in particular, the vegetation not only suffers from water shortage but often heat stress as well. Another consequence of these long hot periods is that vegetated systems often leach nitrogen following microbial and plant die-off (Kim et al, 2003). Chapter 10 describes how to incorporate design features to ameliorate these effects.

Bioretention Swales

Description

Sometimes called filtration trenches or bioretention trenches, bioretention swales are a subsurface water filtration system capable of holding runoff to allow it to infiltrate and/or be temporarily detained to achieve some water quality improvement.

Figure 1.2 Bioretention Swale, Western Boulevard, Melbourne

Source: Courtesy of University of South Australia

Runoff is 'filtered' through a prescribed filter media (for example a sandy loam) as it percolates downwards under gravity. This filtered runoff is then collected at the base of the filter media via perforated pipes and flows to downstream waterways or to storages for potential reuse. Should in-situ soil conditions be favourable, infiltration can be encouraged from the base of a bioretention swale to recharge local groundwater and to reduce surface runoff volumes.

Purpose

Bioretention swales can provide the following functions:

- Provide infiltration of runoff into the ground;
- Provide on-site detention and retention capacity;
- Conveyance;
- Improve water quality discharging from the swale; and
- Reduce the peak flow of a storm event in the system.

Concerns are often raised in relation to such devices in clay or rocky soils. Unlike infiltration systems, bioretention swales are well suited to a wide range of soil conditions, including low hydraulic conductivity 'clay' soils and areas affected by soil salinity and saline groundwater, as their operation is often designed to minimise or eliminate exfiltration from the filter media to surrounding in-situ soils.

Vegetation that grows in the filter media of bioretention swales is an integral component of these treatment systems. Both the vegetation and the filter media have functional roles in the treatment of runoff and it is the intrinsic relationship between the two that ensures the long-term functional performance of the system.

Application / Scale

Bioretention swales can form attractive streetscapes and provide landscape features in an urban development. They are commonly located in the median strip of divided roads, in carparks and in parkland areas. Bioretention swales offer opportunities in both new construction and retrofit situations.

Bioretention Basins

Description

Bioretention basins operate with the same treatment processes as bioretention swales except they do not have a conveyance function. High flows are either diverted (bypassed) away from the basin or are discharged into an overflow structure.

Purpose

Like bioretention swales, bioretention basins can provide efficient treatment of runoff through fine filtration, extended detention treatment and some biological uptake, particularly for nitrogen and other soluble or fine particulate contaminants.

Application / Scale

Bioretention basins have an advantage of being applicable at a range of scales and shapes and therefore provide flexibility for locations within a development.

They are equally applicable to redevelopment sites and greenfield sites. Smaller systems may take the form of 'planters' that can be located within allotments (e.g. gardens) and along roadways at regular intervals (e.g. in traffic calming devices) to create a boulevard aesthetic. All of these systems treat runoff close to its source and prior to entry into an underground drainage system.

Larger bioretention basins may be located at outfalls of a drainage system (e.g. in the base of retarding basins) to provide 'end-of-pipe' treatment to runoff from larger subcatchments where 'at source' applications may not be feasible. The positioning of large size bioretention basins and the resultant delivery of runoff into the basin needs to be considered to avoid scour and to ensure even distribution over the full surface area of the filter media.

A wide range of vegetation can be used within bioretention basins, allowing them to be easily integrated into the landscape theme of an area. As for bioretention swales, vegetation that grows in the filter media of bioretention basins is an integral component of these treatment devices. Bioretention basins are however sensitive to any materials that may clog the filter medium or damage the vegetation and therefore vehicles, building materials and construction washdown wastes should be kept away from bioretention basins.

Figure 1.3 Bioretention Basin, Palmer Road, Aldinga Beach

Source: Courtesy of City of Onkaparinga

1.5.8 Swales and Buffer Strips

(See **Chapter 11** of the WSUD Technical Manual.)

Swales

Description

Swales are linear depressions that are used for the conveyance of stormwater runoff. They can be grassed or more densely vegetated with a variety of species.

Purpose

Swales provide a number of functions, including:

- Reducing the speed of runoff;
- Capturing sediments and attached pollutants;
- Reducing total runoff through infiltration (this is often only significant when coupled with an infiltration trench);
- Accommodating pedestrian movement across and along them when grassed; and
- Adding to the local amenity.

Figure 1.4 Swale at Pine Lakes, City of Salisbury

Source: Courtesy of City of Salisbury

Swales are used to convey runoff in lieu of, or in association with, underground pipe drainage systems and can be used to capture coarse and medium sediment. They are commonly used as part of an overall treatment train to deliver acceptable quality for discharge to aquatic ecosystems or for potential reuse applications.

Swales can be particularly useful for conveying overland flow into other downstream WSUD components such as bioretention basins or wetlands.

Swales also disconnect impervious areas from hydraulically efficient pipe drainage systems. This is important for protecting aquatic ecosystems in receiving waterways by managing the frequency of damage to aquatic habitats by storm flows. This is due to slower travel times for flows along swale systems compared with efficient pipe drainage systems. This reduces the rapid response from impervious areas, particularly for frequent storm events, and reduces the impact on natural receiving waterways.

Application / Scale

Swales can be incorporated into urban designs along streets (within the median strip or footpaths), in parklands and between allotments where maintenance access can be preserved. In addition to their treatment function, these systems can add to the aesthetic character of an area. Careful consideration is required with the establishment phase and irrigation requirements during prolonged dry spells.

Buffer Strips

Description

Buffer strips are broad sloped areas of grass or other dense vegetation, capable of withstanding shallow sheet flow stormwater runoff.

Purpose

Buffer strips:

- Remove sediment and pollutants from runoff prior to entering a drainage system;
- Provide some reduction in runoff volume through infiltration; and
- Offer a small reduction in peak volumes through attenuated runoff.

The vegetation used in buffer strips is important as grass density and length affect performance.

1.5.9 Sedimentation Basins

(See **Chapter 12** of the WSUD Technical Manual.)

Description

Sedimentation basins (otherwise known as sediment basins) can take various forms and can be used as either permanent systems integrated into an urban design or used as temporary structures to reduce sediment discharge during construction activities.

Sedimentation basins are used to retain coarse sediments from runoff and are typically the first element in a treatment train. Within a treatment train they play an important role by protecting downstream elements from becoming overloaded or smothered with sediments, thus optimising treatment performance and minimising ongoing maintenance costs.

Figure 1.5 Brookes Bridge Sedimentation Basin

Source: Courtesy of Australian Water Environments

Purpose

Sedimentation basins operate by reducing flow velocities and encouraging sediments to settle out of the water column.

They can also be designed as ephemeral systems, allowing them to drain during periods without rainfall and then to refill during runoff events.

Sedimentation basins are typically installed to perform two key roles:

- Coarse sediment removal; and
- Flow regulation.

Application / Scale

Within a treatment train, sedimentation basins are typically installed upstream of a constructed wetland or a bioretention basin. In some cases a sedimentation basin can be converted to a wetland when receiving sediment loads have reduced to an appropriate level.

Sedimentation basins are also often used on construction sites.

Example Measures

Sedimentation basins can have various configurations including hard edges and base (e.g. concrete), or a more natural form with edge vegetation.

1.5.10 Constructed Wetlands

(See **Chapter 13** of the WSUD Technical Manual.)

Description

Constructed wetlands are created, constructed versions of a natural wetland system that use vegetation, enhanced sedimentation, fine filtration and biological pollutant uptake processes to improve water quality.

Figure 1.6 Laratinga Wetlands, Mt Barker

Source: Courtesy of the District Council of Mt Barker

Constructed wetlands generally comprise:

- A sedimentation basin in the form of a deep open pond at the stormwater entry point to remove coarse sediments;
- A range of shallow (but variable depth) water areas containing dense macrophytic planting to remove fine particulates and to provide uptake of soluble pollutants; and
- A high flow bypass channel (to protect the macrophyte zone from high velocity flood flows).

Purpose

Wetlands function to improve water quality by:

- Removing sediments and suspended solids, together with their attached pollutants; and
- Removing a range of dissolved nutrients and contaminants.

In addition to playing an important role in water treatment, wetlands can also have significant community benefits. They provide habitat for wildlife and a focus for recreation, such as walking paths and other passive recreational pursuits. They can also improve the aesthetics of a development (and therefore the value) and be a central feature in a landscape.

The detailed design and construction of wetlands is a relatively complex task.

Application / Scale

Wetlands can be constructed on many scales, from housing estate scale to large regional systems. In highly urbanised areas they can have a hard edge form and be part of a streetscape or used in the forecourts of buildings. In regional settings they can be over 10 ha in size and provide significant habitat for wildlife. Wetlands are commonly associated with managed aquifer recharge (MAR) schemes, as a form of pre-treatment and temporary storage.

1.5.11 Wastewater Management

(See **Chapter 14** of the WSUD Technical Manual.)

Overview

The majority of water used for indoor purposes is discharged after use as wastewater. Wastewater can be collected by a reticulated sewerage system and treated at a conventional wastewater treatment plant (WWTP). Alternatively, it can be collected, treated and reused on site, thereby promoting more efficient water use. While this has many economic and environmental benefits for the community, it needs to be balanced against potential health risks.

On-site reuse of treated domestic wastewater is subject to various restrictions due to concerns associated with effluent quality, maintenance of the treatment system and public health issues.

Appropriately utilising treated greywater for non-drinking purposes can save significant quantities of mains water. It can also reduce wastewater volumes requiring treatment at conventional WWTPs.

For reuse schemes, extensive treatment of wastewater is often required for water to be used for toilet flushing and garden irrigation.

Purpose

Sustainable water management is an important goal and a key element of urban development. Government authorities and the land development industry are increasingly seeking to use alternative sources, such as treated wastewater, to conserve drinking water supplies and minimise wastewater disposal to the marine environment.

Application / Scale

Treated wastewater should be considered in the context of the specific development and management of the total water cycle. The potential for treatment and reuse of wastewater will depend on:

- The scale and location of the development;
- The volume, quality and timing of wastewater generated; and
- The volume, quality and timing of treated wastewater demand.

Options for treatment and reuse of wastewater are applicable at a range of scales including on site, community and regional and for a range of types of development including residential, commercial and industrial.

Before developing a wastewater treatment and reuse system it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to wastewater in your area, through consultation with your local council.

1.5.12 Summary Table

Table 1.1 contains a summary of the WSUD measures including:

- The focus of each measure (water quality and/or water quantity);
- Potential benefits;
- Suitable site conditions; and
- Unsuitable conditions.

Table 1.1 WSUD Measures: Role, Focus, Site Conditions and Benefits

Measure	Focus of WSUD Measure		Potential Benefits	Suitable Site Conditions	Unsuitable Conditions
	Water Quality	Water Quantity			
Demand Reduction (Chapter 4)	Low	High	Reduction in mains water supply	Residential, commercial and industrial sites	Where water quality does not meet end use requirements
Rainwater Tanks (Chapter 5)	Low	High	Storage for reuse. Sediment removal in tank. Frequent flood retardation	Proximity to roof. Suitable site for gravity feed. Need to incorporate into urban design	Non-roof runoff treatment. Where tank water is not used on a regular basis
Rain Gardens (Chapter 6)	Medium	High	Volume retention. Water quality improvement	Allotment scale	Reactive clay sites. Near infrastructure
Green Roofs (Chapter 6)	Medium	Medium	Retention of water. Biodiversity	Flat roofs, slopes up to 30 degrees	Roofs that are not structurally suitable
Infiltration Systems (Chapter 6)	High	Medium	Volume retention. Water quality improvement	Precinct scale	Non-infiltrative soils. High groundwater levels
Pervious Pavements (Chapter 7)	High	Medium	Retention and detention of runoff	Allotments, roads and car parks	Severe vehicle traffic movement and developing catchments with high sediment load

Measure	Focus of WSUD Measure		Potential Benefits	Suitable Site Conditions	Unsuitable Conditions
	Water Quality	Water Quantity			
Urban Water Harvesting and Reuse (Chapter 8)	Medium	High	Reduction in mains water supply	Residential, commercial and industrial, generally more viable for precinct scale sites	Locations where demand is limited or adverse impacts to downstream users
Gross Pollutant Traps (Chapter 9)	High	Low	Reduces litter and debris. Can reduce sediment. Pre-treatment for other measures	Site and precinct scales	Sites larger than 100 ha. Natural channels. Low lying areas
Bioretention Systems (Chapter 10)	High	Low	Fine and soluble pollutants removal. Streetscape amenity. Frequent flood retardation	Flat terrain	Steep terrain. High groundwater table
Swales (Chapter 11)	Low	Low	Medium and fine particulate removal. Streetscape amenity. Passive irrigation	Mild slopes (< 4%)	Steep slopes
Buffer Strips (Chapter 11)	High	Low	Pre-treatment of runoff for sediment removal. Streetscape amenity	Flat terrain	Steep terrain
Sedimentation Basins (Chapter 12)	High	Medium	Coarse sediment capture. Temporary installation. Pre-treatment for other measures.	Need available land area	Where visual amenity is desirable
Constructed Wetlands (Chapter 13)	High	Medium	Community asset. Medium to fine particulate and some soluble pollutant removal. Flood retardation. Storage for reuse. Wildlife habitat	Flat terrain. Need available land area	Steep terrain. High groundwater table
Wastewater Management (Chapter 14)	Medium	High	Nutrient reduction to receiving environments. Fit for purpose substitution	Where adequate treatment and risk management can be ensured	

Source: Adapted from City of Yarra (2006) and Knox City Council (2002)

1.6 References

Argue, J. R. (Ed, 2009) *WSUD: basic procedures for 'source control' of stormwater - a Handbook for Australian practice.* Editor: Argue, J.R., Authors: Argue, J.R., Allen, M.D., Geiger, W.F., Johnston, L.D., Pezzaniti, D., Scott, P., Centre for Water Management and Reuse, University of South Australia, 5th Printing, February 2009, ISBN 1-920927-18-2, Adelaide.

CSIRO (1999). *Urban Stormwater: Best Practice Environmental Guidelines.* Victorian Stormwater Committee, Water and Rivers Commission. Melbourne, Australia. http://www.publish.csiro.au/nid/197/issue/3822.htm.

City of Yarra (2006). *Water Sensitive Urban Design Guidelines*. http://www.yarracity.vic.gov.au/Council/Meetings/pdf/agendas06/Nov%20PE&I/3.4%20ATT2a.pdf.

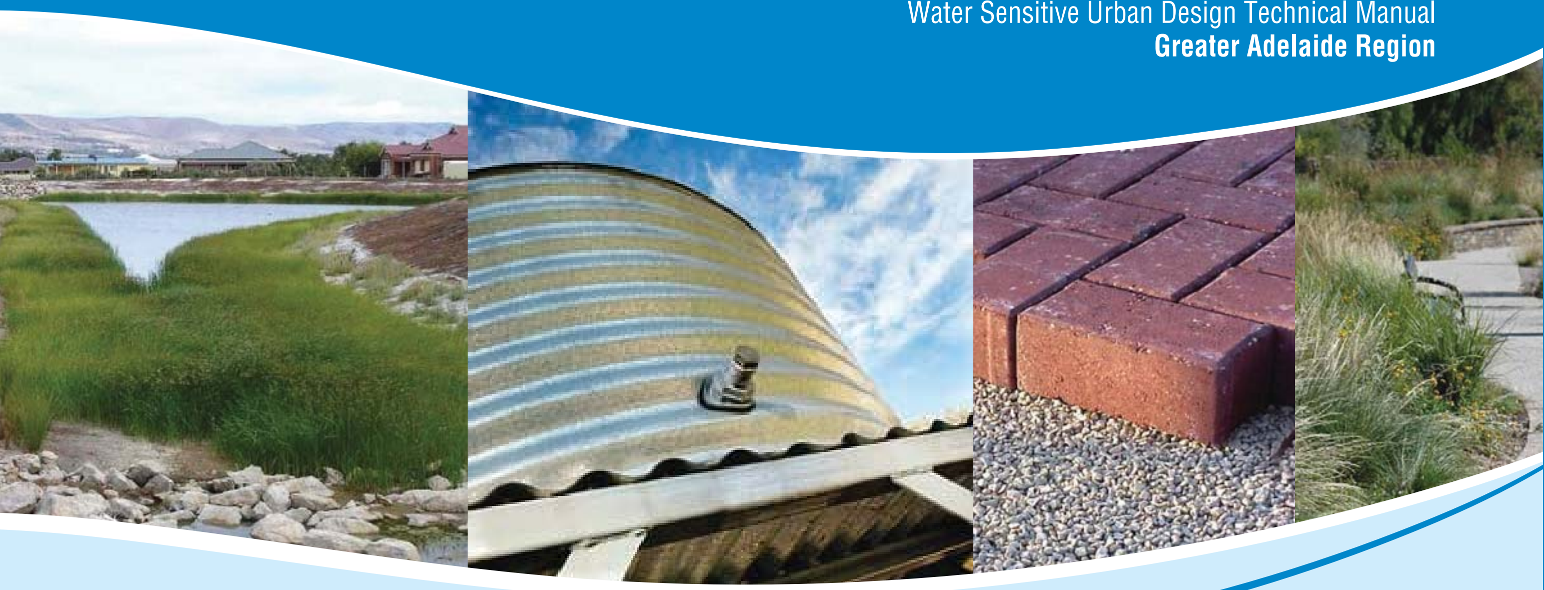
Knox City Council (2002). *Water Sensitive Urban Design Guidelines for the City of Knox.* April. http://www.clearwater.asn.au/resources/357_1.pdf.

July 2009

Chapter 2

WSUD Measures for Different Types and Scale of Development

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Chapter 2
WSUD Measures for Different Types and Scale of Development

2.1 Introduction

As outlined in **Chapter 1**, there is a wide range of WSUD measures available which can be incorporated into development or redevelopment projects.

This chapter provides general guidance about potentially suitable approaches for implementing WSUD across a range of different development types:

- Single residential development (see **Section 2.3**);
- Residential subdivision development (see **Section 2.4**);
- Residential multi-unit development (see **Section 2.5**);
- Streetscape development (see **Section 2.6**);
- Vehicle parking areas (including driveways and access ways on public or private property) (see **Section 2.7**);
- Commercial and industrial development (see **Section 2.8**);
- Upgrade of drainage systems or pavements; and
- Publicly owned land (see **Section 2.9**).

Table 2.1 summarises the potential applicability of various measures.

It should be noted that the preferred optimum solution at one site (i.e. approaches to utilising runoff – e.g. rainwater and stormwater – or reusing treated wastewater) may not be appropriate at another site. A wide range of feasible solutions is usually available and these solutions may need to be ranked according to specific criteria to differentiate them, with selection based on the most suitable solution for the site in question.

Which strategies are selected will depend on factors including:

- Individual site conditions and catchment characteristics (e.g. location, geography);
- Building function and occupancy (e.g. residential, commercial, industrial);
- Development or redevelopment scale and type (e.g. greenfields, brownfields, infill);
- Water use and demand (e.g. garden irrigation demand, industrial use, etc.);

- Water sources available, including local climate (e.g. rainfall seasonality);
- On-site catchment area (e.g. roof and surface);
- Urban landscape design (e.g. architectural and landscape); and
- Greenhouse gas emissions.

It should be noted that WSUD requirements in the Greater Adelaide Region may be different from requirements in other parts of Australia. The Adelaide climate is quite unique and rainfall is highly seasonal. This impacts on everything from supply characteristics for rainwater tanks to irrigation requirements for vegetated WSUD systems, such as rainwater gardens and bioretention systems. Small bioretention basins designed to rely solely on stormwater inflows may work in Melbourne but these same systems may not survive the hot dry summers commonly experienced in Adelaide, where seven to ten day periods of plus 40°C temperatures are not uncommon. Adelaide also has the longest consecutive dry periods of any capital city in Australia. This does not mean that vegetated systems should not be used in Adelaide but it does mean that such systems will often require consideration of additional on-line or off-line storage to provide irrigation water in the inter-storm periods. Chapter 10 describes how to incorporate storages into vegetated WSUD systems.

Selecting the most appropriate WSUD approach will require input from a range of disciplines, including architects, landscape architects, engineers, planners, regulators and local community members with an appreciation of WSUD to produce innovative and optimal solutions.

In some cases the application of certain WSUD measures will be limited due to various constraints which might include space requirements, soil types, groundwater, regulations, etc. A list of potential constraints for each of the WSUD measures presented in this Technical Manual is provided in **Table 2.2**.

As a general rule, site conditions and the characteristics of any target pollutant(s) influence the selection of an appropriate type of treatment measure, while climate conditions and catchment characteristics influence the hydrologic design and ultimately the overall pollutant removal effectiveness of the measures.

It must also be recognised that all WSUD measures should be assessed for design flood capacity. Consultation with local government with regards to local policies should be the first step. Most councils adopt guidelines and procedures for minor and major flood drainage systems as outlined in *Australian Rainfall and Runoff* (IE Aust. 1987).

Table 2.1 Applicability of WSUD Measures to Different Development Types in the Greater Adelaide Region

Situation/Location	Gross Pollutant Trap	Swale	Buffer Strip	Bioretention Swale	Infiltration Trench	Bioretention System	Rainwater Tank	Pervious Pavement	Underground Storage Tank	Managed Aquifer Recharge	Constructed Wetland	Onsite Wastewater Management	Community Wastewater Management
New Streets In large or small development areas:													
- on slopes less than 4%	X	✓	✓	✓	✓	✓	-	✓	✓	X	-	-	-
- on slopes greater than 4%	O	X	X	X	O	O	-	X	O	X	-	-	-
Existing Streets and Roadways Where drainage or pavements to be substantially upgraded or roadway duplicated:													
- on slopes less than 4%	X	✓	✓	✓	✓	✓	-	✓	✓	X	-	-	-
- on slopes greater than 4%	O	X	X	X	O	O	-	X	O	X	-	-	-
Publicly Owned Land Where land area and land use allow additional facilities to be incorporated	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X
Residential Development													
- detached housing (on lots > 500 m²)	-	-	-	-	✓	✓	✓	✓	✓	X	-	O	-
- medium density or integrated housing (lots < 500 m²)	-	-	-	-	O	O	✓	✓	✓	X	-	O	-
Commercial Development Commercial / Industrial properties	✓	✓	✓	✓	✓	✓	✓	✓	✓	O	O	O	
Carparks – Public or Private Property New carpark construction	✓	✓	✓	✓	✓	✓	✓	✓	✓	O	O	O	

✓ - appropriate O limited, requires investigations or approvals X not appropriate - not applicable

Source: Adapted from Knox City Council (2002)

Table 2.2 Potential Constraints Associated with WSUD Application

WSUD Measure	Steep site/catchemnt slope	High water table	Shallow bedrock	Land availabilty limitation	Installation underground is required	High sediment input	Requires pre-treatment	Hydraulic head loss limitation	Installtion in tidal system
Sediment traps	●	●	○	○	●	○	○	○	○
Gross pollutants traps	●	○	○	○	○	○	○	⊕	○
Filter strips	⊕	⊕	○	⊕	⊕	●	●	●	⊕
Grass swales	⊕	⊕	○	⊕	⊕	●	●	●	⊕
Bioretention systems	⊕	○	●	●	●	○	●	⊕	○
Infiltration trenches*	⊕	⊕	⊕	○	●	⊕	●	○	⊕
Rain Gardens	⊕	⊕	⊕	⊕	○	⊕	●	○	⊕
Pervious pavements	⊕	⊕	⊕	⊕	●	⊕	●	○	⊕
Sedimentation basin	○	○	○	⊕	⊕	⊕	●	○	○
Constructed wetlands	⊕	○	○	⊕	⊕	○	●	○	○

Legend:

⊕ Constraint may preclude this measure.

○ Constraint may be overcome with appropriate design.

● Generally not a constraint

* Pretreatment required to remove litter and sediment

2.2 Treatment Train

Runoff can carry a wide range of pollutant types and sizes and in most cases no single treatment measure is able to effectively treat all pollutants carried by runoff.

A series of treatment measures that collectively addressed all runoff pollutants is termed a treatment train. The selection and order of treatments is a critical consideration in developing treatment trains. The coarser pollutants generally require removal so that treatments that target fine pollutants can operate effectively. Other considerations when determining a treatment train are the proximity of a treatment to its source as well as the distribution of treatments throughout a catchment.

It is therefore important to understand the locations where treatment measures may be utilised within a site so that quantities of pollutants and flow likely to be received at each location are appropriate.

Table 2.3 shows a generalised relationship between pollutant characteristics (defined by particle size) and effective treatment processes. It can be seen from these figures that a treatment train needs to include a range of treatment measures in order to address the full range of pollutants likely to be found in urban runoff.

The treatment processes listed in **Table 2.3** can be achieved through:

- Screening – pre-filtering technologies, litter baskets, gross pollutant traps;
- Sedimentation – sedimentation basins, ponds, wetlands;
- Adhesion and filtration – bioretention systems, infiltration systems and wetlands; and
- Biological uptake – wetlands and biofiltration systems.

Table 2.3 Stormwater Pollutant Management Issues and Appropriate Treatment Processes

Particle Size Grading	Management Issue					Treatment Process
	Visual	Sediment	Organics	Nutrients	Metals	
Gross solids	↑	↑	↑			Screening
> 5000 µm						
Coarse to Medium					↑	Sedimentation
5000 – 125 µm				↑		
Fine Particulates		↓				Enhanced sedimentation
125 – 10 µm						
Very Fine / Colloidal	↓				↓	Adhesion and filtration
10 – 0.45 µm						
Dissolved Particles			↓	↓		Biological uptake
< 0.45 µm						

Source: Adapted from Wong et al. (2002)

2.3 Single Residential Development

Description

A single residential development refers to a dwelling on an individual allotment.

Objectives

Example WSUD objectives for a single residential development include:

- Maintain availability of water during restrictions;
- Maximise the efficient use of rainwater and mains water;
- Assist maintenance of garden / landscaping;
- Ensure water supply for fire protection (where appropriate);
- Reduce flood risk;
- Reduce greenhouse gas emissions;
- Improve biodiversity;
- Prevent erosion; and
- Improve water quality.

A range of other objectives can be found in **Appendix C** of **Chapter 3** of the WSUD Technical Manual.

Common Techniques

There are various WSUD techniques which can be used when developing water management strategies for single residential developments. These techniques can assist in achieving mains use reduction, water quality and water quantity targets.

The common techniques are described in detail in the relevant chapters of the WSUD Technical Manual for the Greater Adelaide Region:

- Demand reduction including water efficient fittings and appliances (**Chapter 4**);
- Landscaping (throughout various chapters, but predominantly **Chapter 4**);
- Rainwater tanks (**Chapter 5**);
- Rain gardens (**Chapter 6**);
- Green roofs (**Chapter 6**);
- Infiltration systems (**Chapter 6**);

- Pervious pavements (**Chapter 7**); and
- Wastewater reuse (**Chapter 14**).

Site Strategy

Any combination of the measures (i.e. rainwater tanks, pervious paving, filtration/infiltration devices, landscape practices) listed above can be very effective at achieving the objectives and targets on a single residential development. For maximum effectiveness, these measures need to be carefully designed as part of an overall strategy that considers local site conditions, development scale and layout.

Figure 2.1 opposite shows a possible overall strategy for a typical suburban home. A rainwater tank supplies water for toilet flushing, washing machine usage, and for outdoor use while water efficient fittings reduce mains water consumption elsewhere.

During prolonged or heavy storms, rainwater can overflow from the rainwater tank to an infiltration (or retention) trench. Runoff from paths, driveways and lawns is directed to garden areas (i.e. rain garden). Excess runoff from impervious surfaces is directed to the retention trench, or overflows to the street drainage system.

Landscape practices also influence selection (and location) of species to reduce water demand and to achieve biodiversity outcomes.

Utilising greywater for garden watering and toilet flushing is an emerging area of investigation and technology.

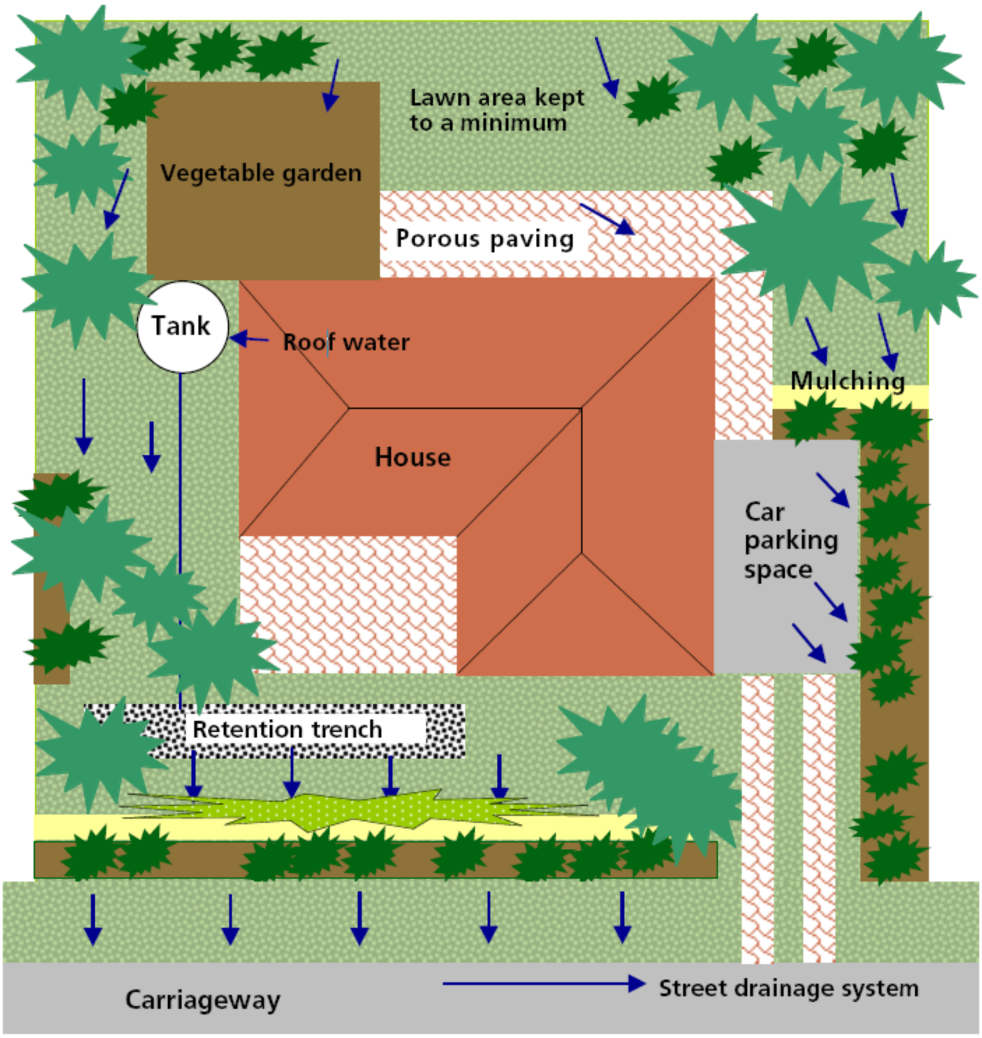


Figure 2.1 Example of an Overall WSUD Strategy for a Typical Suburban Dwelling

Source: LHC CREMS (2002)

2.4 Residential Subdivision

Description

A residential subdivision refers to an area with numerous dwellings on individual allotments.

Objectives

Example WSUD objectives for a residential subdivision development include:

- Integrate natural and/or existing site topographical features into the subdivision design;
- Maximise use of natural and/or existing features for multiple use;
- Minimise capital and maintenance costs per household for municipal infrastructure;
- Maximise amount of public open space;
- Maximise opportunity to direct runoff into the ground or water body (where safe, compatible and appropriate to the function of the area or water body);
- Maintain availability of water during restrictions;
- Maximise efficient use of water;
- Assist maintenance of garden / landscaping;
- Maximise development amenity;
- Ensure water supply for fire protection (where appropriate);
- Reduce flood risk;
- Prevent erosion; and
- Improve water quality.

A range of other objectives can be found in **Appendix C** of **Chapter 3** of the WSUD Technical Manual.

Common Techniques

There are various WSUD techniques which can be used when developing water management strategies for residential subdivision developments. These techniques can assist in achieving mains use reduction, water quality and water quantity.

The common techniques are described in detail in the relevant chapters of the Technical Manual for the Greater Adelaide Region:

- Landscaping (throughout various chapters, but predominantly **Chapter 4**);
- Rainwater tanks (**Chapter 5**);
- Pervious pavements (**Chapter 7**);
- Gross pollutant traps (**Chapter 9**);
- Bioretention systems (**Chapter 10**);
- Swales and buffer strips (**Chapter 11**);
- Sedimentation basins (**Chapter 12**);
- Constructed wetlands (**Chapter 13**); and
- Wastewater reuse (**Chapter 14**).

Site Strategy

Any combination of the techniques (i.e. landscape practices, bioretention systems, swales, constructed wetlands) listed above can be very effective at achieving WSUD objectives and targets for residential subdivision sites. For maximum effectiveness, these measures need to be carefully designed as part of an overall strategy that considers local site conditions, development scale and layout.

WSUD subdivisions offer opportunities for:

- Narrow road reserves which reduce the area requiring irrigation (and maintenance);
- Integrating design of access and crossovers to maximise scope for retention of existing vegetation and for new plantings which minimise water requirements;
- Variation in road reserve widths to facilitate integrated stormwater management and substantial plantings;
- Footpath alignments that respond to natural features and stormwater management to create spaces that are easy to maintain and efficient to irrigate (if necessary);
- Pervious paving for footpaths and parking areas;
- Common trenching and closer alignment of services to improve scope for reduced verges to retain existing vegetation and plant new vegetation;
- Appropriate landscape practices that include the selection of species to reduce water demand;
- Constructed wetlands to detain, retain and treat urban runoff;
- Wastewater treatment and reuse to irrigate public open spaces.

WSUD facilitates the use of smaller, more compact housing lots adjacent to open space areas that typically have high amenity value. This allows greater community access to open space, improving social connectivity and interaction. WSUD measures include natural and landscaped water features forming the local stormwater drainage system.

Where practicable, natural landscape features such as significant remnant vegetation and natural waterways should be incorporated within open space, with housing lots configured around the open space and designed to encourage views over and access to the open space.

The connectivity of the lots to the open space allows the creation of smaller lots through provision of less lawn and garden area on the lot. The reduced lot size is balanced by each lot's direct connectivity to the adjoining open space. Experience would suggest that lots with direct access to open space and water features have elevated values compared to conventional lot designs.

At the subdivision scale, sustainable stormwater management includes conveyance controls such as grass swales and bioretention swales, water sensitive road design and natural waterways, and storage methods such as open ponds or covered tanks, constructed wetlands and aquifer recharge. These storage methods offer opportunities to utilise stormwater for irrigation of parklands, sporting fields and for cluster housing groups thus reducing the importation of water and the subsequent transmission costs and associated greenhouse gas emissions.

2.5 Residential Multi-unit Development

Description

Residential multi-unit development refers to developments such as:

- High rise residential units;
- Retirement villages;
- Aged accommodation;
- Townhouses; and
- Single storey units.

In most of these types of development, residential water demand is similar to a typical household with the exclusion of garden irrigation. Rainwater capture from the roof is limited due to the relative small surface area ratio to water demand (i.e. number of people).

Objectives

Example WSUD objectives for a residential multi-unit development include:

- Integrate natural and/or existing site topographical features into the development design;
- Maximise use of natural and/or existing features for multiple use;
- Minimise capital and maintenance costs per household for infrastructure;
- Maximise amount of public open space;
- Maximise opportunity to direct runoff into the ground or water body (where safe, compatible and appropriate to the function of the area or water body);
- Maintain availability of water during restrictions;
- Maximise efficient use of water;
- Assist maintenance of garden / landscaping;
- Ensure water supply for bushfire protection (where appropriate);
- Reduce flood risk;
- Prevent erosion;
- Improve water quality; and
- Reduce greenhouse gas emissions.

A range of other objectives can be found in **Appendix C** of **Chapter 3** of the WSUD Technical Manual.

Common Techniques

There are various WSUD techniques which can be used when developing water management strategies for residential multi-unit developments. These techniques can assist in achieving mains use reduction, water quality and water quantity targets.

The common techniques are described in more detail in the relevant chapters of the WSUD Technical Manual for the Greater Adelaide Region:

- Demand reduction including water efficient fittings and appliances (**Chapter 4**);
- Landscaping (throughout various chapters, but predominantly **Chapter 4**);
- Rainwater tanks (**Chapter 5**);
- Rain gardens (**Chapter 6**);
- Green roofs (**Chapter 6**);
- Infiltration systems (**Chapter 6**);
- Pervious pavements (**Chapter 7**);
- Gross pollutant traps (**Chapter 9**);
- Bioretention systems (**Chapter 10**); and
- Wastewater reuse (**Chapter 14**).

Site Strategy

Any combination of the techniques (i.e. rainwater tanks, pervious paving, filtration/infiltration devices, landscape practices) listed above can be very effective at achieving the objectives for multi-unit developments. For maximum effectiveness, these measures need to be carefully designed as part of an overall strategy that considers local site conditions, development scale and layout.

Figure 2.2 below shows a possible overall strategy for a multi-unit development. In addition to the features shown, a multi-unit development offers opportunities for:

- Narrow driveways to maximise the pervious area;
- Integrating the design of driveways to maximise scope for retention of existing vegetation and for new plantings;
- Variation in driveway widths to facilitate integrated stormwater management and substantial plantings;

- Footpaths integrated with driveways which respond to natural features and stormwater management to create spaces that are easy to maintain and efficient to irrigate;
- Pervious paving for driveways and parking areas;
- Common trenching and closer alignment of services to improve scope for reduced disturbance and trenching to retain existing vegetation and plant new vegetation;
- Appropriate landscape practices that include the selection of species to reduce water demand;
- Water efficient fixtures and appliances; and
- Community scale wastewater capture, treatment and reuse.

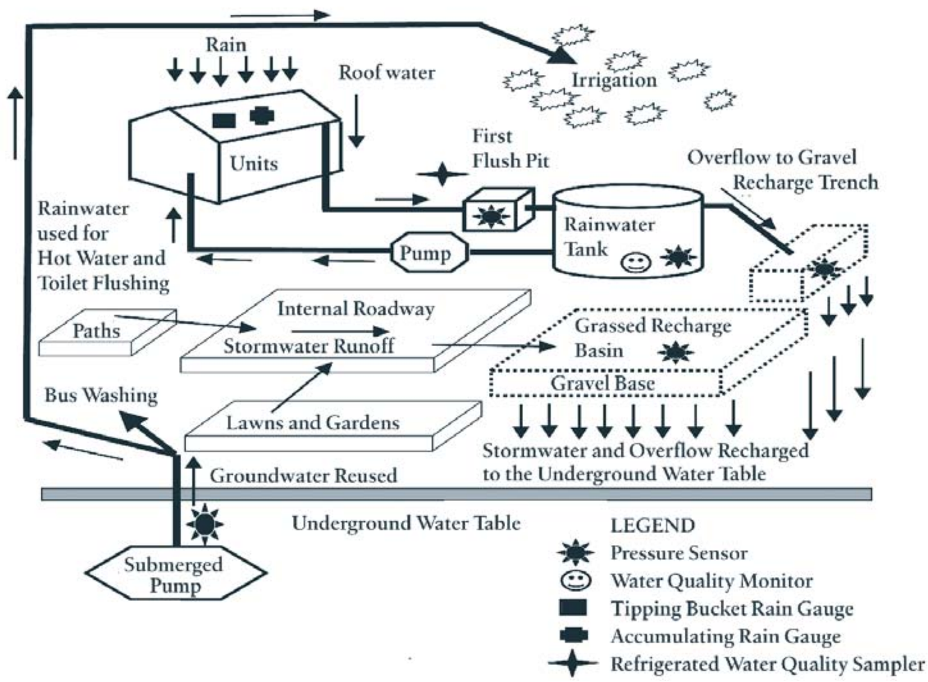


Figure 2.2 Schematic of a WSUD Multi-unit Layout Utilising Groundwater Recharge and Stormwater Reuse

Source: Hobart City Council (2006)

2.6 Streetscape Development

Description

Roads account for a significant percentage of the overall impervious hard surfaces created within a typical development and therefore can significantly change the way water is transported through an area and the volume of runoff that is generated. These areas also generate water borne pollutants that can adversely impact on receiving waterway health (e.g. fine sediments, metals and hydrocarbons). Consequently, it is important to mitigate the impact of runoff generated from road surfaces.

Road alignments and streetscapes should be carefully planned to incorporate some degree of treatment. WSUD drainage elements can be used to collect, attenuate, convey and treat the runoff before discharge to receiving waterways.

Objectives

Example WSUD objectives for a streetscape development include:

- Integrate natural and/or existing site topographical features into the development design;
- Maximise use of natural and/or existing features for multiple use;
- Minimise capital and maintenance costs for infrastructure;
- Maximise opportunity to direct runoff into the ground or water body (where safe, compatible and appropriate to the function of the area or water body);
- Maximise efficient use of water;
- Assist maintenance of landscaping;
- Reduce flood risk;
- Prevent erosion;
- Improve water quality;
- Improve amenity; and
- Improve biodiversity.

A range of other objectives can be found in **Appendix C** of Chapter 3 of the WSUD Technical Manual.

Common Techniques

No single street layout will be appropriate for all development and it is largely dependent on topography, density of development and traffic volume. Areas of low traffic volume (i.e. local access streets) may have the greatest flexibility in design alternatives.

The following techniques are commonly used in WSUD strategies for streetscape development. These techniques can assist in achieving mains use reduction, water quality and water quantity targets.

The common techniques are described in more detail in the relevant chapters of the WSUD Technical Manual for the Greater Adelaide Region:

- Landscaping (throughout various chapters, but predominantly **Chapter 4**);
- Infiltration systems (**Chapter 6**);
- Pervious pavements (**Chapter 7**);
- Gross pollutant traps (**Chapter 9**);
- Bioretention systems (**Chapter 10**);
- Swales and buffer strips (**Chapter 11**); and
- Sedimentation basins (**Chapter 12**).

Site Strategy

A WSUD streetscape integrates road layout, vehicular and pedestrian requirements with water management needs. It uses design measures such as maximising pervious areas, local stormwater detention (and retention) in road reserves and managed landscaping.

Any combination of the techniques (i.e. pervious paving, filtration/infiltration devices, landscape practices) listed above can be very effective at achieving the objectives and targets for streetscape design. For maximum effectiveness, these measures need to be carefully designed as part of an overall strategy that considers local site conditions.

Figure 2.3 Retrofit of Street with a Swale, City of Onkaparinga

Source: Courtesy of City of Onkaparinga

Figure 2.4 shows a possible overall strategy for streetscape development and **Figure 2.5** shows an example of alternative verge design and incorporation of WSUD features.

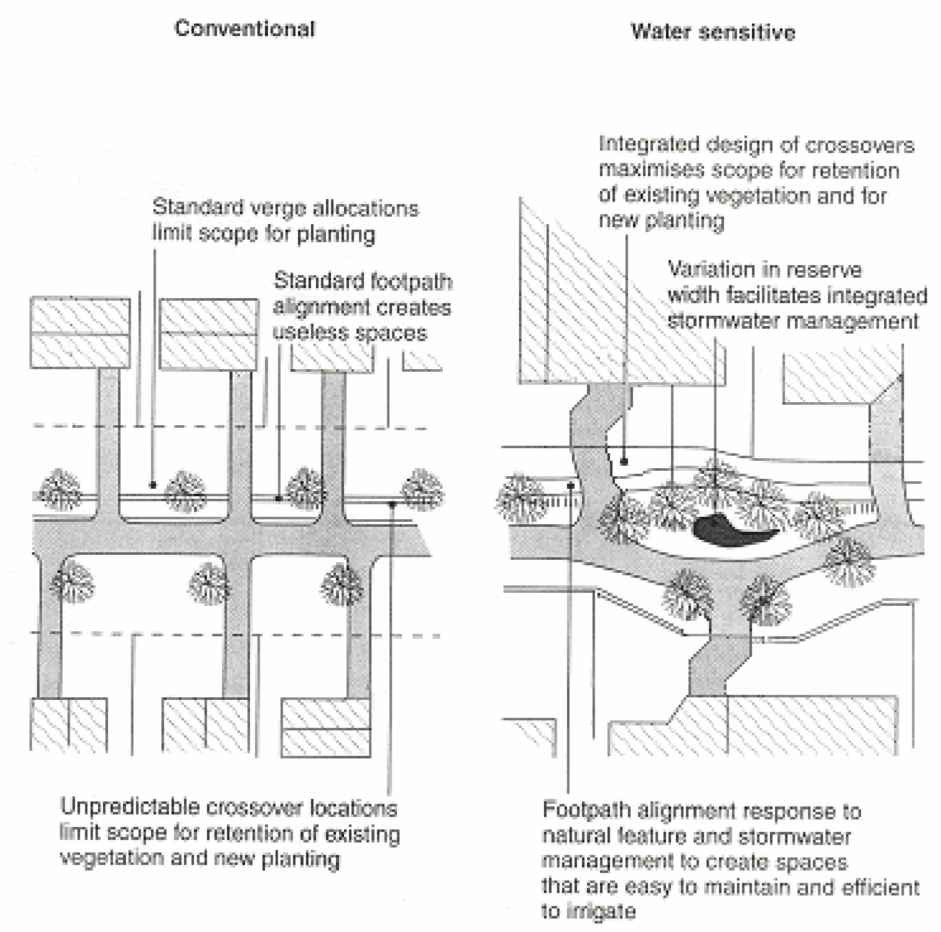


Figure 2.4 Conventional vs Water Sensitive Road Layout

Source: CSIRO (1999)

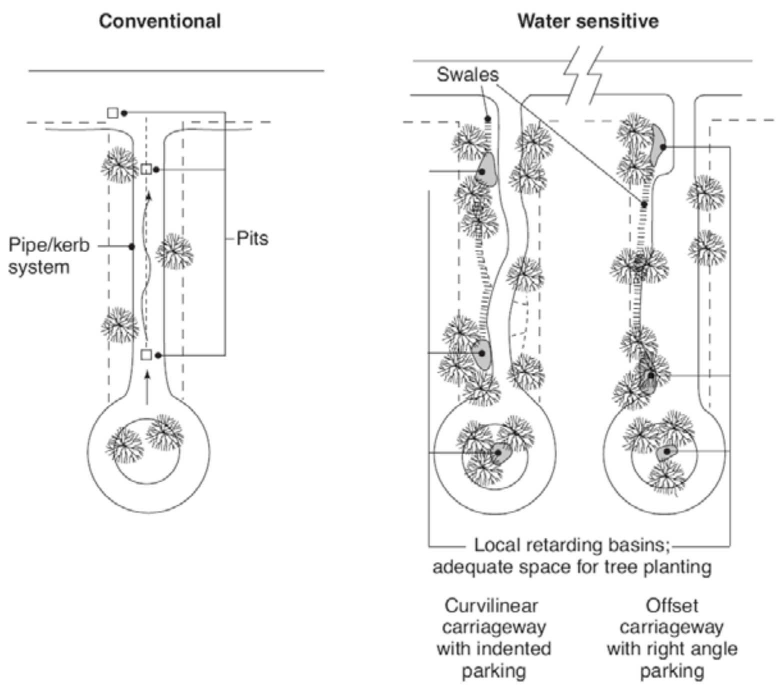


Figure 2.5 Verge Design and Maintenance

Source: CSIRO (1999)

In addition to the features shown, water sensitive streetscapes offer opportunities for:

- Narrowing roads to reduce impervious paved areas (however not at the expense of pedestrian and vehicle connectivity);
- Integrating design of driveways and crossovers to maximise scope for retention of existing vegetation and for new plantings;
- Varying road and road reserve widths to facilitate integrated stormwater management, maximise and enhance open space and landscaping possibilities and streetscape amenity;
- Integrating footpaths within road reserves to respond to natural features and stormwater management to create spaces that are easy to maintain and efficient to irrigate;
- Incorporating pervious paving in roads, driveways and parking areas where appropriate;
- Incorporating water absorbing drainage facilities (e.g. swales or bioretention swales) into the streetscape, using surface exposed systems, rather than underground piping systems;
- Incorporating local filtration by using rock/gravel filter beds with drainage channels;

- Common trenching and closer alignment of services to improve scope for reduced disturbance and trenching to retain existing vegetation and plant new vegetation;
- Installing aesthetically appealing features, with emphasis on verge treatment via natural elements such as locally occurring rock, vegetation, etc., rather than via concrete or bitumen pavement; and
- Appropriate landscape practices that include the selection of species to reduce water demand (including artificial turf).

Roads and streetscapes are continually upgraded in the Greater Adelaide Region. Opportunities exist for incorporating WSUD measures in roadways by diverting the flow from the road to a treatment system, as illustrated in **Figure 2.6** including:

- Traditional road features such as medians, traffic calming bays, street trees and car parking nodes designed to be lower than the road level to collect runoff from the road;
- Kerb and channel can be replaced with swales;
- Street trees can be retrofitted into stormwater treatment bioretention planter boxes whereby stormwater is diverted into the planter box and filtered through a sandy loam prior to discharge to the stormwater systems; and
- Medians and traffic calming bays can be retrofitted as bioretention systems.

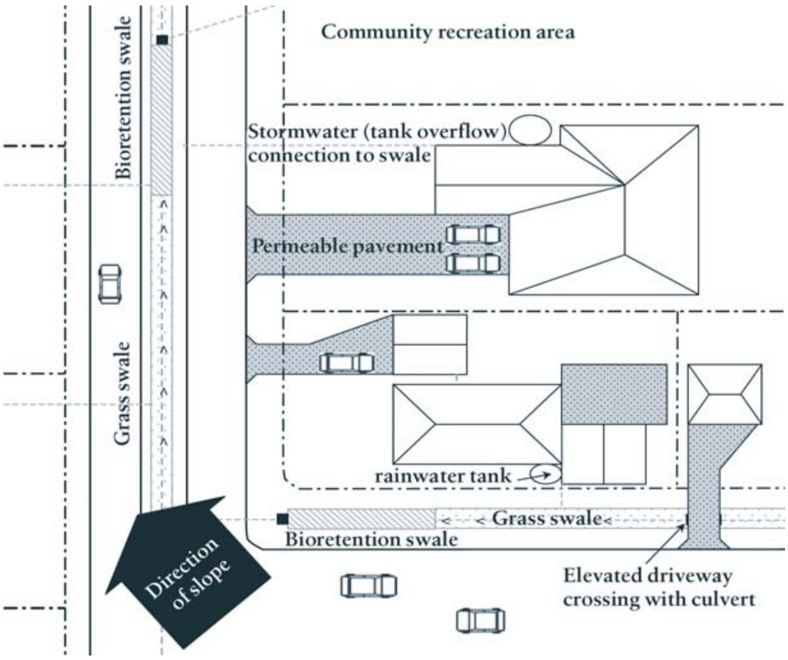


Figure 2.6 Diagram of Water Sensitive Residential Streetscape Showing Bioretention Swale Street Drainage

Source: Hobart City Council (2006)

2.7 Vehicle Parking Area Development

Description

Vehicle parking areas include small scale to large scale car parks. While vehicle parking areas can be large generators of polluted runoff, creative design options can minimise the extent of impervious surfaces in parking areas and subsequent impacts on downstream water bodies.

Objectives

Example WSUD objectives for vehicle parking area development include:

- Integrate natural and/or existing site topographical features into the vehicle parking area design;
- Minimise capital and maintenance costs;
- Maximise opportunity to direct runoff into the ground or water body (where safe, compatible and appropriate to the function of the area or water body);
- Maintain availability of water during restrictions;
- Maximise efficient use of water;
- Assist maintenance of landscaping;
- Achieve high amenity;
- Reduce flood risk;
- Prevent erosion;
- Improve water quality; and
- Improve vehicle parking facility aesthetics.

A range of other objectives can be found in **Appendix C** of **Chapter 3** of the WSUD Technical Manual.

Common Techniques

No single vehicle parking area layout will be appropriate for all sites and it is largely dependent on topography, area available and traffic volume.

There are numerous techniques which can be used in WSUD strategies for vehicle area development. These techniques can assist in achieving mains use reduction, water quality and water quantity targets.

The common techniques are described in the following chapters of the WSUD Technical Manual:

- Landscaping (throughout various chapters, but predominantly **Chapter 4**);
- Rain gardens (**Chapter 6**);
- Infiltration systems (**Chapter 6**);
- Pervious pavements (**Chapter 7**);
- Gross pollutant traps (**Chapter 9**);
- Bioretention systems (**Chapter 10**);
- Swales and buffer strips (**Chapter 11**);
- Sedimentation basins (**Chapter 12**); and
- Constructed wetlands (**Chapter 13**).

Figure 2.7 Road Verge and Carpark Area

Source: Courtesy of City of Salisbury

Site Strategy

It is desirable to incorporate various WSUD measures in the design of vehicle parking areas.

Water sensitive vehicle parking areas are best achieved on sites that are relatively flat to gently sloping, with soils suitable for infiltration (e.g. sandy soils). It is essential that overflow paths for major storms are identified and that these conform to established standards.

Gently sloping grassed areas or recessed basins can be incorporated in vehicle parking areas. These may be used to pond water to allow filtration of pollutants and the deposition of sediment. This is commonly accomplished by incorporating specifically designed or modified inlet structures that permit the temporary storage of runoff.

Any combination of the techniques (i.e. pervious paving, filtration/infiltration devices, landscape practices) listed above can be very effective at achieving the WSUD objectives and targets for the site. For maximum effectiveness, these measures need to be carefully designed as part of an overall strategy that considers local site conditions.

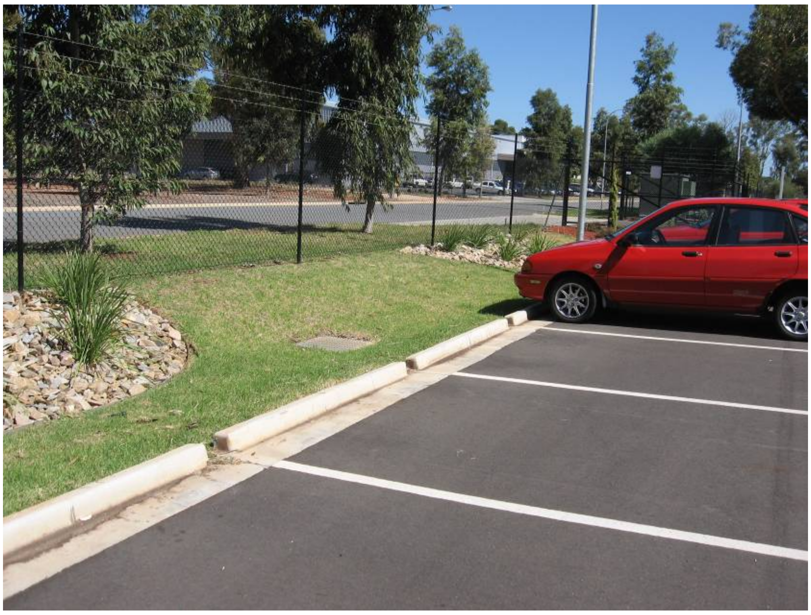


Figure 2.8 Carpark Design Incorporating WSUD Measures

Source: Courtesy of City of Salisbury

Figure 2.9 shows a sample overall strategy for a vehicle parking area which incorporates WSUD measures. In addition to the features shown, vehicle parking areas offer opportunities to:

- Optimise lane widths to maximise the pervious area (if harvesting is not an objective);
- Integrate design of lanes to maximise scope for retention of existing vegetation and for new plantings;
- Integrate stormwater management and substantial plantings;
- Integrate footpaths to respond to natural features and stormwater management to create spaces that are easy to maintain and can be irrigated efficiently;
- Include pervious paving for laneways and parking spaces;
- Incorporate common trenching and closer alignment of services to improve scope for reduced disturbance and trenching to retain existing vegetation and plant new vegetation.

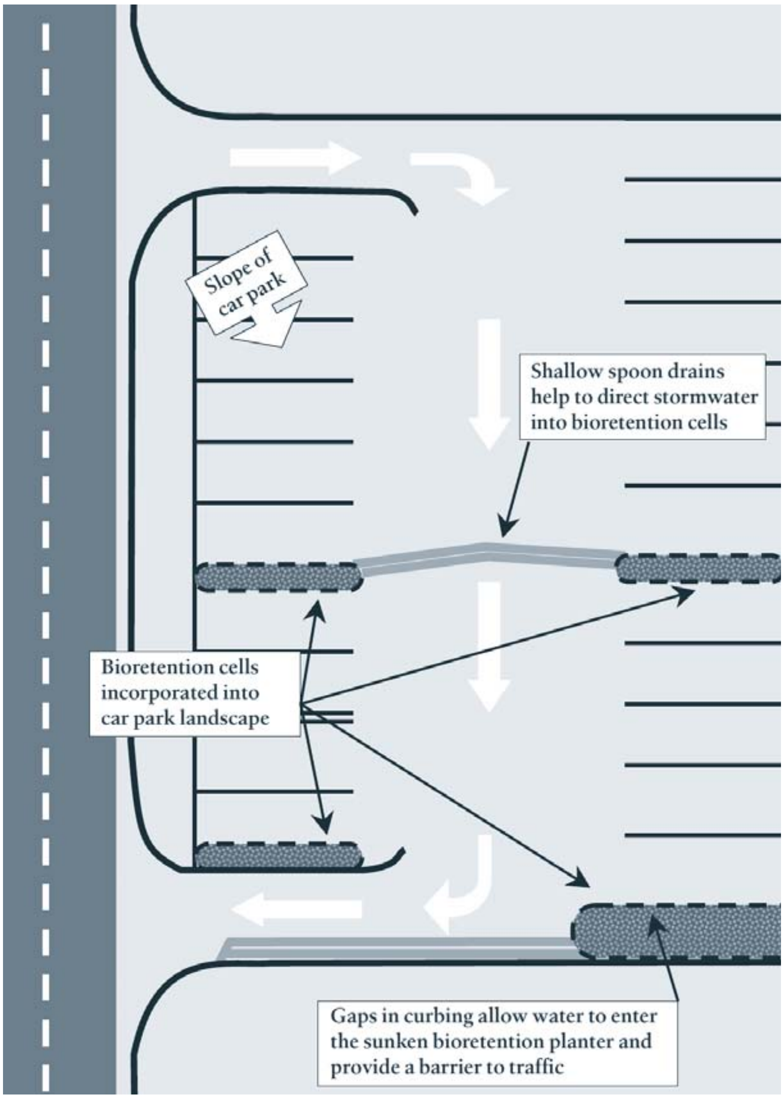


Figure 2.9 Vehicle Parking Area Layout Example Incorporating WSUD Measures

Source: Hobart City Council (2006)

2.8 Commercial and Industrial Sites

Description

Typically in office buildings, water usage is dominated by toilet flushing. Relatively small demand exists for drinking water and garden irrigation. Little greywater generation is expected as there is generally minimal showering in these buildings.

The commercial sector goes beyond offices to include retailing centres, markets, schools, universities, hospitals and event venues.

Industrial water use is dependent on the specific industry and site. For example, water use ranges from cooling water for industrial equipment to very high purity water for technology companies. Industry should use 'fit-for-purpose' water and be able demonstrate best water management and practice.

Objectives

Example WSUD objectives for a commercial or industrial development site include:

- Integrate natural and/or existing site topographical features into the development design;
- Maximise use of natural and/or existing features;
- Minimise capital and maintenance costs for service infrastructure;
- Maximise amount of open space for employee use;
- Maximise opportunity to direct runoff into the ground or water body (where safe, compatible and appropriate to the function of the area or water body);
- Maintain availability of water supply during restrictions;
- Maximise efficient use of water (including reuse);
- Assist maintenance of landscaping;
- Ensure water supply for fire protection (where appropriate);
- Reduce flood risk;
- Reduce peak discharges downstream;
- Prevent erosion;
- Improve water quality;
- Improve biodiversity; and
- Improve aesthetics.

A range of other objectives can be found in **Appendix C** of **Chapter 3** of the WSUD Technical Manual.

Common Techniques

There are numerous techniques that can be used in WSUD strategies for industrial and commercial development sites. These techniques can assist in achieving mains use reduction, water quality and water quantity targets.

The common techniques are described in the following chapters of the WSUD Technical Manual:

- Demand reduction (**Chapter 4**);
- Landscaping (throughout various chapters, but predominantly **Chapter 4**);
- Rain gardens (**Chapter 6**);
- Infiltration systems (**Chapter 6**);
- Green roofs (**Chapter 6**);
- Pervious pavements (**Chapter 7**);
- Bioretention systems (**Chapter 10**);
- Swales and buffer strips (**Chapter 11**);
- Sedimentation basins (**Chapter 12**);
- Constructed wetlands (**Chapter 13**); and
- Wastewater reuse (**Chapter 14**).

Site Strategy

Any combination of the techniques (i.e. rainwater tanks, pervious paving, filtration/infiltration devices, landscape practices) listed above can be very effective at achieving the WSUD objectives and targets for industrial and commercial sites. For maximum effectiveness, these measures need to be carefully designed as part of an overall strategy that considers local site conditions.

Figure 2.10 shows a possible overall strategy for industrial or commercial developments.

Commercial and industrial sites can reduce water demand through efficient toilets and appliances. Buildings with large catchment areas can harvest rainwater which can be utilised for toilet flushing and irrigation, as such sites often have large garden areas. Runoff can also be harvested from large carpark areas.

Other opportunities for industrial sites include multiple uses of water within a manufacturing site, the use of treated wastewater for process cooling applications and harvesting runoff for on-site use. As industrial developments and their water use are varied throughout the Greater Adelaide Region, approaches should be developed on a case by case basis.

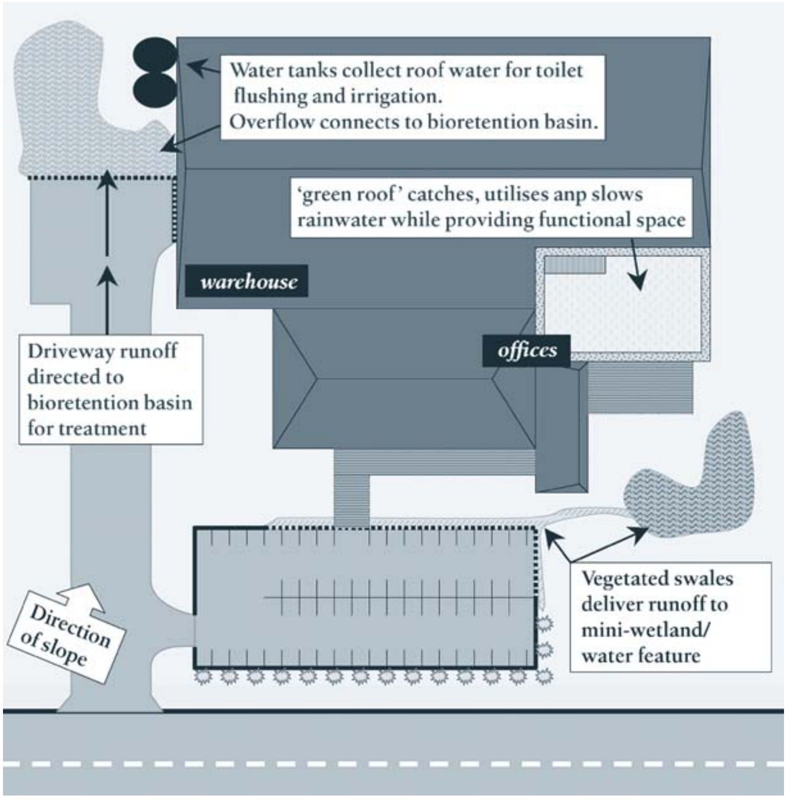


Figure 2.10 Industrial or Commercial Site Layout Example Incorporating WSUD Measures

Source: Hobart City Council (2006)

In addition to the features shown in **Figure 2.10**, industrial and commercial developments offer opportunities for:

- Maximising pervious areas including using pervious paving for driveways and parking areas;
- Integrating design of driveways and parking areas to maximise scope for retention of existing vegetation and for new plantings;
- Varying driveway widths to facilitate integrated stormwater management and substantial plantings;
- Integrating footpaths with driveways to respond to natural features and stormwater management to create spaces that are easy to maintain and efficient to irrigate;
- Incorporating common trenching and closer alignment of service infrastructure to improve scope for reduced disturbance and trenching to retain existing vegetation and plant new vegetation; and
- Using appropriate landscaping measures and practices that include the selection of species to reduce water demand.

2.9 Public Open Space

Description

Integration of public open space with conservation corridors, stormwater management systems and recreational facilities is a fundamental objective of WSUD. Public open space areas can potentially incorporate stormwater conveyance, detention, and retention and treatment systems as landscape features within a multiple use corridor.

This can provide a recreation focus (such as a linear park with bike path or an urban forest) as well as enhancing community understanding and regard of stormwater as a valuable resource.

Objectives

The open space system should be developed with the aim of establishing a network of natural features and compatible land uses that will act as a green network throughout the development.

Key principles and objectives to be considered in locating public open spaces are:

- Align public open space along natural drainage lines;
- Protect/enhance areas containing natural water features (such as creeks and wetlands) and other environmental values by locating them within public open spaces; and
- Utilise public open spaces to provide links between public and private areas and community activity nodes.

A range of other objectives can be found in **Appendix C** of **Chapter 3** of the WSUD Technical Manual.

Strategy

Figure 2.11 compares examples of public open space provision within a conventional urban design layout and a WSUD layout. It shows how stormwater conveyance and treatments systems can become visual focus points of developments.

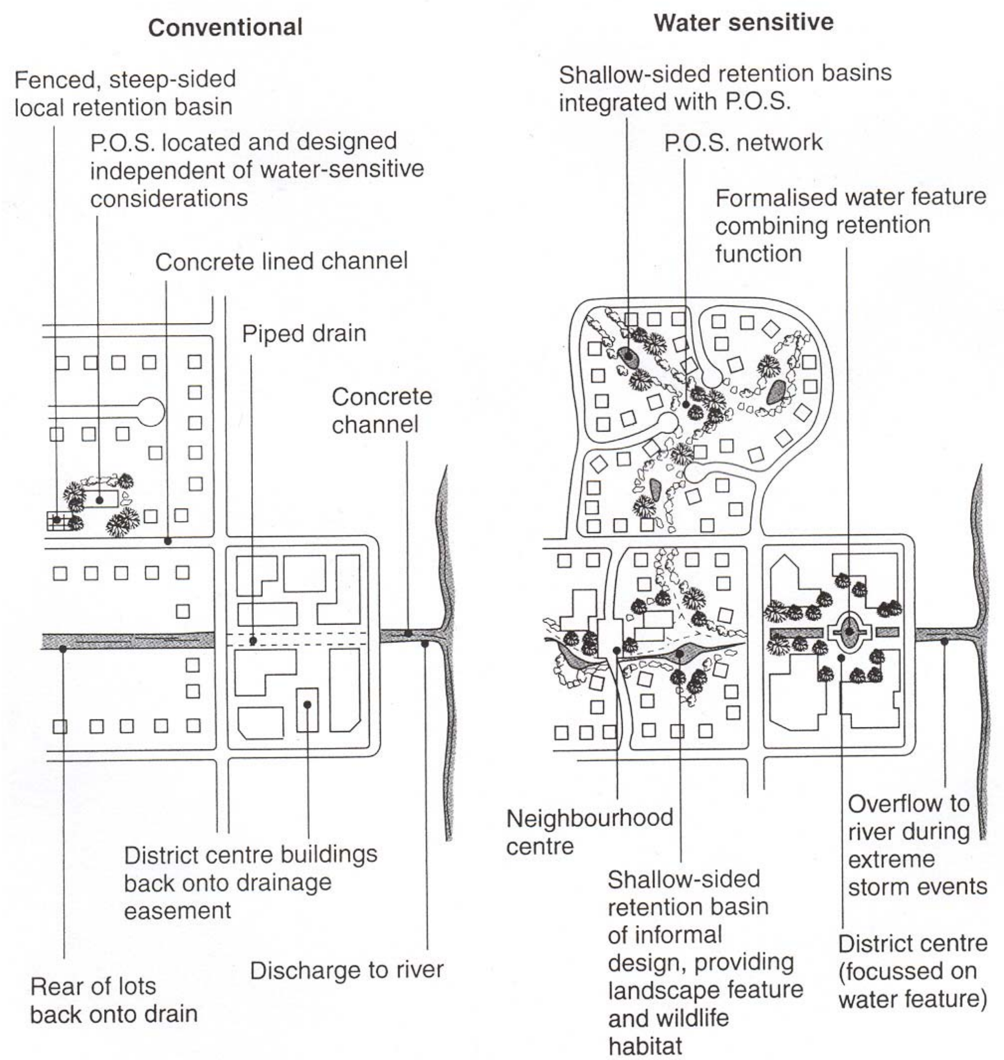


Figure 2.11 Conventional Urban Layout vs WSUD Urban Layout (Showing Public Open Space Provisions)

Note: POS = public open space

Source: CSIRO (1999)

The integration of stormwater management initiatives as components of the open space system contributes to open space outcomes by increasing the physical area of general open space and green elements within a community, enhancing terrestrial and aquatic habitat diversity, and recreational and educational opportunities.

The following are examples of techniques which can be used to integrate water management and the open space network:

- Incorporation of waterways and wetlands within parks as ecological and/or recreational features;

- Integration of playfields within the basin of a dry detention basin;
- Design of subsurface storage and/or infiltration systems beneath playfields within parks or school yards; and
- Development of gardens within open space areas such as bioretention systems.

When public open spaces include waterways it is usually preferable to emphasise natural channel systems rather than engineered solutions. Modifications to catchments contributing to each waterway occur due to urbanisation. This affects natural processes which occur including stream flows and sedimentary processes (sediment nature, delivery rate and transportation). Streams seek to achieve their own dynamic equilibrium, and seek further to adjust, repair and sustain themselves according to their modified environments. Therefore, over time, urban streams respond to a change in catchment conditions and hydrologic response by attempting to modify channel dimensions, and become subject to bed and bank erosion.

To maintain a healthy riverine environment, it is advisable to promote the re-establishment of a naturally functioning system, albeit modified by catchment response. The re-establishment of riparian buffer strips, where necessary along waterways, will maintain and enhance the vegetation corridor and habitat links.

A naturally functioning stream system is often made up of a combination of pool, riffle and chain-of-ponds systems. Riffles (located between meanders in the stream alignment) may be made up of rock, hard bed material, tree stumps or simply gravel bars. A varied pool and riffle system may provide the following stream functions:

- Varied aquatic habitats;
- Bed stabilisation; and
- Improvements in water quality through oxygenation.

2.10 Opportunities for Retrofitting

Description

Retrofitting is the process of installing or undertaking additional water management devices or approaches in an existing developed area. These techniques include increasing storage and infiltration areas to reduce peak flows and using vegetated systems to facilitate pollutant filtration.

Retrofitting can include both structural techniques and non-structural techniques.

Objectives

The multiple WSUD objectives of retrofitting include:

- Reduce flood risk;
- Improve public health and safety;
- Improve water quality;
- Restore and conserve environmental condition;
- Create more attractive and liveable neighbourhoods;
- Enhance the cultural values of the urban water landscape;
- Improve use of open space and enhance recreational opportunities;
- Improve community environmental awareness;
- Increase cost effectiveness;
- Demonstrate best management practices; and
- Utilise alternative water sources to reduce importation of water supplies.

A range of other objectives can be found in **Appendix C** of **Chapter 3** of the WSUD Technical Manual.

Strategy

Retrofitting includes techniques implemented at a variety of scales:

- Lot scale:
  - Maximising opportunities for capture and use of rainfall on site by techniques such as installing rainwater tanks and directing overflow to infiltration systems;
  - Changing gardening practices;
  - Replacing impervious paving with pervious paving;

- Redirecting/disconnecting stormwater pipes to rain gardens;
- Demand reduction through installation of water efficient fixtures and fittings.

- Block and neighbourhood scale:
  - Removing kerbs from some sections of roads, such as where road runoff can flow into adjacent parkland;
  - Installing infiltration devices within roadways/road reserves;
  - Replacing impervious paving with pervious paving.

- Catchment scale:
  - Rehabilitating open urban drains or removing sections of subsurface pipes and allowing surface flow through swales;
  - The removal of 'gross' pollutants from the system through the relatively straight forward installation of gross pollutant traps, trash baskets in existing side entry pits and retrofitting of side entry pits to grated pits.

Another important opportunity is presented by the public open space system in the scope it creates to provide effective water quality improvement (via constructed wetlands) and the potential retardation of runoff in certain rainfall events (retarding basins). This reduction of peak flows in frequent rainfall events has the important consequence of reducing flooding and riparian and aquatic habitat disturbance, a key detrimental impact of urbanised catchments.

However, it is acknowledged that the opportunities for these installations may be somewhat limited and that the primary function of public open space systems is to cater for the leisure and recreation needs of the community.

Another area of retrofitting opportunity lies in the performance improvement of retarding basins to improve water quality, as well as retardation of discharge. Wetland treatments can be constructed within retarding basins with no reduction of their effective volume, but to provide improved water quality outflows, as well as improving the aesthetics and landscape amenity of some of these structures.

2.11 References

CSIRO (1999). *Urban Stormwater Best Practice Environmental Management Guidelines*, Chapter 5: Water Sensitive Urban Design, CSIRO Publishing, Victoria.

Hobart City Council (2006). *Water Sensitive Urban Design Site Development Guidelines and Practice Notes.* Hobart. http://www.hobartcity.com.au/HCC/STANDARD/PC_1124.html.

IE Aust. (1987). *Australian Rainfall and Runoff - A Guide to Flood Estimation*. Barton, ACT. http://www.ncwe.org.au/arr/index.html.

Knox City Council (2002). *Water Sensitive Urban Design Guidelines for the City of Knox.* April. http://www.clearwater.asn.au/resources/357_1.pdf.

LHCCREMS (2002). *WaterSmart Practice Note No. 1*, Lower Hunter and Central Coast Regional Environmental Management Strategy, Hunter Region Organisation of Councils.

Wong, T. H. F., Fletcher, T. D., Duncan, H. P., Coleman, J. R., and Jenkins, G. A. (2002). A Model for Urban Stormwater Improvement Conceptualisation. Paper presented at the 9th International Conference on Urban Drainage, Portland, Oregon, USA, pp. 598.

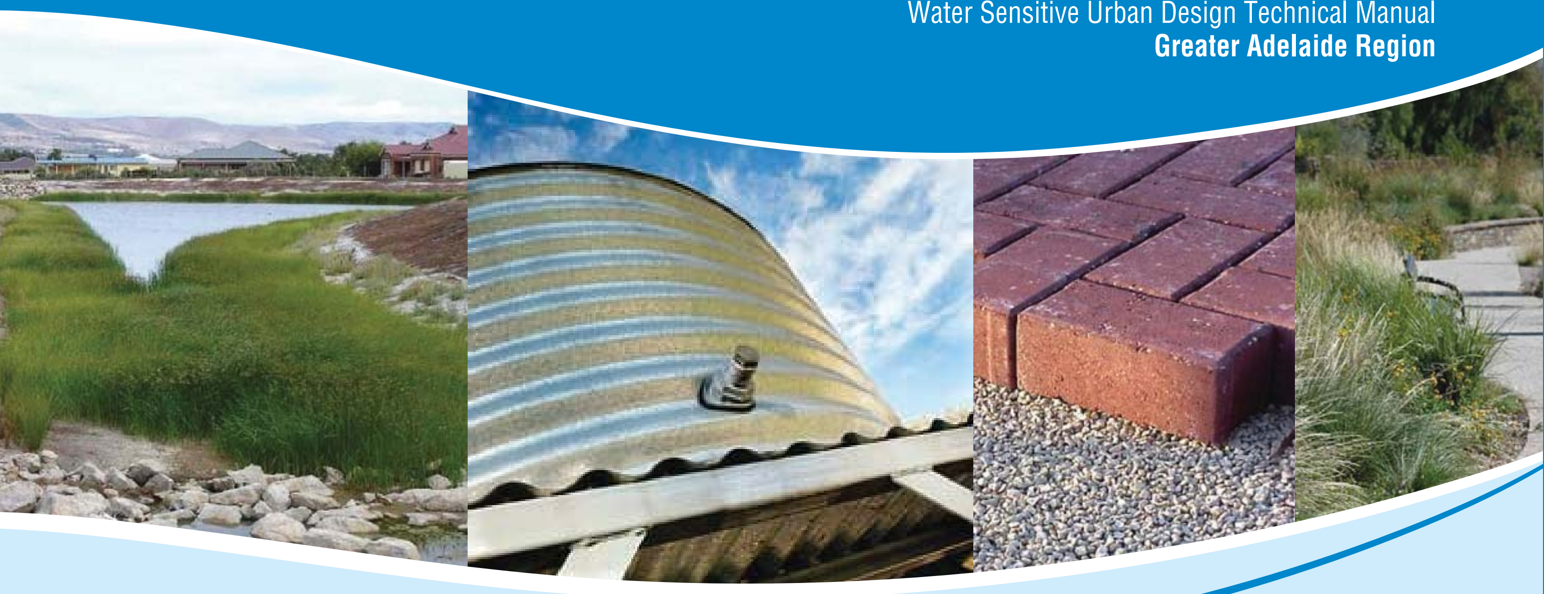
Derwent Estuary Program (2004). WSUD Engineering Procedures for Southern Tasmania, Department of Primary Industries and Water, Hobart.

July 2009

Chapter 3

Designing a WSUD Strategy for Your Development

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 3
Designing a WSUD Strategy for Your Development

3.1 Overview

The main focus of the WSUD Technical Manual for the Greater Adelaide Region is to ensure the consideration of water management in the **initial** layout and design of a development, rather than it being left until all other elements (such as lot layouts and street design) have been completed, or later added as an ad-hoc development requirement.

This chapter of the Technical Manual provides guidance on the matters that should be considered from the outset when formulating or assessing an overall WSUD strategy for a site.

It presents a 12 step process and, where necessary, refers the user to documents that contain greater detail or other processes which may need to be followed to successfully implement WSUD.

It should be noted that the process is consistent with suggested processes used in other states. It is also consistent with the National Guidelines for Evaluating Water Sensitive Urban Design (BMT WBM 2008).

3.2 12 Step Decision Process

The process set out in this chapter highlights 12 key steps in the overall conceptual design process to incorporate WSUD in a development and identifies which professionals are required for input (where appropriate).

In general, a broad scale assessment may initially be appropriate to ensure that a proposal complies with the overall intent of WSUD. Further detailed, local scale assessments may be required to ensure that specific water quality, hydrologic, drinking water use and wastewater generation or reuse objectives are satisfied. Finally, examination of the specific design elements for each measure may be needed to ensure that they are adequate to treat the required runoff rates and volumes being discharged to them and achieve the required targets.

A checklist summarising the steps is provided in **Appendix A** and a flowchart illustrating the steps in the process is provided in Figure 3.1.

It should be noted that for a small scale development, not all of the steps in the outlined design process may be required.

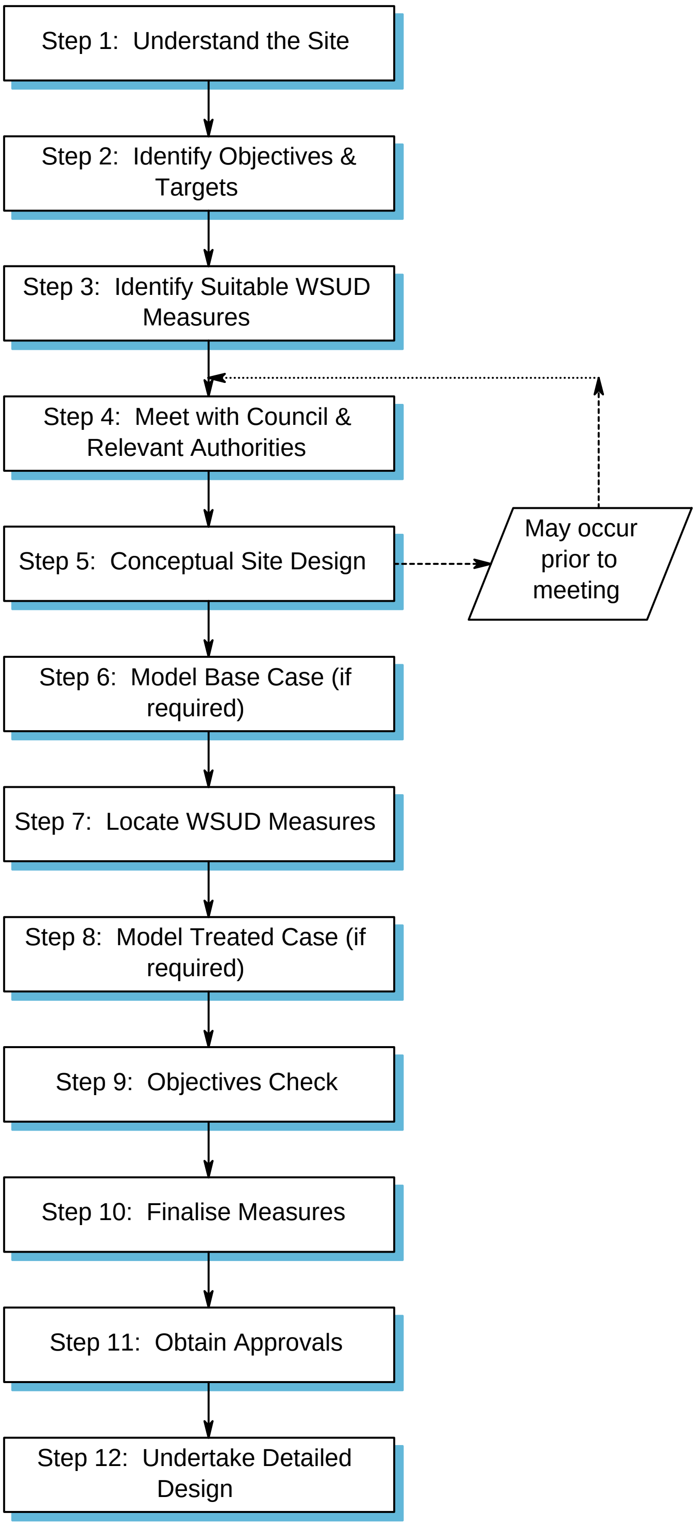


Figure 3.1 WSUD Decision Process Flowchart

The successful application of WSUD requires input from a range of professions, including engineering, ecological, landscape architecture and several other interdisciplinary considerations. A multi-disciplinary team approach is generally required to promote urban design that integrates best practice water planning and management measures with attractive streetscapes and open spaces.

This integration creates attractive and sustainable urban landscapes that can provide developers with a marketing advantage.

For the majority of large scale developments, a person proficient in WSUD will lead a team through the required tasks, or at least seek to facilitate the process. This cannot be conducted separately to other processes such as the overall urban, engineering or landscape design and may require several iterations through the overall urban development project.

Step 1: Understand the Site

Step 1 in the design process is about developing a broad overview of the subject site and identifying those issues that may assist or hamper the overall delivery of WSUD practices.

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of the site conditions is therefore a fundamental part of designing a development that effectively incorporates WSUD.

Appendix B (Site Analysis Information) gives a general guide to the wide range of factors that influence the design, layout, construction and subsequent use and maintenance of a development site. Not all these matters may be relevant to each individual site.

Appendix B outlines issues including: landform; water; soils and geology; plants; wildlife; climate; views; existing site features; services; use of adjacent land; and planning controls.

The breadth of technical expertise required to assess a given site will be dictated by the site itself and particularly its scale. In many cases this will require additional professional expertise.

There are several key characteristics of a site that can influence the overall delivery of WSUD. These characteristics influence the level of detail necessary to give confidence that WSUD can be successfully delivered.

To assist in determining the level of information necessary, **Table 3.1** provides a scoring system to determine the potential risk to the effective implementation of WSUD on a subject site. If the risk is identified as being high, the level of detail necessary to demonstrate that the WSUD strategy can be successfully implemented will also need to be high.

A suggested set of information requirements related to the risk profile is then provided in **Table 3.2**.

Such a site analysis can be submitted to support a development application.

From the site assessment, a list of opportunities and constraints as they apply to WSUD at the subject site should be prepared to assist with the remaining steps in the decision process.

Table 3.1 Site Suitability Review

Characteristic	Potential Implementation Constraint			Score
	Low	Moderate	High	
% Imperviousness (post implementation)	1 = 0-10%	2 = 10-50%	3 = 50-100%	
Soils	1 = Sand	2 = Loam	3 = Clay	
Average slope	1 = 0-1%	2 = 2-5 %	3 = > 5%	
Developed area	1 = < 1ha	2 = 1-10 ha	3 = > 10 ha	
Depth to groundwater	1 = > 3m	2 = 1.5-3 m	3 = < 1.5 m	
Mean annual rainfall	1 = < 400 mm/yr	2 = 400-600 mm/yr	3 = > 600 mm/yr	
			Total score	

Source: Adapted from BMT WBM (2008)

Table 3.2 Indicative Information Requirements

Total Score	Implementation Risk	Local Scale Assessment Level	Suggested Information Requirements
6 – 8	Low	Demonstrate implementation of best practice techniques	Site plan showing location, size and dimensions of WSUD measures Detailed design calculations
9 – 12	Medium	Demonstrate how relevant WSUD objectives are achieved (e.g. load based reduction targets achieved, peak flows compliant with hydraulic objectives)	Overall water management plan provided including: Site plan showing location, size and dimensions of WSUD measures Detailed design calculations Estimates to show how WSUD targets achieved
13 - 18	High	Demonstrate how relevant WSUD objectives are achieved (e.g. load based reduction targets achieved, peak flows compliant with hydraulic objectives) Demonstrate how high risk factors addressed	Overall water management plan provided including: Site plan showing location, size and dimensions of WSUD measures Detailed design calculations Estimates to show how WSUD targets achieved Detailed assessment of proposed mitigation to address risk factors

Source: Adapted from BMT WBM (2008)

Step 2: Identify Objectives

The implementation of WSUD in a development seeks to achieve a range of outcomes relating to water quality, hydrology, conservation, biodiversity and amenity. Each of these outcomes can be met by ensuring development complies with the appropriate objectives and targets identified for the site. Therefore, before any other activities are undertaken with respect to site planning, the objectives should be clearly established so that they can be referred to during remaining steps in the concept design process.

The objectives should focus on:

- Water quality;
- Water quantity;
- Integrated water cycle;
- Landscape;
- Biodiversity; and
- Social.

These objectives should reflect the overall objectives of WSUD in the Greater Adelaide Region to ensure delivery and integration consistency and facilitate achievement of the desired overall water and environmental protection outcomes of WSUD.

In considering and applying WSUD objectives, site specific constraints may in some cases not allow compliance with the complete suite of objectives. In most cases the objectives will not be equal in terms of importance and due consideration is therefore required.

Hence, in developing objectives, care must be taken to ensure that the end result is something that can be practically achieved using existing techniques.

Information to assist with setting objectives is contained in **Appendix C** and in **Appendix D**, which outlines key principles of WSUD.

Step 3: Identify Suitable WSUD Measures

To assess whether a WSUD measure is appropriate requires an understanding of the requirements of the WSUD outcomes and the suitability of the particular measure to assist in achieving those outcomes. In developing a proposed WSUD strategy, it is often necessary to review this on an iterative basis, so that the characteristics of different WSUD measures can be appropriately integrated.

The list of possible WSUD measures (see **Chapters 1 and 2**) should be used to develop a series of potential retention systems and treatment trains for the proposed development, based on the interpreted site conditions, and site opportunities and constraints.

Other factors that should also be taken into consideration in selecting appropriate treatment measures include:

- Cost – benefit ratio of the devices (capital and maintenance costs) against the water quality, water quantity and biodiversity results achieved;
- Workplace health and safety issues (for maintenance crews);

- General public amenity and safety;
- Greenhouse gas emissions and savings;
- Whether a distributed or 'bottom of catchment' approach will be utilised;
- Integration with urban design including road and lot layouts; and
- Life cycle costs and ongoing maintenance requirements and resources.

These factors should be considered alongside the opportunities and constraints identified at the site and the opportunities to layout the development to respond to WSUD requirements.

The information provided in **Appendix E** is intended to assist in the strategy development and review process, which is based upon the information contained in the National Guidelines for Evaluating Water Sensitive Urban Design (BMT WBM 2008).

Step 4: Meet with Council and Relevant Authorities

In the majority of situations, it will be beneficial to the overall development process to meet with council officers to:

- Discuss the site of the proposed development, including opportunities and constraints of the site;
- Discuss the concept design of the proposed development;
- Establish objectives and targets for the proposed development;
- Discuss any likely council requirements, including any modelling expectations;
- Discuss land and asset ownership issues including future maintenance and operation; and
- Determine the necessary approvals including any State Government approvals.

Typically, this would form part of a 'pre-lodgment' meeting which allows informal discussions between the developer (and/or their consultants) and council.

In relation to delivery of WSUD on the site, the primary purpose of this meeting will be to establish that the objectives and targets identified in **Step 2** are the most appropriate and current for the area in question.

A draft concept design of the proposed development (including potential WSUD locations) could be prepared to form the basis of discussion at the pre-lodgment meeting. Further guidance on this is provided in **Step 5**.

This meeting will also allow proponents to discuss the opportunities and constraints identified in **Step 1** to determine whether any compromise may be necessary in the objectives to address the issues noted.

This meeting should also be used to discuss the implications, if any, of council Catchment and Stormwater Management Plans, particularly in relation to the opportunity or requirement for larger catchment scale detention or water quality treatment measures.

Guidance should also be sought from council as to whether it expects modelling of the WSUD measures to be undertaken. If so, the results should be submitted with the development application.

At this meeting it will also be necessary to determine what approvals might be necessary for the proposed development. Other approving authorities (such as the Environment Protection Authority, the Department of Health, the Department of Water, Land and Biodiversity Conservation, the Natural Resources Management Boards, SA Water) may subsequently need to be consulted to ensure that their requirements are taken into consideration at the conceptual and detailed design stages.

Land and asset ownership issues are key considerations prior to construction of any WSUD measures. A proposed design should clearly identify the asset owner and who is responsible for maintenance. This aspect should also be discussed during the initial meeting with the local council.

Step 5: Conceptual Site Design

WSUD principles are most effective and economical when integrated into development design at the concept design stage. Each development type may vary significantly and present different WSUD opportunities. There are many ways to incorporate WSUD in development projects to meet the objectives and targets. The design strategies used in a project will depend upon:

- The location and geography of the site;
- Land use and activity (residential, commercial, industrial);
- Development or redevelopment scale;
- Water use and demand (garden irrigation, industrial needs, etc.);
- Water sources available, including rainfall, stormwater and wastewater;
- On-site catchment area (roof and surface);
- Groundwater and soil type;
- Infrastructure (building and roads);
- Surrounding environment opportunities and constraints;
- Operation and maintenance (council or site owner);
- Urban landscape design (architectural and landscape); and
- Catchment water quantity and quality objectives and targets.

Based on the outcomes of **Steps 1** and **2**, an initial conceptual site design based on broad development outcomes should be undertaken. This may simply be a sketch using intended land uses (e.g. residential areas, local open space, regional open space, protected zones) and should identify areas for possible implementation of lot, local and regional scale WSUD measures.

The objectives identified previously should provide guidance. However, the key to this conceptual design will be the opportunities and constraints identified in **Step 1** and addressing these in a 'whole of development' context. This conceptual site design becomes the overall vision for more detailed design in later steps.

The emphasis of the concept design is on minimising the impacts of development, managing construction activities and considering the ongoing use and dynamics of the proposed development and the landscape in which it sits. Each aspect is interrelated with the others. Adherence to the principles outlined in **Appendix D** will make a considerable contribution to reducing impacts on the total water cycle.

Step 6: Model Base Case (if required by approving authority)

At this stage, sufficient information would have been collected to allow modelling of both the existing site (i.e. pre-development) and the 'untreated' developed site that would form the 'base case' with which to compare future modelling of the WSUD systems proposed for the development (if required by the approving authority).

In the majority of developments, water quality modelling should focus on total suspended solids, total nitrogen, total phosphorus and gross pollutants as the key pollutants of interest, in addition to the hydraulic outcomes. Faecal coliforms and organics should also be considered, depending on the measure being assessed.

Further guidance on modelling is provided in **Chapter 15** of the WSUD Technical Manual.

Step 7: Locate WSUD Measures

When determining the optimal WSUD measures for a site, some consideration should be given to the site analysis and the opportunities available, and the 'natural' or obvious areas for WSUD measures (e.g. overland flow paths). The site analysis may provide information on whether a 'bottom of catchment' approach or a distributed approach to WSUD is optimal for the site.

Step 8: Model Treated Case (if required by approving authority)

Evaluation and assessment of alternative water management strategies are based on predictions made using forecasting tools.

The emergence of new models and design methods to evaluate the use of roofwater and stormwater, and reuse of treated wastewater allow more reliable assessment of the multiple benefits of utilising these alternative sources.

Modelling tools such as MUSIC and WaterCress should, depending on the scale and type of the development, be used to demonstrate that the proposed strategy:

- Achieves the load reduction targets adopted by council; and
- Results in adequate hydrological control of the site as per council's water quantity targets.

Other tools may include water balance modelling (which may include greywater recycling) and flooding or hydraulic modelling where this is appropriate to the site. **Chapter 15** of this Technical Manual should be referred to for further guidance.

Step 9: Objectives Check

At this stage, several iterations may be required to ensure that the majority of objectives set out in **Step 2** are achieved. Note that it may not be possible for all objectives to be met and it may be that a degree of compromise is required in some areas to achieve an optimal outcome.

Where necessary, if particular objectives are essential, then it may be appropriate to revisit the conceptual site design and/or the type of WSUD measures used.

Step 10: Finalise Measures

Once the final WSUD conceptual design has been developed, it will be necessary to confirm sizing and locations of measures prior to entering the detailed design process. Of key importance at this stage will be the identification of services and completed design elements (e.g. roads, open space areas, final lot layouts, hydraulic design) within which WSUD measures may need to be integrated.

A conceptual design should be developed that shows:

- The location of the WSUD measure(s) within the development;
- The proposed layout of the measure in its specific location (also showing key features such as roads and other services). The proposed layout should also provide detail of proposed access to the WSUD measure for maintenance and monitoring and, where relevant, any surrounding recreational infrastructure. This is to ensure that adequate consideration has been given to ongoing maintenance and that the functionality of open and other recreational spaces is not impeded.

The 'design considerations' in each chapter of the Technical Documents should also feed into the conceptual design. Designers may also use the Design Assessment Checklist in each chapter during the concept design to check that no key issues will arise later in the detailed design.

At this stage, it will also be appropriate to document operation and maintenance plans, including all ongoing requirements of each of the measures.

An implementation plan should also be developed for the WSUD measures, particularly where they will be used as interim erosion and sediment control measures, and when the final setting of the system will take place some time after initial functional installation of the device.

The plan should identify:

- When structural elements of the device are to be constructed;
- If devices are to be used as temporary sediment control measures, and for what period; and
- How the final setting of the WSUD measure is to be undertaken.

For soil and water management during the construction phase, it is recommended that procedures outlined in the following references are followed:

- The South Australian EPA's *Stormwater Pollution Prevention Code of Practice for the Building and Construction Industry* (see www.epa.sa.gov.au);
- The NSW Department of Housing 'Blue Book', *Managing Urban Stormwater – Soil and Conservation* (see www.environment.nsw.gov.au/stormwater/usp/docs.htm).

These references outline the general requirements for the preparation of a soil and water management plan.

All erosion and sediment control measures must be maintained in a functional condition throughout the duration of the works.

Where it is envisaged that the final setting of the WSUD measure will take place some time after the functional installation of the device (e.g. after the building phase of the contributing catchment area has been completed), discussions should be held with council to determine the process by which the WSUD device will be completed. Options are to either provide a contribution to council to complete the WSUD asset/s or for the developer to return and complete the asset as designed at a later time. These options should be discussed at the pre-lodgment meeting with council outlined in **Step 4**.

Further guidance can be found in the 'construction and establishment' sections of the Technical Documents.

Step 11: Obtain Approvals

The required relevant approvals, as determined during **Step 4**, should be sought prior to continuation with the detailed design phase.

Step 12: Undertake Detailed Design

Following approval of the development and the conceptual water management plan, the detailed design should be undertaken.

3.3 References

BMT WBM (2008). *National Guidelines for Evaluating Water Sensitive Urban Design (WSUD)*. March. www.nwc.gov.au/publications/index.cfm

Gold Coast City Council (2007). *Water Sensitive Urban Design Guidelines*. June. http://www.goldcoast.qld.gov.au/t_standard2.aspx?PID=6866

Upper Parramatta River Catchment Trust (2004). *Water Sensitive Urban Design, Technical Guidelines for Western Sydney*. Prepared by URS Australia Pty Ltd. http://www.wsud.org/tech.htm

Appendix A
Design Implementation Process Checklist

Water Sensitive Urban Design

Design Implementation Process Checklist

Item	Checked / Considered		Comments
	Y	N	
Step 1: Understand the Site			
1. Land use planning information obtained			
2. Slope and terrain information obtained			
3. Groundwater conditions			
4. Soil properties (reactivity)			
5. Information on natural features obtained (waterways, wetlands, vegetation, etc)			
6. Information on planning constraints obtained (waterway buffers, open space, flood lines, general land use planning information)			
7. Receiving waters identified			
Step 2: Identify Objectives and Targets			
8. Water quality objectives identified			
9. Water quantity objectives identified			
10. Flood management objectives identified			
11. Integrated water cycle objectives identified			
12. Landscape objectives identified			
13. Vegetation and natural features objectives identified			
14. Social objectives identified			
Step 3: Identify Suitable WSUD Measures			
15. Range of suitable WSUD measures identified			
16. Optimal range of WSUD measures identified based on site-specific constraints and opportunities, maintenance requirements and costs			

Item	Checked / Considered Y	Checked / Considered N	Comments
Step 4: Meet with Council and Relevant Authorities			
17. Pre-lodgement meeting held with council			
18. Objectives, targets and site constraints discussed			
19. Relevant legislative requirements identified			
20. Land and asset ownership issues discussed			
Step 5: Conceptual Site Design			
21. Sketch of conceptual site design undertaken			
Step 6: Detailed Site Analysis			
22. Hydrologic patterns and features identified			
23. Site characterised			
24. Ecological assessment undertaken and significant vegetation / habitat / trees identified			
25. Soil / geology description and analysis undertaken			
26. Existing and planned infrastructure identified			
27. Opportunities and constraints summarised			
Step 7: Model Base Case			
28. Water quality of base case modelled			
29. Hydrology / hydraulics of base case modelled			
Step 8: Locate WSUD Measures			
30. WSUD locations identified			
31. WSUD incorporated into development design giving consideration to space and infrastructure requirements			
32. Open space, lot layout and street configuration considered and appropriately managed			

Item	Checked / Considered		Comments
	Y	N	
Step 9: Model Treated Case			
33. Water quality of treated case modelled			
34. Hydrology / hydraulics of treated case modelled			
35. Life cycle costs presented			
Step 10: Objectives Check			
36. Water quality objectives achieved			
37. Water quantity objectives achieved			
38. Flood management objectives achieved			
39. Integrated water cycle objectives achieved			
40. Landscape objectives achieved			
41. Vegetation and natural features objectives achieved			
42. Social objectives achieved			
Step 11: Finalise Measures			
43. Size and location of WSUD measures confirmed			
44. WSUD measures shown to fit within development layout without impacting on open space, road function or service functioning			

Source: Adapted from Gold Coast City Council (2007)

Appendix B
Site Analysis Information

Site Analysis Information

Landform

- Topography is critical to the design and layout of buildings, stormwater controls and drainage. Show contours (1 metre intervals), survey benchmarks and areas of steep slopes (at or greater than 10 degrees or 18%).
- Existing natural features (e.g. cliffs, rock outcrops, vegetated areas, potential groundwater recharge areas, creek lines, permanent water bodies).
- Orientation of the site (e.g. north point).
- Terrain – areas of high and low gradients, flatter areas which may allow larger WSUD measures such as wetlands, level areas which may present difficulties in terms of hydraulic head and high groundwater table.

Water

- Catchment boundaries – internal to the site and catchment areas external to the site.
- Sources of water flowing onto the site and general quality of that water.
- Drainage patterns, areas of concentrated run-off, ponding, flood prone land.
- Adjoining riparian zone, if within 40 metres of waterway.
- Characteristics of the site's downstream catchment (e.g. bushland creek, sensitive potential groundwater recharge area, constructed stormwater drainage channel).
- Receiving environment – identify those waterways or drainage lines where discharge off site is likely to occur.
- Groundwater – depth to, quality, any surrounding usage of the groundwater.

Soils and Geology

- Depth of soil/regolith.
- Soil reactivity.
- Soil pH to indicate affects of soil microorganisms and nutrient availability for plants.
- Soil condition, fertility, whether it has been compacted, cut or filled.
- Erosion problems.
- Contamination potential.

Plants

- Undertake a vegetation survey.
- Existing individual trees, stands of trees and shrubs – show height, spread, condition and species name (common and scientific, if known).
- Trees listed as 'significant' in the council's Planning Schemes.
- Existing ground levels around the base of trees.
- Weed species present and extent of weed infestation.
- Plants that grow well on the site or that are characteristic of the local area.
- Any threatened species or ecological communities present on the site or nearby land (consult council's GIS).
- Trees and vegetation proposed to be removed.

Wildlife

- Habitats present on the site or nearby land.
- Potential to provide fauna habitat, such as niches in rockeries, ponds for frogs, habitat plants (nectar-bearing shrubs for small birds).

Climate

- Direction of summer and winter winds.
- Windbreaks and their likely permanence.
- Frost pockets.
- Areas of full or partial shade in summer and winter at 9am, midday and 3pm.
- Direction and extremity of bushfire threat.

Views

- Views from the site – good views to be retained where possible, unpleasant views to be screened if possible.
- Views into the site, privacy and security problems.
- Qualities of the site that are important in the view to and from the site (e.g. major trees).

Existing Site Features

- Location and uses of any existing buildings and structures on the site showing those to be removed and retained.
- Location and height of walls and fences built to the boundary.

- Heavily shaded areas from existing structures, mature trees or dominant landforms.
- Archaeological and heritage (Aboriginal and European) sites.
- Any easements, rights-of-way and their restrictions.

Services

- Location of existing overhead and underground utility services (electricity, gas, telephone, water, sewer and stormwater drainage lines, inlets and collection points).

Use of Adjacent Land

- Location and use of adjacent buildings.
- Rooftop ridge levels and floor levels of adjacent buildings.
- Potential for overlooking into and from window openings in walls adjacent to the development site.
- Potential for shading adjacent properties.
- The form and character of adjacent and nearby development, including characteristic styles of buildings and landscaping, and bulk and scale of buildings.
- Street frontage features, such as street trees, poles, kerb crossovers and bus stops.
- Potential sources of nuisance, dust and noise, such as main roads.

Planning Controls

- Planning objectives, zoning, design criteria, lot size, site coverage, density controls and other provisions in local area Development Plans or other state legislation.
- Restrictions on development due to hazards (such as flooding, landslip, land contamination).
- Controls on removing vegetation or trees or on earthworks.
- Building setbacks, envelopes, height restrictions, view corridors.
- Planning constraints – environmental corridors, waterway corridors, flood lines, open space or recreational nodes.
- Strategic catchment planning – identify catchment or subcatchment plans (this will include natural resource management plans, stormwater management plans and infrastructure plans) to identify any regional or catchment-scale strategies applicable to the site.

Appendix C
Setting Objectives

Setting Objectives

The overarching objective (or vision) of WSUD in the Greater Adelaide Region is to stabilise and improve the health of the Region's coastal waters, watercourses and groundwater systems while maintaining and enhancing human health and reducing the ecological footprint of the Region.

WSUD Frameworks and Guidelines interstate and overseas have wide-ranging and varied objectives which relate to the context in which they were written. A key outcome of consultation undertaken during the development of the Framework was the identification of a number of objectives which were considered to be appropriate for the Greater Adelaide Region.

The key objectives that the implementation of WSUD seeks to achieve are:

- To move towards a natural flow regime (for example lower flows to reduce erosion of creeks and improve/maintain ecological value);
- To manage risk in relation to drought, flood, climate change and public health;
- To protect, enhance, value and conserve water resources;
- To encourage leading practice in the use and management of water resources to increase water efficiency, reduce reliance on imported water and apply at-source reduction of impacts on water quality, flooding, erosion and sedimentation;
- To raise awareness and catalyse change in the design, construction and management of urban development and urban infrastructure; and
- To recognise and foster the significant environmental, social and economic benefits that result from sustainable and efficient use of water resources.

Water Quality Objectives

One of the primary roles of WSUD is to reduce the impacts of urban development on receiving water quality. As part of the design process, relevant environmental values and water quality objectives of receiving waters or other water quality targets relevant to the site must be identified and documented. These may include:

- Concentration-based water quality objectives for receiving waters;
- Concentration-based discharge standard from a site;
- Load-based criteria (mass per unit of time) or reduction in load.

The relevant water quality objectives should be used as primary performance criteria on which a development is assessed for its ability to ensure protection of receiving water quality.

Different types of land use typically generate specific stormwater pollutants in significant quantities. Consequently, the 'key' pollutants to be addressed from new development, and the control techniques employed, are a function of the type of development. **Table C1** identifies the significance of pollutants likely to be generated by different land uses.

Table C1 Range of Pollutants Likely to be Generated by Different Land Uses

Development Style	Litter	Coarse Sediment	Fine Particles	Total Phosphorus	Total Nitrogen	Heavy Metals	Hydrocarbons, Motor Fuels, Oils & Grease
Low Density Residential	M	L	L	M	M	L	L
High Density Residential	M	M	M	M	M	M	M
Commercial, Shopping and Retail Outlets	H	M	M	M	M	M	M
Industrial	M	M	M	L	L	H	H
Fast Food Outlets and Restaurants	H	L	M	M	M	L	M
Carparks, Service Stations and Wash Bays	H	M	M	L	L	H	H

Source: Adapted from Upper Parramatta River Catchment Trust (2004), Gold Coast City Council (2007)

Note: H = High, M = Medium, L = Low

Note: for industrial and commercial developments, site-specific assessment should be undertaken to identify key pollutants that need to be targeted for the proposed development

It should be noted that gross pollutant and sediment load is not necessarily a product of allotment-specific development types; it can also be as a result of the street network associated with them and the street cleaning regime adopted. Street trees are often a major contributor.

Water Quantity Objectives

Another key principle of WSUD is to reduce the impact of urban development on the natural hydrologic conditions of a site. Inundation times should be considered as part of the setting of water quantity objectives. This will be particularly relevant where inundation times may be increased for downstream properties.

Further discussions should be held with council development assessment officers during **Step 4** to ensure appropriate quantity targets have been identified.

It should be recognised that WSUD elements in isolation will not be sufficient to address all flooding/hydraulic requirements but may be integrated within the overall hydraulic design of the development.

Integrated Water Cycle Management Objectives

One of the major benefits of WSUD is the ability to incorporate measures that can benefit all parts of the water cycle. Specific objectives may be defined for the subject site. WSUD elements such as rainwater tanks, water efficient devices, aquifer storage and recovery, and wetlands can all be useful elements in an overall integrated water management plan.

Landscape and Amenity Objectives

While deterministic objectives may not be available, broad objectives for the integration of landscape elements into WSUD may include the following:

- Ensure the integration of landscapes, recreational amenity and WSUD functionality facilitates creative expression and solutions, meets standards of service for recreation and landscape amenity, can be comprehended by the community and is sensitive to the environment and the local setting;
- Provide appropriate buffers to open space areas or environmental corridors;
- Ensure the functionality of open space areas is not compromised by the WSUD elements in most circumstances;
- Provide a desirable community amenity and integrate WSUD into the overall design of the urban framework;
- Ensure the sustainability of landscape amenity through design which accounts for longevity of the system considering maintenance and community use aspects (e.g. vandalism, litter protection);
- Provide 'green' elements and visual breaks in the urban landscape.

Landscape objectives for WSUD should identify specific features within and surrounding the site to ensure:

- Consistency with the current character of the area;
- The qualities of the existing or built environment landscape are retained;

- Retention of existing landscape and heritage features;
- Provision of social and recreational opportunities; and
- Retention of important view and vistas.

Vegetation and Natural Features

The objectives of WSUD relating to vegetation and natural features include:

- Protection and enhancement of waterways, wetlands and their buffers;
- Ensuring appropriate development setback from waterways and wetlands;
- Protection of remnant vegetation communities;
- Retention and reinstatement of native vegetation;
- Natural channel design responses for natural gullies and waterways.

Each of these objectives should be developed in conjunction with **Step 7** to ensure natural features of the site are identified and their protection/enhancement, specific to the identified feature, is listed as an objective for that development.

Social Outcomes

Increasingly, developers are recognising the benefits of incorporating social design into the delivery of new urban areas. Objectives relating to public safety, community enhancement and recreational opportunities may be identified through other processes. However, it is important that they are considered as a specific outcome.

Appendix D
WSUD Principles

WSUD Principles

There are numerous guiding principles that underpin the objectives for water management and the implementation of WSUD in the Greater Adelaide Region. These principles should be addressed when undertaking the planning and implementation of water management.

The guiding principles include:

- Incorporate water resources as early as possible in the land use planning process;
- Address water resource issues and conservation of biodiversity at the catchment and subcatchment level;
- Ensure water management planning is precautionary and recognises inter-generational equity, conservation of biodiversity and ecological integrity;
- Recognise water as a valuable resource and ensure its protection, conservation and reuse;
- Recognise the need for site-specific solutions and implement appropriate non-structural and structural solutions;
- Protect ecological and hydrological integrity;
- Integrate good science and community values in decision making; and
- Ensure equitable cost sharing.

The emphasis is on minimising the impacts of development, managing construction activities and considering the ongoing use and dynamics of the proposed development and the landscape it sits within. Each aspect is interrelated with the others. Adherence to the following principles will make a considerable contribution to reducing impacts on the natural water cycle.

Minimise Disruption to Landforms and Drainage Patterns

By minimising disruption to landforms and drainage patterns you can avoid related impacts on vegetation, weed growth and loss of habitat, both on and off the site. According to Hobart City Council (2006), soil surface disturbance creates an immediate potential for:

- Loss of topsoil by wind and water erosion;
- Sediment to be carried away and deposited downstream;
- Changes to nutrient and moisture conditions in deposition zones which may make existing plants unsuitable for the conditions, cause native plants to die or not regenerate and create conditions for weeds to establish and dominate; and

- Long-term effects on the pattern of runoff and infiltration for established areas of vegetation, damp spots, creeks and watercourses, thereby causing irreversible changes to natural systems.

Therefore, the minimisation of cut and fill is recommended by:

- Using natural ground levels where possible for siting houses and other structures;
- Using house construction techniques to accommodate slope (e.g. pole construction, split level or stepped design);
- Using pier and beam foundations rather than slab on ground construction to minimise ground and tree root disturbance; and
- Designing driveways to contour around slopes. Use grassed swales to direct flow towards vegetated areas at regular intervals (every 3 metres) to reduce water volume and to permit smaller depressions in the driveway profiles.

It is also recommended that stormwater flow be managed by:

- Slowing down flow rates where possible to prevent erosion, promote infiltration and reduce reliance on supplementary watering and irrigation;
- Using pervious paving, pebble paths, infiltration trenches, swales, terraced garden walls, mulched garden beds or other landscaping elements to slow down and infiltrate runoff (where soil conditions are appropriate e.g. sandy soils).

Minimise Disruption to Existing Vegetation

Maintaining existing vegetation avoids many soil and weed management problems, and helps conserve biodiversity. In doing so, consideration should be given to:

- Minimising removal of plants and root systems as this makes the site prone to erosion and can alter water table levels, causing potential flooding problems or vegetation decline;
- Avoiding increased light levels on bare soils as this encourages weed growth;
- Maintaining the area's full ecological spectrum of plants as this helps to conserve habitats for all sizes of fauna, including insects, lizards, fogs and insectivorous birds. Their disappearance from gardens and their natural ability to help control pests can lead to the reliance on chemical control and detrimental impacts on other natural elements such as soil ecology.

Assess the health, vigour and longevity of existing mature trees at the site planning stage. Existing trees may not tolerate construction activity in the root zone, resulting in a decline in tree health, accelerated limb loss, pest and disease attack or complete demise, which can lead to injury or property damage.

If removing trees, consider planting replacement trees that are deep rooted species to:

- Maintain or lower the water table to mitigate potential for flooding;
- Bind the soil and reduce soil erosion;
- Decrease runoff velocities;
- Filter nutrients and capture sediments.

Minimise Impacts on Neighbouring Areas

The minimisation of impacts on neighbouring areas includes adjoining lots as well as nearby natural areas (e.g. bushland areas, waterways, swamps, groundwater recharge areas, foreshores):

- Consider your site as one part of the whole landscape. For instance, planting large trees to provide shade in summer may be unpleasant for neighbours by providing unwanted shade in winter;
- Avoid impacts on adjoining sensitive environments due to construction works, gradual accumulation of sediment or exotic plants that become weeds and displace other plants;
- Manage construction works so as to minimise environmental impacts on soil, water, vegetation and air. Limit nuisances such as noise and waste. Make detailed plans to:
  - Protect the site and adjoining properties prior to commencement of work. This will provide long-term benefits for ongoing site use and management;
  - Prevent sedimentation in waterways and drainage lines, as this can reduce flow capacity, increase localised flooding and cause property damage.

Prevent or Repair Ongoing Problems

Some sites are already disturbed or experience problems caused by external activities. These may include soil loss, sediment deposits, weed invasion or risk from bushfire, landslip or other hazards. These must be factored into decisions regarding layout, construction materials and ongoing management:

- Carry out measures to reverse existing damage and control/prevent further damage (e.g. soil conditions or weed invasion);
- Choose building materials and planting species to suit conditions (e.g. bushfire hazard);
- Place pavement areas so as to redirect or reduce impact of large stormwater flows;
- Reduce reliance on supplementary garden watering by species selection and placement, grouping species with similar water needs, creating and utilising microclimates to advantage, changing maintenance and watering regimes, or other horticultural practices.

Consider Siting Requirements

Buildings, utilities and stormwater measures have particular siting requirements:

- Position and orientate buildings to take best advantage of solar access, views, microclimate and natural site features;
- Position driveways so as to minimise gradient to reduce the velocity of runoff;
- If possible, site water tanks so that water can be fed by gravity;
- Filtration/infiltration devices need to observe minimum separations from buildings. These vary according to soil conditions;
- Place pervious paving in locations that will not receive significant amounts of sediment, debris or other material likely to hinder performance;
- Place landscaped areas in positions that will receive runoff from upstream areas to promote infiltration and filtering of runoff;
- Place structures on sites that are already cleared to minimise ground disturbance;
- Set structures below the topmost point of a property to reduce the intensity of wind exposure. Take advantage of established wind breaks or other natural features to create a pleasant microclimate;
- Reduce driveway, paths and other pavement areas to a minimum by re-dimensioning, choosing alternative materials or rationalising the layout so that some areas become multi-purpose (and more economic to construct);
- Consider the safety of the general public adjacent to the WSUD device. Consideration should be given to the risks associated with open water bodies, ponded water etc and should be appropriately managed through selection of devices and subsequent detailed design;
- The device must be able to integrate with the local character and built environment and be suitably located to treat the maximum amount of runoff from the site.

Maintenance and Operation

A poorly maintained treatment measure may not only perform badly; it may become a hazard or a source of pollution itself. Treatment measure operation and maintenance requirements vary widely. When assessing the treatment measure's maintainability and operability, the following issues should be considered:

- Ease of maintenance and operation: the selected treatment should be easy and safe to maintain and operate;
- Extent of maintenance: ensure the maintenance requirements are within the operator's capability;

- Access to the treatment site: consider the ease of site access when reviewing the treatment's maintenance requirements;
- Frequency of maintenance: ensure that resources are available to carry out maintenance at the required frequency;
- Debris and pollutant clearing: during clearing, the treatment should not require direct human contact with debris and trapped pollutants (automated clearing facilities are preferred); and
- Disposal: consider the disposal of any waste (e.g. gross pollutants, vegetation etc) from the treatment process.

The devices selected should represent a reasonable maintenance burden, particularly where the asset will be handed over to council at some time in the future.

The maintenance requirements must be within council's capacity in terms of skills, resources and equipment. The treatment devices should be safe to maintain and should not require direct contact by maintenance staff with pollutants and other trapped materials. Furthermore, maintenance procedures should be simple without the need for specialised equipment.

The devices and their locations must be accessible for ongoing maintenance, including for all equipment (such as any heavy machinery).

Appendix E
WSUD Treatment Train Suitability Assessment

Table F1 below can be utilised to assist in the development and review process. If a particular goal is determined as being an essential component, a score of 1 for that objective suggests that the measure needs to be re-examined.

This is simply a guide to assist the practitioner where other, more detailed, guidelines are not available, but can also provide an overview of how measures can be optimised to achieve objectives.

Particular measures may not achieve all objectives and some may be completely unsuitable. As such, guidance is also required on which types of measures or practices are most appropriate to specific objectives.

Table F1 WSUD Treatment Train Suitability Assessment

Objective	Suitability			Score
Water Quality				
Treatment Train Elements				
Primary Treatment (screening / sedimentation)	1 = None (no specific measure)	2 = Incidental (measure may treat though not designed to)	3 = Dedicated (e.g. GPT, sedimentation basin)	
Secondary Treatment (enhanced sedimentation / vegetative filtering)	1 = None (no specific measure)	2 = < 50% vegetation coverage	3 = > 50% vegetation coverage (e.g. wetland, swale)	
Tertiary Treatment (biological uptake)	1 = None (no specific measure)	2 = Filtration only (e.g. infiltration trench, pervious pavement)	3 = Filtration + vegetation (e.g. biofilter, raingarden)	
Water Quality Outcomes achieved	1 = No compliance for any parameter	2 = Partial compliance	3 = Full compliance (or not applicable)	
Load based reductions achieved	1 = No compliance for any parameter	2 = Partial compliance	3 = Full compliance (or not applicable)	
Water Quantity				
Disconnection of impervious areas	1 = No disconnection	2 = Conveyance provides disconnection, but >10% directly connected impervious area	3 = Disconnection achieves < 10% directly connected impervious area	
Detention	1 = No detention capacity	2 = Detention component provided for minor flows	3 = Detention for major flows integrated into measure	
Water harvesting	1 = None	2 = < 10% of storage volume available for harvesting	3 = > 10% of storage volume used for harvesting	

Objective	Suitability			Score
Water Supply				
Measure can provide alternative sources of water	1 = none possible	2 = one potable water source can be substituted	3 = two or more water sources can be substituted	
Reduces potable water demand	1 = no demand reduction possible	2 = 0-20% reduction expected	3 = >20% reduction expected	
Amenity				
Multiple uses provided by the measure	1 = only has one function	2 = has an amenity function in addition to primary function	3 = has multiple functions	
Form is integrated into landscape	1 = discontinuous from other landscape elements	2 = has one or more consistent features with overall landscape character	3 = completely integrated within landscape	
Existing natural features retained	1 = < 25% natural features retained	2 = 25-75% features retained or enhanced	3 = > 75% of natural features retained	
Public safety elements addressed	1 = likely to pose public safety hazard	2 = public safety elements incorporated into design	3 = no public safety issue	
Linkages (pedestrian, bicycle, vehicular) maintained or enhanced	1 = links severed by measure	2 = existing links retained through measure	3 = existing links maintained and additional linkages provided	
Functionality				
Maintenance elements incorporated within measure	1 = no dedicated maintenance elements incorporated	2 = maintenance access provided	3 = maintenance access provided, working areas highlighted and provision for waste handling included	
Maintenance plans provided	1 = no maintenance plans given	2 = generic maintenance plan provided	3 = maintenance plan specific to measure provided, including costings	
Service corridors allowed for	1 = no service areas allowed for	2 = services can be included, but constrained	3 = service corridors dedicated and sufficient	

Source: BMT WBM (2008)

Total score:

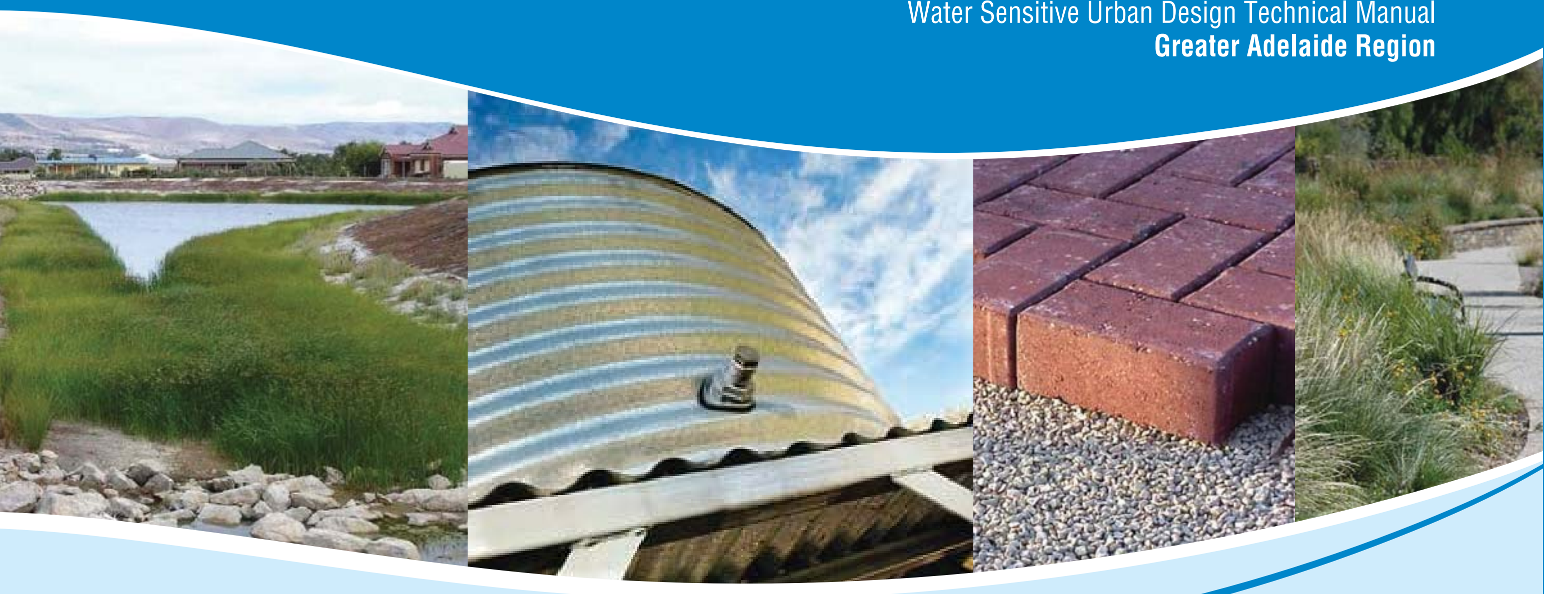
18 – 27 = strategy, measure or treatment train may need considerable refinement
28 – 40 = strategy, measure or treatment train may achieve WSUD objectives, however further refinement would be beneficial
41 – 54 = strategy, measure or treatment train has a high likelihood of successful implementation.

July 2009

Chapter 4

Demand Reduction

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 4
Demand Reduction

4.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment).

Demand reduction is one of those WSUD measures.

Water demand can be reduced through changing behaviour, through technology, and through design.

This chapter of the Technical Manual provides an overview of demand reduction measures. Other chapters to be read in conjunction with this chapter include:

- Introductory chapters (**Chapters 1-3**)
- Rainwater Tanks (**Chapter 5**)
- Rain Gardens, Green Roofs and Infiltration Systems (**Chapter 6**)
- Urban Water Harvesting and Reuse (**Chapter 8**); and
- Wastewater Management (**Chapter 14**)

Scale and Application

Demand reduction can be applied to all scales of development, including residential, commercial, industrial and open space.

Demand reduction measures are also appropriate for retrofitting existing residential, commercial (including retail, educational and institutional uses) and industrial development as well as parks and public open space.

4.2 Water Restrictions and Applicable Legislation

Water Restrictions

Water use restrictions apply in South Australia.

The level of water restrictions is regularly revised depending on water supply issues relating to the River Murray and Greater Adelaide Region catchments.

The level of water restrictions currently exceeds the permanent water conservation measures outlined below.

SA Water's website (www.sawater.com.au) is constantly updated with information relating to restrictions. It is recommended that the website is visited regularly to obtain the most current information.

Permanent Water Conservation Measures

Permanent water conservation measures are effectively the base level of 'water restrictions' South Australians are required to comply with on an ongoing basis. These were introduced in 2003.

(Note: as outlined above, temporary water restrictions in place at any time may exceed these permanent measures.)

Under the permanent water conservation measures, public or private gardens, recreational areas, sports grounds or nurseries can be watered:

- By hand (through a handheld hose, from a bucket or watering can); or
- Through a drip-feed irrigation system; or
- Where the watering takes place through a sprinkler – after 5pm and before 10am on any day (or, when daylight saving is in force, after 6pm and before 10am).

No hosing down of external paved areas with water at any time is permitted unless it is absolutely necessary to do so.

Water must not be used to clean a motor vehicle or boat unless the water is applied:

- From a bucket or watering can filled directly from a tap; or
- By a high pressure low volume water cleaner; or
- From a handheld hose that is fitted with a trigger nozzle.

Motor vehicles or boats can be cleaned at a commercial car wash or by means of an automatic washing system that recycles water. Boat motors may be flushed or rinsed after use.

Further details of the permanent water conservation measures can be obtained from SA Water's website (www.sawater.com.au).

Anyone found in breach of the water conservation measures will, in the first instance, be issued with a warning notice reminding them of their responsibilities. If non-compliance continues, a $315 expiation notice will be issued. Serious or ongoing breaches could result in court action and fines of up to $5000 for individuals and $10,000 for corporations are applicable.

Industrial Water Efficiency Plans

From 1 July 2007 there is a requirement (under the *Waterworks Act 1932*) for industrial users to prepare a water efficiency plan that identifies where they can make water savings in any area of their operations where water is used. Proformas for completing the plans are available on the SA Water website (www.sawater.com.au/SAWater/Environment/WaterRestrictionsConservationMeasures/water_efficiency_plans.htm).

Industrial use of water for the purposes of this provision means water used not only for conventional industrial purposes such as processing, production, manufacturing and smelting, but also for commercial and business purposes, institutions such as schools and hospitals, construction, mining, aquaculture and intensive animal farming. Government agencies also have to comply with these requirements.

All industrial users of water are treated the same way, regardless of whether they obtain the water via SA Water infrastructure or by pumping directly from the River Murray under a water licence.

Applicable Legislation

Various legislation relevant to water management in South Australia is outlined below. Further detail regarding each of these and its effect is provided in **Appendix A**:

- *Water Efficiency Labelling and Standards Act 2006*;
- *Water Conservation Act 2006*;
- *South Australian Water Corporation Act 1994*;
- *Waterworks Act 1932*;
- *Sewerage Act 1929*;
- *Natural Resources Management Act 2004*;
- *Public and Environmental Health Act 1987*;
- *Environment Protection Act 1993*; and
- *Local Government Act 1999*.

4.3 Where Do We Use Water?

A range of local and interstate material is available to provide general guidance on where water is used in different types of development.

Residential households are the largest group of users (45%) of Adelaide's water (from all sources), followed by primary production (28%), community purposes (17%) and commercial and industrial uses (10%). A total of 40% of this is used in gardens and the outdoors. (Government of South Australia Water Proofing Adelaide (2005), p27.)

The table below provides an indication of estimated household water demand for different types of residential development.

A range of tables is provided in **Appendix B** for other types of developments.

Table 4.1 Estimated Typical Household Water Demands (litres/day)

Water Use	Design Number of Occupants				
	1	2	3	4	5
Bathroom	65	107	145	189	223
Toilet	49	107	145	189	223
Laundry	38	54	100	137	174
Gardening	87	220	220	220	220
Kitchen	14	38	60	83	123
TOTAL	253	526	670	818	963

Source: Upper Parramatta River Catchment Trust (2004), Melbourne Water (2005) [1] 1

[1] Data from Melbourne Water has been used for the one person scenario and the remainder of information in the table is sourced from Upper Parramatta River Catchment Trust

4.4 Demand Reduction Approach

Overview

There are a number of steps to be taken in determining the demand reduction measures which are most appropriate for a particular development or redevelopment. The steps include:

- Site analysis;
- Determining objectives and targets;
- Technique selection;
- Meeting with local council and other relevant authorities;
- Identifying funding opportunities; and
- Review of objectives.

These various elements are discussed in detail in the following sections. Reference should also be made to **Chapter 3** for a general discussion on the approach.

Site Analysis

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of site conditions is a fundamental part of designing a development that effectively incorporates WSUD.

Before being able to determine what demand reduction approaches are suitable for a new development or redevelopment it is important to understand, for each site:

- How much water is used (or intended to be used);
- Where water is used (or intended to be used);
- By whom water is used (or intended to be used);
- How water is used (or intended to be used); and
- When water is used (or intended to be used).

If the site is existing, an audit of the water usage should be conducted in the first instance to obtain the information listed above. An audit can range from a broad overview to a detailed study.

There are tools and services available to assist developers, existing businesses, industry, schools and householders to complete this process (see **Section 4.9** - Useful Resources and Further Information), but the following basic steps will help gain an understanding of water usage and costs for an existing development:

- Check water bills for the past two years (ideally five) to see how much water has been used. Sudden or gradual increases in water use may indicate leakage;
- Read water meters regularly to identify any unexpected increases in water use that may indicate leakage. To confirm if there are leaks, carry out a night flow test when water use is nil or at a minimum;
- Identify the water intensive areas of your business or home to target specific areas of high consumption. In particular, identify equipment and practices that utilise water and/or that potentially waste water;
- Investigate seasonal trends in water usage.

The information provided in **Appendix B** can be used to inform the auditing process, or can be used for new development sites where no historical data is available.

The outcomes of the site analysis should assist in setting objectives and targets for water use reduction.

Determining Objectives and Targets

To achieve reductions in water consumption, it is important to set realistic water conservation objectives and targets and track progress against any targets set. If the objectives for selecting a demand reduction approach (and measures) are clearly defined, the task is simplified.

For the commercial and industrial sector an option is to incorporate water efficiency and reduction targets into an environmental policy.

Targets should be:

- Specific – clearly state what you aim to achieve;
- Measurable – ensure that the data is available and that systems are in place to measure the data;
- Achievable – assess if it is possible to meet the goal with the available resources and timeframe;
- Realistic – set targets that are possible to achieve for the type of program you are implementing; and
- Timely – set a timeframe for achieving each target and goal, and monitor on a regular basis.

Further information on objectives and targets is contained in **Chapter 3** of the Technical Manual.

Technique Selection

The next stage of the process is to identify and prioritise water conservation and water reuse opportunities. Through the site analysis process a range of opportunities will have been identified.

There is a range of measures available that can be undertaken to meet the identified opportunities (see **Section 4.6**). Selection of measures will need to take into account factors such as:

- Site conditions;
- Effectiveness;
- Economics; and
- Energy consumption (or greenhouse gas emissions).

Opportunities should be categorised to assist in planning the implementation phase. For example:

- Quick wins that can be implemented immediately (i.e. installation of water efficient fittings, planting of more drought tolerant species);
- Opportunities requiring some capital outlay (i.e. installation of a rainwater tank or diversion of roof runoff or rainwater tank overflow to a rain garden);
- More capital outlay required, therefore could be considered to be lower priority initiatives (i.e. replacement of paving with pervious paving); and
- Initiatives requiring further investigation (i.e. installation of greywater treatment and reuse system).

It is important in the commercial and industrial sector to identify someone who will be responsible for water management within the business.

In relation to larger capital items, more opportunities will be available for a new development compared to an existing development where retrofitting is required.

Meeting with Council or Other Relevant Authority

Before designing or installing demand reduction measures, it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to demand reduction measures in your council area. A discussion with your local development assessment officer at council is therefore recommended.

The council will also be able to advise whether:

- Development approval is required and, if so, what information should be provided with the development application;
- Any other approving authorities should be consulted; and

- Any specific council requirements need to be taken into consideration.

Further information can be obtained in **Section 4.2** - Water Restrictions and Applicable Legislation.

Identify Funding Opportunities

Australian governments, at all levels, are actively encouraging demand reduction to help reduce the stress on the current water supply network.

Listed below are a number of rebate schemes currently available to South Australians. Funding opportunities should be investigated to see if they may be able to assist in undertaking the demand reduction measures which have been identified for the particular site.

It should be noted that the details provided below are correct as at May 2008. It is therefore important to check whether your local council or water provider is offering a rebate scheme.

Adelaide and Mt Lofty Ranges Natural Resources Management Board

The Adelaide and Mount Lofty Ranges Natural Resources Management (NRM) Board often releases community grants to assist the local community to take action to better understand and manage the region's natural resources.

Further information on community grants available from the Board can be found at www.amlrnrm.sa.gov.au/

Local Government

A number of local government bodies also have rebates available for their residents. Information can be obtained from the respective council or on their website.

For example, the Adelaide City Council's Water Conservation Incentive Scheme (as of May 2008) offers reimbursements on the purchase and installation of a range of water conservation devices in an effort to improve efficiency in the use of water. Items covered by the scheme include rainwater tanks, greywater reuse systems and water efficient showerheads, as well as the plumbing of rainwater tanks to household appliances.

Further information on the Adelaide City Council's grants can be obtained at www.adelaidecitycouncil.com

The City of Prospect also (as at December 2007) offers a range of financial incentives to encourage property owners and/or occupiers to implement various water conservation measures which aim to reduce usage of mains water. The incentives cover rainwater tanks, dual flush toilet cisterns and water efficient showerheads.

Further information on the City of Prospect's grants can be obtained at www.prospect.sa.gov.au

State Government

The home rebate scheme has been introduced by the South Australian Government to encourage South Australian households to achieve greater water savings inside and outside the home. Rebates are available for approved water efficient products purchased on or after 1 November 2007. Rebates towards home water audits are available from 1 January 2008.

The rebates available are:

- Up to $30 for a low flow (3 stars or more) showerhead;
- $150 for retrofitting a dual flush toilet suite;
- $200 for the purchase of a new water efficient (4 stars or more) washing machine;
- $50 rebate when you spend $150 or more on specified water efficient garden goods;
- $100 rebate for a home water audit plus the installation of up to two free low flow showerheads; and
- Between $200 and $1000 towards the cost of purchasing and plumbing a rainwater tank to retrofit into your home.

More information on the particular rebates can be obtained from the SA Water website (www.sawater.com.au).

To help householders to better monitor and manage their water consumption, SA Water will bill residential customers on a quarterly basis, starting 1 July 2009.

4.5 Water Efficiency Labelling and Standards Scheme

There is a growing body of information for consumers on how to save water and money.

The Water Efficiency Labelling and Standards (WELS) Scheme was established as a cooperative Commonwealth/state and territory regulatory system to help reduce domestic water consumption.

It came into force in January 2006 and replaced the previous voluntary AAAAA water rating scheme.

Labelling under the WELS Scheme is compulsory and requires product suppliers to label clothes washers, dishwashers, showers, taps, toilets, urinals and flow controllers with water efficiency information and star-ratings to enable consumers to choose the most water efficient product for their needs.

The scheme is based on the existing successful energy efficiency labelling standards (which clothes washers and dishwashers must also carry) (see **Figure 4.1**).

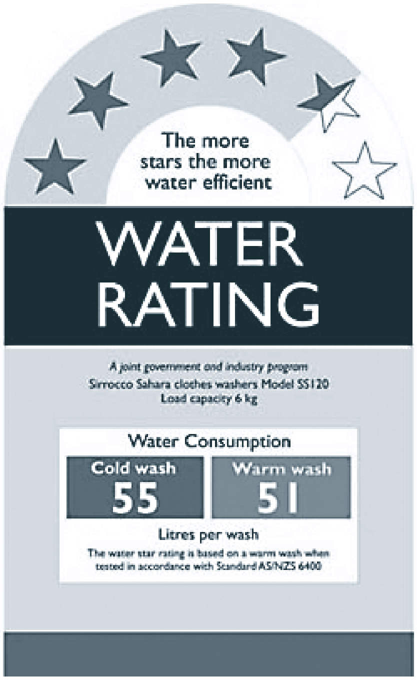


Figure 4.1 Water Rating Label Example

The label provides valuable information for consumers about

- a star rating for a quick assessment of the product's water efficiency and
- a figure showing water usage ie litres per kilogram of clothes washed.

Table 4.2 outlines what the labelling scheme generally means in terms of water efficiency.

Table 4.2 Water Efficiency Rating

Rating	Water Efficiency
★★★★★	Excellent
★★★★	Very high
★★★	High
★★	Good
★	Poor

For example, a showerhead that uses less than 9 litres/minute will be '★★★' rated. One that uses 9 to 12 litres/minute will receive '★★' rating. A 12-15 litre/minute showerhead will have an '★' rating. Those using more than 15 litres/minute do not comply with this scheme.

Products must conform to the appropriate Australian Standard for performance, such as Australian Standard AS/NZS 3662 for showerheads.

Additional consumer information is provided by WaterMark which is a product quality certification mark provided by independent certifying authorities. It confirms that the product complies with the requirements of the Plumbing Code of Australia and the specifications listed in relevant Australian Standards. These relate to the quality of the product, including aspects of health and safety, and warrant that it is fit for purpose.

WaterMark certification is mandatory for products to be legally installed in accordance with state and territory plumbing regulations. Those products required to be certified are listed in the Plumbing Code of Australia and AS5200.000.

The WaterMark logo, the relevant product Standard and the License Number are required to be marked on the product itself. However, WaterMark is not required for a product to be legally sold in Australia.

WELS products must carry a WELS label in order to be legally sold, but may not necessarily have the WaterMark. Consumers buying a WELS labelled product which does not carry the WaterMark should ask their local water authority or plumber if it can be legally installed.

4.6 Techniques

There is a range of measures which are available to assist in reducing the water demand for various types of developments which are summarised in Table 4.3 and discussed in more detail below.

Table 4.3 Demand Reduction Measures Applicable to a Range of Development Types

Measures	Development Type				
	Residential blocks	Multi-unit residential	Estate development works	Commercial, industrial and institutional developments	Capital works (roads, ponds, earthworks, public areas)
Water efficient fittings and fixtures	Yes	Yes	-	Yes	-
Water efficient mechanical plant	-	-	-	Yes	-
Water efficient landscaping	Yes	Yes	Yes	Yes	Yes
Rainwater storage and use	Yes	Yes	Yes	Yes	Yes
Stormwater storage and use	Yes	Yes	Yes	Yes	Yes
Use of greywater	Yes	Yes	Yes	Yes	-
Use of treated wastewater (if available)	Yes	Yes	Yes	Yes	-

Appliances and Fixtures

There are many, often inexpensive, ways to improve water efficiency including:

- Well maintained fixtures (i.e. no drips);
- Tap aerators;
- Efficient toilets;
- Water efficient shower roses;
- Washing machines; and
- Dishwashers.

Each of these measures is discussed briefly below.

Well Maintained Fixtures

The first step to achieving maximum water efficiency is to keep a well maintained plumbing system in all buildings. A dripping tap can waste up to 20,000 litres each year.

Other leaks that often go unnoticed are toilet cistern leaks. A toilet can run constantly from the cistern into the pan without being audible or visually noticeable. A slow, barely visible leak can waste more than 4000 litres per year. Visible leaks can waste more than 95,000 litres.

The best way to check if a toilet cistern is leaking is to put a few drops of food colouring into the cistern and watch to see if coloured water runs into the pan when the toilet has not been flushed.

Taps

Typical taps discharge 15 to 18 litres/minute. Low flow and aerating models may use as little as 2 litres/minute depending on the intended application.

Tap aerators are simple to install and cost very little (generally under $5). They reduce the flow of water through the faucet while maintaining water pressure. Tap aerators should be installed on all sink faucets, kitchen, bathroom and laundry.

Taps with an aerator or flow restrictor may reduce flow to less than a third of standard taps. Examples of the different types of flow aerators available are illustrated in **Figure 4.2** and described below.

Figure 4.2 Types of Tap Flow Aerators

Source: www.sydneywater.com.au

Aerated Flow (picture 1)

Aerated flow types introduce air into the water stream. This softens the stream and reduces water splash when, for example, you are washing dishes.

Laminar Flow (picture 2)

Laminar flow types remove air to provide a clear water stream. They are commonly used in hospitals and medical clinics to prevent airborne bacteria from entering the water.

Spray Flow (picture 3)

In low flow conditions, where aerators and laminar devices would not function effectively, spray flows spread the tap's water stream over a wider area. This type of aerator ensures full coverage when washing your hands and is recommended for use in public toilets to reduce water consumption.

Other options for reducing water usage from taps include:

- Ensure that all new taps are water efficient. Look for the AAA rating as a minimum;
- Install mixer taps in showers. They can reduce the potential for scalding and save large quantities of water wasted through running the shower while trying to get a comfortable water temperature;
- Install separate hot and cold taps or mixer taps which provide cold water only in the middle position over basins and sinks. Mixer type taps are usually left in the middle position. This means that each time the tap is run for a glass of water or to rinse a toothbrush, hot water is drawn off just to cool in the pipe without ever being used.

Toilets

While dual flush toilets are mandatory for all new installations, flush volumes do vary significantly. Some older dual flush toilets have a full flush volume of about 9 litres while some newer models have reduced the full flush volume to as low as 4.5 litres. This represents significant additional savings when considered over the toilet's usage for a year.

Within the commercial/industrial sector, consideration should also be given to toilet fixtures. The use of waterless urinals or water efficient urinals with motion sensors should be considered. The average urinal uses approximately 2.2 litres per flush, while the most efficient urinals reduce flush volumes to 1.5 litres per flush – a reduction of more than 30%.

The most water efficient toilet is a waterless toilet, of which there is a range of models and types available. They work with no odour and little maintenance while providing excellent compost. The Department of Health should be contacted if a waterless toilet is to be considered.

Shower Roses

A water efficient shower rose will save a large volume of water, when considered over a year, and are easily installed. The technology has improved greatly and more recent water efficient shower roses can provide both good pressure and spread.

An inefficient showerhead can use more than 20 litres of water every minute while an efficient AAA rated one will provide a high quality shower using a maximum of 9 litres every minute.

AAA rated showerheads cost about the same as conventional ones (average price is around $45) but can save around $100 annually on household energy and water bills. This is because they use less water and less hot water, meaning less energy is used for water heating.

Washing Machines

In recent years there has been increasing focus on the development of appliances for water efficiency. Most front loading washing machines now use far less than older front loaders and top loaders (although there is a number of efficient top loading machines available).

In purchasing a washing machine, a consumer should look for the water efficiency labelling of the appliance (see **Section 4.5**).

Water efficient washing machines will save 50 L or more per load (or about one-third the water of an older model). Water efficient washing machines also use less detergent, which can be a big money saver.

Other ways to save water when using a washing machine include:

- Adjusting the water level on the machine so it is appropriate for the size of the load;
- Washing only full loads of laundry;
- Using the 'economy' cycle if the washing machine has one;
- Using the 'suds saver' function if the machine has one; and
- Diverting the treated wash water from your laundry to other uses, such as flushing your toilet or watering your garden (see **Chapter 14** – Wastewater Management).

Dishwashers

Water consumption in dishwashers varies greatly. There are many water efficient models available; however these units are often only efficient when run on a specific cycle. It is important to read the manufacturer's instructions carefully to ascertain how an appliance may be operated in the most efficient manner.

In purchasing a dishwasher, a consumer should look for the water efficiency labelling of the appliance (see **Section 4.5**).

Some newer model dishwashers are very water efficient, and can use less water than if you wash dishes by hand (depending on water use habits). The water use of dishwashers can range from 1.6 to 4.8 litres per place setting, with efficient machines using 18 litres of water or less per cycle. The most efficient dishwashers use half the water of average models.

It is important to always try to fully load the dishwasher before using it and use the 'economy' cycle if there is one.

Landscaping Practices

Overview

The application of WSUD principles to landscape design aims to achieve the following:

- Maximising the survival of plants during periods of low rainfall;
- Conserving an effective vegetation cover for WSUD measures that incorporate vegetation such as bioretention swales and rain gardens; and
- Enhancing biodiversity and habitat values by giving preference to locally indigenous plant species.

Landscaping practices:

- Can be applied to all scales of landscape development including residential, commercial, industrial and open space; and
- Are appropriate also for retrofitting existing landscape areas within existing residential, commercial and industrial development as well as parks and open space.

A variety of landscape measures can be used to reduce mains water use for irrigation including:

- Plant selection;
- Limiting the extent of lawn and the selection of the type of lawn (including artificial turf);
- Efficient irrigation;
- Choosing areas to receive less irrigation;
- Using surface mulches;
- Improving soil for plant growth;
- Wind and sun protection;
- Alternative sources of water; and
- Effective landscape maintenance.

For optimal results, these measures need to be undertaken in conjunction with careful site planning, drainage design and appropriate landscape practices.

Some of these measures are discussed below.

It should be noted that tree canopies intercept and detain a considerable amount of rainfall. This detention capacity has been equated with significant stormwater infrastructure cost savings.

Integrated Planning

The design and installation of water sensitive landscape measures needs to be undertaken as part of the planning for an integrated functional system for the whole site or area i.e. landscape measures should be designed in conjunction with other water management measures. For example, locating plants with similar water needs together is an aspect of efficient landscaping.

Plant Selection

Diversification

The aim of this approach is to create a diverse system within the landscape that is not reliant on a single device to manage water.

As an example, a gravel-lined basin (or infiltration basin) collects overflow from a water tank, spills over to a turfed filter strip, drains gently to a series of drainage swales spot planted with species that tolerate temporarily saturated soil, drains to a soak area … and so on. This interconnecting system collects flow at a point source, reduces its speed and allows it to progressively infiltrate the soil, thereby reducing the risk of erosion, sedimentation and flooding, and use of reticulated water supply.

Species Diversity

Planting a variety of species will help ensure that there is not a complete loss of screen planting in the event of unfavourable circumstances such as prolonged drought, attack by a host specific pest, disease or unsuitable growing conditions. Unless a formal avenue of a single species is required for a landscape theme or style, choose hardy specimens from various genera, but with similar horticultural, watering and soil fertility requirements.

Suitable Plants

Select plants suited to the site’s soil and microclimatic conditions. Some species are able to withstand low soil moisture or high wind exposure due to special adaptations such as hard leaf tissue, small leaves, deep root systems, deciduous leaves or silvery or furry leaves (or combinations of these). Local native plants have evolved to handle local conditions while other Australian natives also cope with very little water.

Some exotic plants from the Mediterranean region, California and Southern Africa are able to survive on limited water and a range of soil conditions. Some plants are so well adapted to severe conditions that they can colonise and dominate native bush areas.

When selecting low water demand plants, preference should be given to locally indigenous species that are adapted to the local soils and climate. However, the use of non-indigenous species may be appropriate in some situations to achieve a particular landscape outcome.

Check that plants chosen for the site (including native species from other parts of Australia) are not environmental weeds or declared noxious weeds with your:

- Relevant State Government agencies;
- Local council;
- Land care group(s);
- Regional botanical gardens; or
- Native plant nursery(s).

Explore the neighbourhood to determine which species grow well, including street trees and other rarely watered plantings.

Examples of different levels of water use include the following:

- Low use – most Australian natives including banksias, grevilleas, hakeas, wattles and eucalypts. Succulents and cacti and some exotic ornamentals such as bougainvillea also fall within this category.
- Medium use – hardy vegetables like pumpkins and potatoes, hardy fruit trees and vines like nut trees and grapes, many herbs, some exotic shrubs, most grey-leaved or tomentose (hairy) plants, roses and daisies.
- High use – lawns, leafy vegetables, soft fruit trees, exotic shrubs like azaleas and camellias, flowering herbaceous annuals and many bulbs.

Place plants in the areas of the garden that suit the conditions provided. For example, place moisture loving plants in protected spots with deeper soils, and hardy silvery-leaved plants in full sun, all with layers of mulch on the surface.

SA Water provide information on selecting plant species appropriate for Adelaide 'waterwise' and Mediterranean type gardens (see **Section 4.9** – Further Information and Useful Resources). The Department of Environment and Heritage (DEH) also provide information to assist the selection of species.

Minimising Lawn and Selection of Lawn Type

Lawns are shallow-rooted groundcovers that generally require regular watering to maintain a green leaf cover. Compared to garden beds, lawn areas require significantly more fertiliser, water and maintenance per unit area to maintain healthy growth. Lawn areas also require greater inputs of energy, time and money.

Rationalising the size and design of lawn areas can be easily undertaken, resulting in significant reductions in water use. There are many options including:

- Replace lawn areas with vegetable patches, garden beds, screen planting, or a shade tree and garden bench;
- Site turfed areas closer to the house for more efficient watering from rainwater tanks;

- Choose other groundcovers and low growing shrubs for a green outlook;
- Utilise artificial turf where possible;
- Use other pervious surfaces for trafficked areas, such as mulch, gravel or pervious paving units. This will avoid the need to repeatedly repair worn out tracks across the turf;
- Alter maintenance practices to encourage deeper root growth (reduced mowing frequency, higher blade height, less frequent but deeper watering);
- Replace with grass species that are slower growing and require less fertiliser and water to remain green.

Check with your local supplier for native and introduced grasses that suit local conditions.

Warm season grasses and cultivars have the lowest water demand and are drought tolerant including:

- Common or Bermuda Couch;
- Santa Anna Couch;
- Windsor Green;
- Greenless Park;
- Wintergreen; and
- Kikuya

Efficient Irrigation

Only install irrigation systems if needed. Landscape measures that collect and utilise runoff by slow infiltration can replace reliance on supplementary water.

Irrigation will generally not be required if plant species are carefully chosen to suit the soil, climate, aspect and microclimate, and appropriate planting and maintenance techniques are implemented. However, some gardeners have different preferences, such as for species that do not thrive with natural rainfall. The aim in this case is to apply water in the most efficient manner.

Points that should be considered regarding the choice of an irrigation system, its installation and use, are outlined below:

- Match the system's design and specifications to the conditions on your site, including water source and quality, soil types and depth, moisture infiltration rates, evapotranspiration rates, frequency and intensity of rainfall, slope, plant choice and layout. Consult an irrigation specialist for a tailor made efficient system;

- Refit an existing system with the most efficient lowflow fittings (jets, sprays and nozzles, etc.). Fix any leaks from joiners, hoses and pipes. Rationalise its layout. Adjust it to suit the changing requirements of plants as they mature (generally reduced water demand);
- Connect each garden area to separate valves to create 'hydrozones' where plants grouped with similar water needs can be precision watered to suit them. Lawn areas will require the most water;
- Water according to the weather and plant needs, not to a fixed time schedule. Install soil moisture indicators as a guide. Allow soils sensors to override an automated system;
- Reduce the frequency of watering so that plants become less reliant on irrigation. Monitor plants individually and replace systematic watering with manual watering of stressed plants;
- Install drip systems for sparsely distributed plants, and underground or surface leak systems for dense garden beds. As the most efficient form of irrigation, there is less vapour loss from spray or misdirected water;
- With spray systems, avoid overlapping areas or directing it onto paths and driveways.
- Ensure that the water is directed to the roots as much as possible;
- Set a timer to turn off watering systems if it is not automated. Adjust according to the season and plant needs; and
- Maintain the whole system routinely, inspect for blockages, repair leaks and replace worn parts.

Irrigation is best done in combination with mulching of garden beds to conserve applied water. Always avoid overwatering to the point where the soil is saturated and excess water flows away from where it is intended.

The costs and maintenance of an efficient irrigation system should be measured against the benefits.

The Code of Practice for Irrigated Public Open Space should be referred to for further information (www.sawater.com.au/SAWater/WhatsNew/Publications).

Mulching

Mulching can reduce irrigation water use by as much as 70%. A 50 millimetre layer of organic mulch spread over garden beds will break down slowly and feed plants, restrict weed growth, prevent wind and water erosion, and shade the ground.

However, if organic mulch is used, it should be ensured that it is placed such that it is not transported off site with resultant water quality issues.

Shading

Providing protection from harsh climatic forces makes garden areas more pleasant and reduces moisture loss from soil and plant tissue. Sun and wind exposure will strip moisture from leaves, requiring the plant to use greater levels of available soil moisture than in less exposed conditions.

Management

Correct management by properly trained and qualified staff for commercial and industrial sites and for State Government agencies and councils is essential for efficient irrigation. Training staff on irrigation systems auditing and scheduling is a key step.

Monitoring and Maintenance

For landscape areas, the following items should be inspected:

- Signs of plant moisture stress;
- Dead or damaged vegetation;
- Weed infestation; and
- Signs of surface erosion and scouring.

The following maintenance activities should be undertaken, with inspection frequencies shown in the example Maintenance and Inspection Checklist (**Appendix C**):

- Repair/replace any damaged vegetation;
- Reapply or apply mulch layer;
- Watering (in accordance with water restrictions); and
- Repair surface erosion and scouring.

Alternative Water Sources

Reducing potable (or mains) water demand also means finding alternative sources of water. How water is used can determine the appropriate quality – and source – of water. Most domestic, commercial and industrial water does not need to be of drinking standard, so it is possible to supply water from different sources.

Alternative water supply sources include:

- Runoff (including rainwater and stormwater);
- Groundwater;
- Treated greywater (i.e. from laundry and bathroom);
- Treated wastewater (i.e. from local wastewater treatment plants or sewer mining); and
- Treated plant water (i.e. at an industrial premise).

To determine an appropriate source of water for reuse, the following issues require consideration:

- Availability of the alternative source of water;
- Proximity to the use;
- Timing of the water requirements (i.e. constant or seasonal);
- Infrastructure requirements;
- Risk of cross connections (health impacts);
- Method of treatment required to achieve quality appropriate for reuse;
- Occupant behaviour and attitude; and
- Other environmental objectives such as energy efficiency and greenhouse gas emissions.

A hierarchy of options for water reuse, grading from the easiest to implement to the most extensive water reuse options, is presented below. Choosing the best option for a development will depend on:

- The scale of the development;
- The proximity to treatment facilities; and
- The importance of reducing water consumption.

The recommended hierarchy for household reuse options is:

- Rainwater reuse for toilet and garden;
- Household greywater for garden; and
- Treated wastewater to toilet and garden, rainwater for hot water.

The use of groundwater is becoming a critical issue as people respond to water restrictions and shortages by wanting increased access to groundwater supplies. Groundwater must be managed within sustainable limits.

The use of treated wastewater for irrigation by councils is quite common and presents an excellent opportunity to conserve mains water.

Further information on alternative water sources can be found in the following chapters of the Technical Manual:

- Rainwater Tanks (**Chapter 5**);
- Urban Water Harvesting and Reuse (**Chapter 8**); and
- Wastewater Management (**Chapter 14**).

4.7 Education and Incentives

Overview

Raising awareness is one of the most cost effective and sustainable methods to save water. Education and incentive schemes can be used to encourage the uptake of water conservation practices and technologies.

There is already a number of community water conservation programs run by government agencies such as SA Water, the EPA, WaterWise, WaterCare and the Natural Resources Management Boards.

Incentives

Incentive programs generally provide a financial or service incentive for people to conserve water. They fall under the general categories of:

- Subsidised audits and advisory programs;
- Loan programs for the purchase of water conserving appliances, hardware or landscaping;
- Rebate programs which reduce the normal sale price of water saving fixtures;
- Give-away programs offering free water saving devices; and
- Subsidised retrofits.

In addition, for commercial and industrial operations, businesses and agencies can:

- Provide incentives for staff to save water by linking water conservation to staff performance reviews;
- Use visual tools like charts and graphs to highlight water savings to employees;
- Mention water conservation plans and progress in staff meetings;
- Use communication tools like bulletins, newsletters and emails to send staff water saving ideas, announcements, progress reports and news of special achievements;
- Include water conservation policies and procedures in staff training programs;
- Involve staff by seeking their ideas and rewarding those who make a positive contribution; and
- Reward achievements in water use reduction.

A number of these methods could also be considered as ’education‘ approaches.

Education

There are numerous methods to engage people through education and communication – from informal learning and engaging activities (often hands on) to professional development and continuing education, formal education, presentations, performances, information, artwork and media. Budget will often influence the methods that are used.

Generally, a series of coordinated activities will be required; building on existing activities and programs is one effective approach.

A range of examples of education and communication programs is summarised in **Table 4.4**.

Importantly, communication programs must be tailored to be relevant to the intended audience, with the best communication tending to involve participation.

For example, hosting workshops which invite participants to take action can build ownership and support in ways that simply sending out information will not do.

Table 4.4 Examples of Education and Communication Programs

Type of Program	Examples
Informal learning and engaging (often hands on)	■ Demonstration sites and gardens ■ Launches ■ Festivals and fairs ■ Competitions and awards ■ Grant programs
Presentations and performances	■ Talks, presentations, seminars ■ Demonstrations ■ Tours ■ Performances
Professional development / continuing education	■ Workshops (e.g. workshops about rainwater tanks) ■ Courses ■ Study groups ■ Advisory services
Formal education	■ School education ■ TAFE courses ■ University education ■ Training for teachers ■ Community college courses
Information	■ Printed material ■ Display material ■ Electronic and audio visual material ■ Products

Type of Program	Examples
Demonstrations	■ Implementation of water saving initiatives at community facilities
Signage and public art	■ Signage at, for example, parks ■ Community artworks and exhibitions
Media	■ Media releases and articles ■ Paid advertising

Source: Adapted from Department for Environment and Heritage (2005)

4.8 Case Studies

The Water Campaign

Australian councils taking part in the Water Campaign are conserving water and improving the water quality of local rivers, streams and groundwater through implementing on ground actions ranging from practical adjustments to innovative initiatives.

The Water Campaign is an international freshwater management program that motivates and empowers local government to work toward the sustainable management of water resources. The program builds the capacity of councils to take action to address water quality and water conservation within their own corporate operations, and influence their community through land use planning, education, regulation and various other incentives.

As part of the campaign, participating councils undertake an inventory of their water consumption and management practices that influence water quality. This provides baseline data, highlighting the current state of play. Based on the baseline data, councils then establish water reduction and water quality improvement goals. These water reduction goals outline the percentage of water the council wants to reduce, based on its baseline year by a specific target year.

There are currently 23 councils participating in the Water Campaign in South Australia. To date, four of these councils have set their corporate and community water reduction goals. Case studies below highlight actions undertaken by a number of Water Campaign participants from the Greater Adelaide Region. The actions are highly transferable and provide examples of how local government is approaching sustainable water management.

City of Mitcham

The City of Mitcham is located 6 kilometres south of the Adelaide Central Business District (CBD) and has a population of 61,900. The City of Mitcham has the following demand reduction targets:

- Corporate – 20% reduction in water use by 2013 (projected total savings = 49.8 megalitres); and
- Community – 20% reduction in water use by 2013 (projected total savings = 1670 megalitres).

The City of Mitcham has developed a Water Management Plan in order to provide the council with a strategic direction and an implementation schedule for water related activities over a five year period.

The City of Mitcham has made some innovative changes to its watering regimes in response to a detailed open space review. A key water saving component of this involves browning off in strategically identified low use open spaces. In high use areas and sporting fields, council is watering for longer periods, less frequently, to promote deep root growth and reduce water requirements.

The City of Mitcham is also saving water by replacing inefficient hose and sprinkler systems with automatic irrigation systems, undertaking night watering and trialling soil additives to increase water retention. Drought tolerant native vegetation is being planted on council land and wood chips from council operations and tree trimming is being used to mulch council gardens. Stormwater diversion devices are being installed on Claremont Ave for street tree watering, in partnership with the Department for Transport, Energy and Infrastructure (DTEI), the University of South Australia and TREENET.

As a result of browning off and reduced watering, the council estimates it is achieving an annual saving of 29,900 kilolitres of mains water.

Browning -off has saved Council $5000 per year through reduced water costs. Importantly, there was no financial cost to implement this action.

The City of Mitcham's action occupies the top of the water conservation hierarchy, as it avoids water use. This action is also carbon neutral; there is no water use, there is no pumping requirement and therefore no energy use.

Campbelltown City Council

The Campbelltown City Council is located 8 kilometres from the Adelaide CBD and has a population of approximately 47,000.

Council's main water usage in 2001-2002 was for open space (64%), playing fields (32%) and administration buildings and community centres (3% combined).

Playing fields are irrigated more intensively than other assets to maintain a suitable playing surface for active recreational purposes, such as soccer, football and cricket. Open space and playing fields are priority areas for action by council.

The Campbelltown City Council is predominantly residential land use with some retail, commercial and light industrial users. Water consumed by these sectors in 2001-02 was 5373 megalitres.

Households account for the majority of water consumed followed by the non-residential and commercial sectors. On average, non-residential users consume more water per property than other land uses.

Around 48% of all water is consumed by households. On average, each household uses about 280 kilolitres of water a year.

The Campbelltown City Council has the following demand reduction targets:

- Corporate – 25% reduction in water use by 2015 (projected total savings = 62.9 megalitres); and
- Community – 25% reduction in water use by 2015 (projected total savings = 1262 megalitres)

The Campbelltown City Council has developed a Water Management Plan in order to provide the council with a strategic direction and an implementation schedule for water related activities over a five year period.

Victoria Square 1 (VS1), City of Adelaide

SA Water's new headquarters under construction in Victoria Square in the City of Adelaide has been granted a 6 Green Star Rating – the first building in South Australia to gain such a ranking by the Green Building Council of Australia.

The building – Victoria Square 1 (VS1) – will house SA Water as the major tenant, and will deliver considerable savings in terms of energy and water conservation with its innovative design and construction.

The 10-storey building will use in excess of 70% less mains water compared with a conventional office building – saving 11 million litres of water a year.

The innovative features of the building include:

- Collection of rainwater and treatment of the building's wastewater for reuse in toilet flushing, irrigation and cooling towers; and
- Use of water efficient taps toilets and waterless urinals with AAAA rating.

Colliers International, City of Adelaide

Colliers International's Adelaide office at 10 Pulteney Street is leading the field in the implementation of water saving initiatives. The installation of waterless urinal cubes throughout the 18-floor complex has seen a reduction in water consumption in the building of about 4 million litres (Australian Government 2006).

The initiative cost $2400 and delivered water cost savings and reduced plumbing costs of $8200. Colliers International continues to implement this and other initiatives across a number of portfolios around the country (Australian Government 2006).

Commonwealth Law Courts, City of Adelaide

The Commonwealth Law Courts is a recently completed landmark building constructed to house cutting edge technology and ecologically sustainable design initiatives. The building accommodates 22 court rooms and support facilities for four federal jurisdictions.

It incorporates a number of water and energy saving features including:

- Collection and reuse of rainwater for irrigation, toilet flushing and make up to the evaporative pre-cooling systems in the plant room;
- Water conservation AAAA rating water conservation devices throughout the complex;
- Solar hot water generation with gas boost for times of peak demand.

The selection of locally based sanitary ware, tap ware and piping systems manufactured within South Australia offers greenhouse emissions benefits in terms of less transport energy used.

Schools

Like all government agencies, the Department of Education and Children's Services (DECS) is required to meet South Australia's Strategic Plan targets. These targets include a requirement to manage water use within sustainable limits. In line with this target, all DECS sites have been set a target to reduce water consumption by 10% from the 2000-01 base year.

In 2000-01 the total mains water usage of DECS was around 5 million kilolitres. A 10% saving on this amount would translate to a saving of 500,000 kilolitres. This is equivalent to a saving every year of 500 Olympic-sized swimming pools or a saving each year of the water consumed by around 1600 South Australian homes.

A number of steps have begun to be taken in the Central Office, which includes the installation of waterless urinals in March 2006 and the use of flow restrictors on taps. The waterless urinals are estimated to save between 4 and 5 million litres of mains water per year.

New measures applied for schools from the start of the 2008 school year, with the rolling average utility resource formula replaced in line with the water consumption targets.

Information and assistance is available to assist schools to meet their targets, including:

- Publishing water consumption data and water management information through the internet, available to schools;
- Distributing the Code of Practice for Irrigated Public Open Space;

- Developing a suite of policies to guide schools and pre-schools on water management;
- Providing grants to schools and other locations to undertake irrigation audits and irrigation management plans;
- Providing infrastructure grants to implement actions from detailed irrigation audits;
- Assisting suitable schools to use treated wastewater for irrigation;
- Seeking partnerships to encourage managed aquifer recharge (MAR) projects for turf irrigation; and
- Supporting schools to harvest rainwater or stormwater for toilet flushing and irrigation.

Green Schools Grants will be used to engage irrigation auditors to develop measures to assist schools to achieve at least a 10% reduction on 2000-01 consumption levels. By 2009-10 at least 200 schools and other DECS services will have been audited by an auditor accredited by the Irrigation Association of Australia.

4.9 Useful Resources and Further Information

General Information

www.greenhouse.gov.au/yourhome/technical/fs21.htm

Environment Australia (2001). *Your Home: Technical Manual and Consumer Guide*

www.savewater.com.au

Australian website dedicated to promoting better water conservation

www.homepages.tig.com.au/~foesyd/SustainableConsumption/garden/gardenhome

Friends of the Earth (Sydney)

www.thegreendirectory.com.au

The Green Directory

www.greenplumbers.com.au

Green plumbers association

www.ata.org.au

Alternative Technology Association

www.waterrating.gov.au

Australian Government, Water Efficiency Labelling and Standards (WELS) Scheme

www.smartwater.com.au

Smart Water

www.iclei.org/index.php?id=water_home

ICLEI Local Government for Sustainability

www.sydneywater.com.au/everydropcounts

Sydney Water's water conservation and recycling site

www.smartwatermark.info

Smart Water Mark: Australia's outdoor water saving labelling program

www.waterforgood.sa.gov.au

Water For Good – the State Government's plan to provide for water security for South Australia

www.nabers.com.au

Office and home ratings advice including water conservation calculator www.mitchamcouncil.sa.gov.au/site/page.cfm?u=259

City of Mitcham water conservation tips

www.grebe.com.au/about.html

City of Mitcham Sustainable Home Rating and Incentive Scheme

www.sawater.com.au/SAWater/YourBusiness/SaveWaterInYourBusiness/Business+Water+Saver+Program.htm

SA Water – Business Water Saver Program

www.urbanforest.on.net

SA Urban Forest Biodiversity Program

www.mda.asn.au/download.cfm?DownloadFile=A4BBC949-E081-51EF-A74702E9E228C3B8

Water Conservation Handbook for Local Government

www.urbanwater.info/engineering/BuiltEnvironment/WaterSavingFixtures.cfm

Water Saving Fixtures

www.workgreen.com.au/

Work Green

www.deh.sa.gov.au/sustainability

Best Practice Water Conservation Principles

www.watercare.net

Comprehensive schools education resource

www.notdownthedrain.org.au

Water Not Down the Drain

www.wsud.org

Water Sensitive Urban Design in the Sydney Region

www.yourhome.gov.au

Your Home

www.aila.org.au

Australian Institute of Landscape Architects

www.treenet.org

Treenet

www.sawater.com.au/interactivehouse

An interactive learning program including a home water use calculator

Education and Incentives

www.aaee.org.au/index.htm

Australian Association for Environmental Education

www.environment.gov.au/education/aussi/publications/aussi-factsheet.html

Sustainable Schools and Children's Services Initiative

www.captaingreen.com.au

Captain Green

www.communication.org.au/htdocs/

Communication Research Institute of Australia

Irrigation and Plant Species Information

www.australianplantsa.asn.au

Australian Plant Society

www.sewl.com.au/sewl/upload/document/WaterConManual.pdf

Efficient Irrigation: A Reference Manual for Turf and Landscape

www.sawater.com.au/SAWater/WhatsNew/Publications/

Code of Practice – Irrigated Public Open Space

www.irrigation.org.au

Irrigation Association of Australia

www.ngia.com.au

Nursery and Garden Industry Association

www.alma-lawn.com

Australian Lawn Mowers Association

www.stateflora.com.au/

State Flora, Belair National Park

www.sgaonline.org.au

Sustainable Gardening Australia

www.environment.sa.gov.au/botanicgardens/pdfs/sustainable_plants.pdf

Native and exotic plants suitable for South Australian conditions

www.sawater.com.au/NR/rdonlyres/74E31A43-783D-458A-91ED-FEDC041EB858/0/beautiful_gardens.pdf

Waterwise garden

www.sawater.com.au/SAWater/AboutUs/InTheCommunity/Med_garden.htm

Mediterranean type garden

www.enduroturf.com.au

Endoturf – suppliers of synthetic surfacing

www.decorpebble.com.au/artificial-grass-lawn.htm

Artificial grass lawn

Water Audits

www.sawater.com.au/SAWater/YourHome/SaveWaterInYourHome/How+water+wise+is+your+home.htm

SA Water – Home Water Audit

www.murrayusers.sa.gov.au/water_audit_kit.php

Murray Care – Water Audit Kit

www.watercare.net/images/WaterSmart_Home_Audit.pdf

Home Water Audit Kit

Fact Sheets

www.decs.sa.gov.au/docs/documents/1/FactSheet3WaterTargets.pdf

Fact Sheet 3 Department of Education Water Efficiency Measures

www.decs.sa.gov.au/docs/documents/1/WaterSmartAuditingWater.pdf

Water Smart: Auditing Water Use in School Buildings

www.decs.sa.gov.au/docs/documents/1/BorewaterIrrigation.pdf

Water Smart: Bore Water for Irrigation in Schools

www.decs.sa.gov.au/docs/documents/1/WaterSmartIrrigationMgt.pdf

Water Smart: Irrigation Management and Auditing in Schools

www.decs.sa.gov.au/docs/documents/1/WaterSmartLandscapeDesign.pdf

Water Smart: Landscape Design and Management in Schools

www.decs.sa.gov.au/docs/documents/1/WaterSmartManagingLeakage.pdf

Water Smart: Managing Water Leakages in Schools

www.decs.sa.gov.au/docs/documents/1/WaterSmartMonitoringWater.pdf

Water Smart: Monitoring Water Use in Schools www.decs.sa.gov.au/docs/documents/1/WaterSmartWaterEquipment.pdf

Water Smart: Water Saving Hardware and Equipment for Schools

www.decs.sa.gov.au/docs/documents/1/WaterSmartToiletsUrinals.pdf

Water Smart: Toilets and Urinals for Schools

www.lga.sa.gov.au/webdata/resources/files/FACTSHEET_IPOS.pdf

SA Water Information Sheet - Code of Practice: Irrigated Public Open Space (IPOS)

www.environment.gov.au/education/aussi/publications/pubs/aussi-factsheet-may07.pdf

Australian Sustainable Schools Initiative Fact Sheet

www.sawater.com.au/NR/rdonlyres/F1A6F3E9-933C-4C35-8C6D-60C39AB4C055/0/WWIndustry.pdf

WaterWise in Industry Fact Sheet

www.adelaidecitycouncil.com/adccwr/publications/guides_factsheets/water_fact_sheet.pdf

Adelaide City Council Conserving Urban Water Fact Sheet

4.10 References

Australian Government (2006). *Water efficiency: office and public buildings.* Department of Environment and Heritage. Canberra. http://www.environment.gov.au/settlements/publications/government/pubs/water-efficiency-guide.pdf.

Department for Environment and Heritage (2005). *Water Conservation Handbook for Local Government*. Government of South Australia. Adelaide.

Department of Natural Resources and Mines Queensland (2005). *Planning Guidelines for Water Supply and Sewerage* - **Chapter 5** - Demand / Flow and Projections.

Government of South Australia (2005). *Water Proofing Adelaide: A Thirst for Change (2005 - 2025).*

Melbourne Water (2005). *WSUD Engineering Procedures: Stormwater.* CSIRO Publishing.

Upper Parramatta River Catchment Trust (2004). *Water Sensitive Urban Design, Technical Guidelines for Western Sydney*. Prepared by URS Australia Pty Ltd. http://www.wsud.org/tech.htm.

Upper Parramatta River Catchment Trust, Sydney Coastal Councils Group, Western Sydney Regional Organisation of Councils, Lower Hunter Central Coast Regional Environmental Management Strategy (2003). *Water Sensitive Planning Guide for the Sydney Region.* Upper Parramatta River Catchment Trust. Sydney. May. http://www.wsud.org/downloads/Planning%20Guide%20&%20PN's/WSPP%20Final.pdf.

Appendix A
Legislation

National

The Commonwealth Government has a limited role in water conservation, as resource issues are generally the jurisdiction of state and local governments. However, the COAG water reform framework aims to improve water management and to ensure that extraction of water is sustainable. At its meeting in June 2004, COAG agreed to a National Water Initiative (NWI), covering a range of areas in which greater compatibility and the adoption of best practice approaches to water management nationally will bring substantial benefits. Key elements of the NWI include the return of over allocated systems to sustainable levels and actions to better manage demand in urban areas.

A potentially powerful regulatory role for the Commonwealth Government and its agencies is the Building Code of Australia (BCA), which can be used as a significant tool to ensure water efficient appliances are standard in new buildings. For example, under the BCA only dual flush cisterns can now be installed in Australia.

Water Efficiency Labelling and Standards Act 2006

The *Water Efficiency Labelling and Standards Act 2006* is an Act to provide for water efficiency labelling and standards as part of a cooperative scheme between the Commonwealth and the states and territories, as well as for other purposes. The Minister for Environment and Conservation has responsibility.

The objects of this Act are to:

- Conserve water supplies by reducing water consumption;
- Provide information for purchasers of water use and water saving products; and
- Promote the adoption of efficient and effective water use and water saving technologies.

Further information on the labelling scheme is contained in **Section 4.5**.

Water Conservation Act 1936

The *Water Conservation Act 1936* consolidates certain Acts relating to the conservation of water.

The responsible ministers include the Minister for Water Security and the Minister for Government Enterprises.

South Australian Water Corporations Act 1994

The South Australian Water Corporation (the Corporation) was established on 1 July 1995 pursuant to the *South Australian Water Corporation Act 1994*.

The key objectives of the Corporation are to:

- Ensure South Australia's water and wastewater services are operated in a way which provides continuous, high quality supply, protects the health of the public, and minimises environmental impacts;
- Ensure South Australia's water and wastewater services are operated in a commercial manner, delivering high quality, value-for-money services to customers and adequate financial returns to the Government as owner within the context of government pricing decisions; and
- Facilitate the development of a viable, export-focused, vigorous water industry in South Australia.

The primary functions of the Corporation in accordance with the *South Australian Water Corporation Act 1994* are to provide services for the:

- Supply of water by means of reticulated systems;
- Storage, treatment and supply of bulk water; and
- Removal and treatment of wastewater by means of sewerage systems.

Additional functions of the Corporation, as set out in the Act, include researching and undertaking works to improve water quality and wastewater treatment; developing and marketing commercially viable products, processes and intellectual property; and encouraging and facilitating private or public sector investment and participation in the provision of water and wastewater services and facilities.

Waterworks Act 1932

SA Water administers the *Waterworks Act 1932*. The responsible ministers include the Minister for Water Security and the Minister for Government Enterprises.

SA Water may, with the approval of the Minister by notice published in the Gazette, do one or more of the following under the *Waterworks Act 1932* (Section 33A(1)):

- Prohibit the use of water for a specified purpose or purposes, or restrict or regulate the purposes for which water can be used;
- Prohibit the use of water in a specified manner or by specified means, or restrict or regulate the manner in which, or the means by which, water may be used; or
- Prohibit specified uses of water during specified periods, or restrict or regulate the times at which water may be used.

The *Waterworks Act 1932* contains the Waterworks Regulations 1996 and more recently the Waterworks Variation Regulations 2007. The variation regulations relate to the development of water efficiency plans (as discussed above). Part 6 of the Waterworks Regulations 1996 relates to water restrictions and permits.

Sewerage Act 1929

SA Water administers the South Australian *Sewerage Act 1929* which is applicable to areas where there is a government sewerage system available. These areas are known as proclaimed drainage areas. Areas where an SA Water sewerage system is not available are the responsibility of the local government authority and/or the Department of Health.

Section 36 of the *Sewerage Act 1929* provides for an exemption from the requirement to discharge to the sewerage system from a property. The Act allows for the exemption to be granted by SA Water and is used when application is made for the installation of a permanent greywater diversion system.

Exemption may be granted by SA Water in cases when SA Water is satisfied that the proposal does not compromise the sewerage or drinking water systems.

Natural Resources Management Act 2004

The *Natural Resources Management Act 2004* has integrated the management of land, water, plants and animals into one piece of legislation.

The Department of Water, Land and Biodiversity Conservation (DWLBC) is the principal department which assists the Minister responsible for the administration of the *Natural Resources Management Act 2004*. Through effective administration of the Act, the DWLBC seeks to encourage the use of water for its highest and best return within sustainable limits.

In addition to DWLBC, the Natural Resources Management Boards have three main legislative functions under the *Natural Resources Management Act 2004*:

- To prepare and implement Natural Resources Management Plans;
- To provide advice to the Minister and councils about water resource management; and
- To promote awareness and involvement in best practice water management.

Public and Environmental Health Act 1987

The Environmental Health Service of the Department of Health provides a range of scientific, engineering and technical services related to public and environmental health, specifically in the areas of drinking water (including rainwater), sanitation and wastewater management. This includes administration of the Waste Control Regulations, assessment and approvals of wastewater management systems and treated wastewater reuse systems, and support for local government in the administration of the *Public and Environmental Health Act 1987* and associated Regulations.

Permanent greywater systems such as diversion devices or treatment systems require installation approval from council or the Department of Health and all systems must be installed by a licensed plumber. Installation of greywater systems must take into account the Department of Health requirements for setback distances outlined in South Australian Health Commission Code Waste Control Systems – Standard for Construction, Installation and Operation of Septic Tank Systems in South Australia and Supplement B – Aerobic Wastewater Treatment Systems.

Where it is intended to install a greywater treatment/diversion system in a sewered (or other reticulated system) area, approval must be obtained from the owner/operator of the system.

Environment Protection Act 1993

The Environment Protection Authority (EPA) regulates and prosecutes for water pollution activities (under the *Environment Protection Act 1993*) and also runs water education programs for business and the community including Codes of Practice for Stormwater Pollution Prevention in South Australia.

The Environment Protection (Water Quality) Policy 2003 establishes thresholds above which it is an offence to discharge wastewaters to a water resource. This policy provides the legislative controls (*Environment Protection Act 1993*) to bring about improvements in the management to wastewaters, of which one method is the application of wastewater to a beneficial use.

The South Australian Reclaimed Water Guidelines [Environment Protection Authority South Australia, 1999 #68] describes methods by which treated wastewater can be used in a sustainable manner without imposing undue risks to public health or the environment.

The National Guidelines for Water Recycling [Environment Protection and Heritage Council, 2006 #67] are intended to replace the Reclaimed Water Guidelines and are now the primary reference for assessment of all treated wastewater reuse projects.

Local Government Act 1999

Local government approves the planning and development aspect of proposed developments.

The important role of local government in promoting sustainability initiatives is acknowledged through the Intergovernmental Agreement on the Environment, Local Agenda 21 and the following sections of the *Local Government Act 1999*:

- Section 6(b) outlines council's roles to provide and coordinate various public services and facilities, and to develop its community and resources in a socially just and ecologically sustainable manner;
- Section 7(e) outlines council's functions to manage, develop, protect, restore, enhance and conserve the environment in an ecologically sustainable manner;
- Section 8(f) outlines council's objectives to encourage sustainable development and the protection of the environment, and to ensure a proper balance within its community between economic, social, environmental and cultural considerations.

Appendix B
Water Usage Data

Water Usage Data

Water usage data is provided below from a range of local and interstate sources to assist with undertaking an audit of a site or determining what the water use reduction of a site might be. Local (and more recent) data should be utilised wherever possible.

Limited information on commercial, industrial and community uses is available. The information available has been included in this Appendix. Please note that these figures are from pre-drought water restrictions.

Table B1 Domestic Water Use in Adelaide

Use	Percentage	Volume (kL)
Garden and outdoor	40%	112
Bath and shower	20%	56
Laundry	16%	44.8
Kitchen	11%	30.8
Toilet	11%	30.8
Other	2%	5.6
Total	100%	280 kL

Source: Government of South Australia; Water Proofing Adelaide (2005)

Table B2 Indicative Water Usage Rates for a Range of Buildings

Development	Demand (L/day/unit)	Unit
Apartment/home unit	300-500	1 bed
	550-750	2 bed
	700-900	3 bed
Caravan park- van	550-750	Site
Caravan park - tent	150-250	Site
Central business	14,000– 20,000	Ha
Child care centre	40-70	Staff and pupils
Commercial premises	500-800	100 sqm GFA*
Convalescent home	600-1100	Bed
Crematorium	500-700	100 sqm GFA
Education- primary school	50-80	Staff and pupils
Education- secondary school	90-150	Staff and pupils
Education – tertiary institution	90-150	Staff and pupils
Fast food store	1400-4200	100 sqm GFA
Food services	1200-2000	100 sqm GFA
Heavy industry	10,000-35,000	Ha
Hospital	500-1800	Bed
Hostel accommodation	200-600	Bed
Hotel	700-1200	100 sqm GFA
Light industry	10,000-35,000	Ha
Major shopping development	300-800	100 sqm GFA
Medical centre	400-700	100 sqm GFA
Motel	300-600	Room
Multiple units	500-700	1 bed
	800-1000	2 bed
	1000-14,000	3 bed

Development	Demand (L/day/unit)	Unit
Place of worship	200-400	100 sqm GFA
Public building	500-600	100 sqm GFA
Restaurant	800-1800	100 sqm GFA
Retirement village	300-700	1 bed
	500-1000	2 bed
	700-1400	3 bed
Service station	500-700	100 sqm GFA
Shop	600-800	100 sqm GFA

** GFA - Gross Floor Area*

These figures are for indicative and comparative purposes only. Caution should be exercised in the use of this data.

Source: Department of Natural Resources and Mines Queensland (2005)

Table B3 Estimated Typical Household Water Demands (litres/day)

Water Use	Design Number of Occupants				
	1	2	3	4	5
Bathroom	65	107	145	189	223
Toilet	49	107	145	189	223
Laundry	38	54	100	137	174
Gardening	87	220	220	220	220
Kitchen	14	38	60	83	123
TOTAL	253	526	670	818	963

Source: Upper Parramatta River Catchment Trust (2004), Melbourne Water (2005)2

[2] Data from Melbourne Water has been used for the one person scenario and the remainder of information in the table is sourced from Upper Parramatta River Catchment Trust

Table B4 Estimated Annual Water Use by Dwelling Type

Dwelling Type	Townhouse		Small Villa		Moderate Sized New Dwelling		Older 'Large Allotment' Dwelling	
Allotment area (m^2)	240		300		650		800	
Roof area (m^2)	120		120		200		200	
Irrigated area, including trees and shrubs (m^2)	40		100		330		400	
Typical number of occupants	2		2		4		3	
Dual flush toilet	Yes		Yes		Yes		No	
With or without water conservation devices	Without	With	Without	With	Without	With	Without	With
Inhouse water use (L/day)	239	216	239	216	458	400	413	314
Outdoor water use (L/day)	72	72	162	147	519	470	618	558
Miscellaneous losses	47	47	60	60	147	147	155	155
Total indoor and outdoor (L/day)	358	335	461	423	1124	1017	1186	1027
Total (kL/year)	130	122	168	154	410	371	433	374
Reduction in water use (kL/year)	8		14		39		59	
Reduction in water use (%)	6		8		10		13	

Source: Department for Environment and Heritage (2005)

Table B5 Assessment Aid for Mains Water Conservation (Based on a Typical Three Person Household)

Appliance/Fixture	Typical Use (L/day)	Potential Reduction %		
Shower	185	**AAAA**	**AAA**	**AA**
		50%	39%	22%
Toilet	177	**2/4 litre flush**	**3/6 litre flush**	**Flush arrester**
		55%	35%	42%
Washing machine	135	**AAAA**	**AAA**	**AA**
		61%	40%	19%
Kitchen sink	37	**Flow regulator**		
		50%		
Bathroom basin	21	**Flow regulator**		
		50%		
Other	58			
Typical irrigation water demand = 1.0 L/day/m² of irrigable landscaped area. Demand is estimated based on information provide for the BASIX project by Sydney Water. It assumes an occupancy rate of three persons per dwelling. Saving in mains water due to use of rainwater or stormwater tanks for internal/external uses are estimated by calculating the percentage harvest runoff and then multiplying it by the stormwater volume flowing into the tanks (change units to L/day). Total savings in the site's mains water demand is the sum of saving from using water efficient fixtures/appliances and the use of rainwater/stormwater tanks. Total unmanaged water demand is the sum of the total unmanaged indoor water demand and the irrigation water demand. Percentage reduction in the site's mains water = total site saving /total unmanaged site water demand x 100.				

Source: Upper Parramatta River Catchment Trust (2003)

Table B6 Indicative Savings for Using Water Conservation Methods or Devices

Use	% of Water Use in Typical Home^	Typical Water Use Per Year (kL)	Water Conserving Method	Approximate Cost for Water Conserving Device	Typical Water Saving Per Year (kL)
Garden	50%	180	More careful garden watering, planting of water efficient species	$20	45
Bathroom	20%	75	Install a water efficient shower head or flow control device	Typically, no more than an equivalent inefficient showerhead, about $20-$60	25
Laundry	15%	55	Replace with a water efficient washing machine	About $70 per kg dry clothes capacity more than a water inefficient machine	25
Toilet	10%	35	Replace with a water efficient 6/3 litre dual flush toilet	$200	15
Other	5%	20	Flow control devices on taps etc	Variable	Variable

^ *Water use assumes a three or four bedroom home, large garden and three occupants*

Source: Department for Environment and Heritage (2005)

Table B7 Water Efficiency Opportunities in Office and Public Buildings

	Heating, Ventilation and Air Conditioning (HVAC)	Amenities	Leakage
Design	Investigate site water collection and reuse options. Investigate wastewater treatment options. Specify use of water wise landscaping. Negotiate water ruse, discharge and pricing options with utilities.	Specify minimum 4 star WELS rated fittings. Consider waterless urinals. Set a water intensity target for the building against benchmarks.	Design to include submetering of tenancies, plant and landscape uses.
Construction	Ensure runoff is contained and sediment removed prior to leaving site. Consider setting goals for drinking and non- drinking water use on site.		
Fit out and commissioning	Ensure that water saving and water treatment technologies are installed and commissioned as designed.	Ensure that WELS ratings are specified for water using fittings and appliances installed in any fit out.	Ensure sub-metering of tenancies occurs and is supported by appropriate leak detection and reporting signage.
Occupancy	Ensure that responsibilities for water efficiency are clearly stated in leases and contract for facilities management. Ensure that cooling towers are monitored and that risks of excessive water consumption (such as from blowdown) are managed proactively.	Provide information and training to building managers and users on efficiency measures and opportunities. Ensure cleaning staff are aware of water issues, including issues specific to waterless urinals. Cover amenities use in a water management plan. Be proactive about maintenance of valves etc.	Audit building water use periodically to identify base flows and unaccounted for water. Develop and implement a water management plan for the site (possibly as part of an EMS). Take a proactive approach to maintenance for leak prevention and remediation. Task cleaners and staff to report leaks promptly.

	Heating, Ventilation and Air Conditioning (HVAC)	Amenities	Leakage
Refurbishment	Investigate opportunities to upgrade cooling towers to improve efficiency. Consider installation of water storage and opportunities to install grey water 'third pipe' plumbing. Consider including water intensity target in any new lease.	Benchmark building water performance before commencing refurbishment and set an intensity target for the refurbishment building. Specify higher WELS rated appliances and fittings. Upgrade toilets and urinals to newest efficiencies.	Benchmark base flows before the refurbishment (including when building is empty). Identify leaks and correct while doing building works. Identify any overpressure problems that may require altering mains supply pressures. Improve submetering of tenancy spaces and specific uses.
Re-occupancy	Ensure building management information and training takes advantage of new water efficiencies in the refurbished building. Ensure that responsibilities for water efficiency are clearly stated n lease and contracts for facilities management.	Provide information and training to building managers and users on efficiency measure and opportunities. Ensure cleaning staff are aware of water issues. Cover amenities use in water management plan. Be proactive about maintenance of valves etc.	Audit building water use periodically to identify base flows and unaccounted for water. Develop and implement a water management plan for the site (possibly as part of an EMA). Take a proactive approach to maintenance for leak prevention and remediation.
End of life	Ensure stormwater runoff is contained and sediment removed prior to leaving site. Consider setting goals for potable and non-potable water ruse on site during demolitions. Consider reuse of water storage, transport and treatment technologies form the old building if appropriate.		

Source: Australian Government (2006)

Appendix C
Landscape Maintenance Checklist

Landscape Development

Maintenance and Inspection Checklist

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
	Y	N	Y	N	
Plant Survival					**3 months**
1. Dead plants identified and replaced					
2. Alternative plants used if soil moisture unsuitable					
Irrigation System Check					**3 months**
3. Plants show no evidence of moisture stress					
4. Repair / replace any damaged components					
5. Adjust irrigation program if necessary					
Drainage Pattern					**3 months**
6. Subsurface drainage required to prevent water logging					
7. Modification of surface drainage required to direct runoff to planted areas					

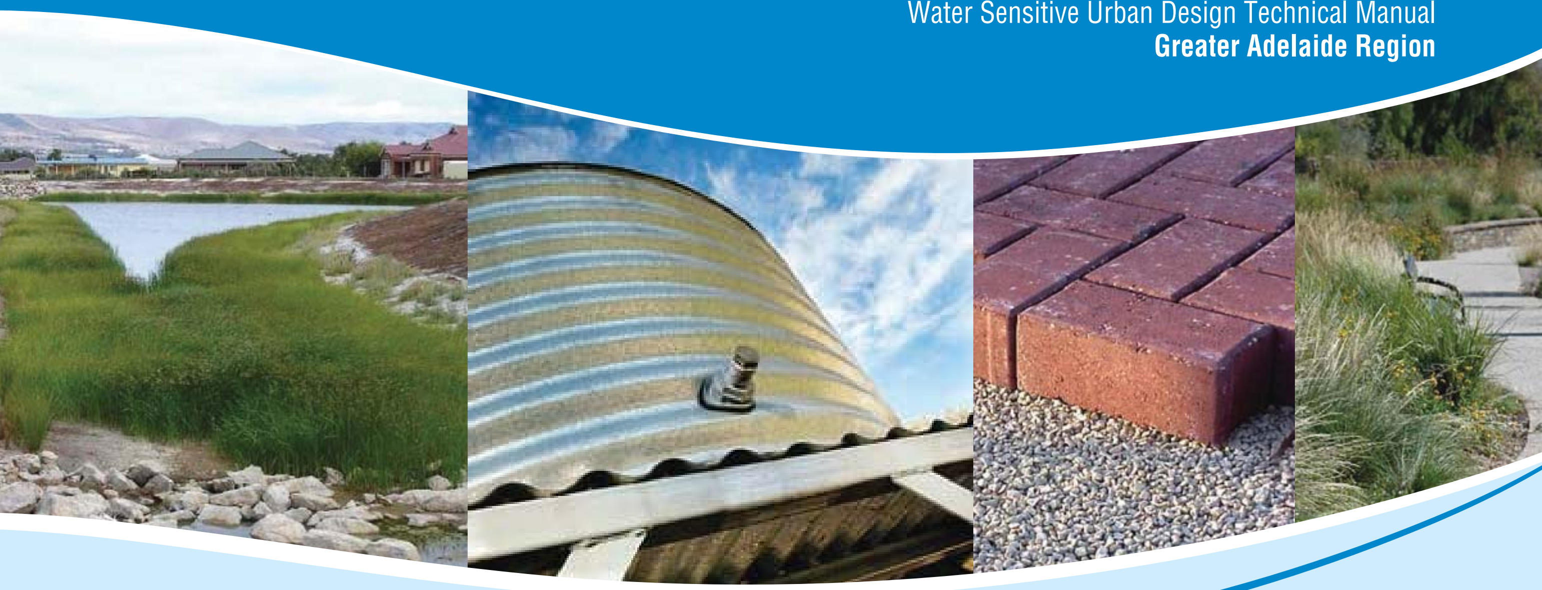
Source: Upper Parramatta River Catchment Trust (2004)

July 2009

Chapter 5

Rainwater Tanks

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

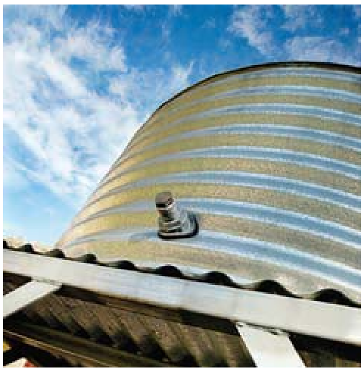
Appendices

Chapter 5
Rainwater Tanks

5.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Rainwater tanks are one of those measures.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing an overview of rainwater tanks and how they can be utilised to assist in achieving the objectives and targets of WSUD.



Description

A rainwater tank is designed to capture and store rainwater from gutters or downpipes on a building.

A rainwater tank does not collect water other than rainwater or mains water. Captured water is then available for commercial, industrial or domestic uses.

Purpose

The main function of rainwater tanks is water conservation.

Rainwater can be used to irrigate gardens or used to supply interior demands, such as toilet flushing or laundry use. Meeting interior demands ensures that stored rainwater is utilised at a relatively constant rate, allowing rainwater to refill the storage more often. Using rainwater for various uses (such as toilet flushing and garden watering), each with different usage patterns, can result in optimum mains water savings and large reductions in runoff discharges.

Rainwater tanks provide limited water quality control, primarily through sedimentation processes. This can be enhanced by elevating the outlet tap to a height equal to or greater than 100 millimetres above the tank floor.

Both Beecham (2003) and Coombes et al (2001) have studied the capacity of rainwater tanks to contribute to flood control. It can be assumed that approximately one third of the tank volume can provide flood control.

Scale and Application

Rainwater tanks are generally applied at the lot level, but can be applied at the street level in larger development projects.

It should be noted that it is currently a mandatory building requirement for new Class 1 buildings to have an alternative mains water supply which is often met through installation of a rainwater tank plumbed into the dwelling (see **Section 5.2**).

5.2 Legislative Requirements and Approvals

Before undertaking a concept design of a rainwater tank system it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to rainwater tanks in your area.

The legislation which is most applicable to the design and installation of rainwater tanks includes:

- *Development Act 1993* and Development Regulations 2008
- *Waterworks Act 1932* and Waterworks Regulations 1996
- *Natural Resources Management Act 2004*
- *Environment Protection Act 1993*; and
- *Public and Environmental Health Act 1987*

In addition, there are a number of standards which apply to the construction and installation of rainwater tanks which are also summarised below.

Development Act 1993 and the Building Code

Since 1 July 2006 new homes and household extensions greater than 50 square metres are required to have an additional water supply to supplement mains water. The additional water supply must be plumbed to a toilet, to a water heater or to all cold water outlets in the laundry. This requirement generally applies to new Class 1 buildings which are defined by the Building Code of Australia (BCA2006 – Volume 2).

Installing a rainwater tank plumbed for internal use is the most common way of achieving this requirement. Other means of providing the required additional water supply could include developments using a dual reticulated (fixed pipe) water supply system – such as Mawson Lakes – or approved bore water.

The State Government's policy is implemented through the existing development approval system in accordance with the *Development Act 1993* and Development Regulations 2008, and is contained in a South Australian variation to the BCA (SA2 to Volume 2). The plumbing aspects of the policy are regulated by the South Australian Water Corporation (SA Water) in accordance with the *Waterworks Act 1932* and Waterworks Regulations 1996.

If a rainwater tank is used to meet the requirement for additional water supply, it must have a storage capacity not less than 1 kilolitre (1000 litres). The requirement for a minimum 1 kilolitre plumbed rainwater tank is additional to any other water storage tank requirements that might be required (e.g. other tanks are required in some areas for bushfire fighting purposes).

Where a number of dwellings contribute to a communal rainwater storage tank, each dwelling must contribute rainwater from 50 square metres of its roof catchment area to the rainwater tank and water from the tank must be plumbed back to each individual dwelling. In these situations, the minimum rainwater tank size required is determined by multiplying the number of dwellings that contribute to the rainwater tank by 1 kilolitre for each dwelling.

For more information on these requirements go to **www.planning.sa.gov.au/go/rainwater-tanks**

Installation of rainwater tanks is covered under the South Australian Development Regulations 2008 Schedule 3 (acts and activities which are not development). A rainwater tank does not require development approval provided it satisfies the following criteria:

- Is part of a roof drainage system;
- Has a total floor area not exceeding 10 square metres; and
- Has no part higher than four metres above the natural surface of the ground.

Installing a rainwater tank will generally be part of a larger development (for new developments), however whenever a rainwater tank is planned (such as retrofitting), it is advised that the local council be contacted to:

- Determine whether development approval is required under the *Development Act 1993*; and
- Determine what restrictions (if any) there may be on the installation of rainwater tanks on the site. Factors such as height and boundary setback requirements need to be checked.

Waterworks Act 1932

The *Waterworks Act 1932* authorises the responsible Minister and SA Water to supply water to urban and regional communities and to provide safe drainage of wastewater, rating and pricing arrangements, and the construction of necessary infrastructure.

SA Water should be consulted regarding the conditions which need to be met to allow the transition between rainwater and mains water supply should the proposed rainwater harvesting system involve connection to mains supply.

Specific issues addressed by SA Water include the need for installation by a licensed plumber, signage, certification of the materials used, certificates of compliance upon installation and the need for an automated switching device. See **Section 5.9** for where to obtain more information on plumbing requirements.

Natural Resources Management Act 2004

Water resources in South Australia are primarily managed under the *Natural Resources Management Act 2004*. Where increased development causes stress on water resources and a higher level of management is warranted, the associated water resources can be prescribed under the *Natural Resources Management Act 2004*.

Any rain that falls on a roof is considered to be surface water. A water licence is required to 'take' surface water in an area where surface water is prescribed, such as the Western Mt Lofty Ranges. A licence is not required for:

- Stock and domestic purposes;
- Fire fighting;
- Chemical use on non-irrigated crops, non-irrigated pasture and for the control of pest plants and animals;
- Road making; and
- Specific exemptions (see below).

Roof runoff that is not 'taken' (collected and used) returns to the environment and does not require licensing.

Commercial, industrial, environmental and recreational users are currently exempt from requiring a water licence to take roof runoff where the volume of water collected from the connected roof area is equal to or less than 500 kilolitres per year.

Environment Protection Act 1993

Any development, including the installation of a rainwater tank, has the potential for environmental impact, which can result from vegetation removal, stormwater management, and construction processes. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on a site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when planning the installation of a rainwater tank are discussed below.

Water Quality

Water quality in South Australia is protected using the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development. In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, building sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise potential for environmental impact during construction. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 5.9**).

Measures also need to be taken to ensure that erosion and subsequent water quality impacts do not result after the installation of a rainwater tank by ensuring that overflow from the tank is directed to a location which is protected from erosion.

Waste

Any wastes arising from any excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*. For example, during construction all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 5.9**).

Public and Environmental Health Act 1987

The Department of Health (Environmental Health Branch) is responsible for the implementation of the *Public and Environmental Health Act 1987* in South Australia. This agency provides the required information and assistance in establishing a rainwater harvesting and reuse system with regards to health issues.

Standards

Australian Standards for tank manufacturers ensure that modern tanks have child-safe access and full protection against mosquito and other animal invasion.

Rainwater tanks may need to be installed in accordance with the standards summarised in Table 5.1, depending on the type of tank.

Table 5.1 Standards Relating to Rainwater Tanks

Standard	Title	Purpose
AS/NZS 3500 2003	Plumbing and Drainage Standards and the South Australian Variations	
AS/NZ 3500.1.2	Water Supply – Acceptable Solutions	Provides guidance for the design of rainwater tanks with dual water supply (rainwater and mains water)
AS/NZS4020	Testing of Products for Use in Contact with Drinking Water	Any materials in contact with water to be used for drinking must comply with this standard A concrete or soldered galvanized tank should be lined with an approved tank liner/coating if the water is for drinking
AS2179	Rain Water Storage Tanks – Metal (Rain Water) Specifications	If a metal rain water tank is to be used, it shall comply with this Australian Standard
AS/ NZ 1170	Loads on Rainwater Tanks	
AS/NZ 4766 (Int)	Polyethylene Storage Tanks for Water and Chemicals	Polyethylene rainwater tanks shall comply with this standard

5.3 Design Considerations

Some of the design issues that should be considered when conceptualising and designing a rainwater tank harvesting system include:

- Water quality;
- Roof materials;
- Tank materials;
- System configuration; and
- Embodied energy and greenhouse gas impact.

The following sections provide an overview of these key design issues.

Water Quality

The design of a rainwater harvesting system is dependent on the intended use of the rainwater. Water quality is an important consideration for all rainwater systems, especially in urban areas. Rainwater poses little health risk for non-drinking uses such as garden watering, toilet flushing, hot water supply and washing machines. Additional treatment is generally required when rainwater is to be used as a drinking water supply (see references to further information in **Section 5.9**).

The 'roof-to-gutter-to-rainwater-tank-to-use' pathway is a treatment train. The quality of rainfall runoff from roofs is generally lower than the quality of rainfall. Soil, leaves and debris can accumulate on roof surfaces during dry periods and wash off the roof during storm events. Also, the ambient quality of rainfall is influenced by the geographic location of the rainfall event. For example, if the rainwater harvesting site is in an area of heavy air and dust pollution, the rainwater may not be suitable for potable uses, and advice should be sought.

The quality of runoff therefore depends on roofing materials (see below), the types of material deposited on the roof and the roof maintenance regime.

Acceptable water quality for potable use can be maintained in rainwater tanks provided that (Parsons Brinkerhoff 2006):

- Mesh screens are installed over all inlets and outlets to prevent leaves, debris, vermin and mosquitoes from entering the tank;

- A first flush device is installed to discard the first portion of rainfall;
- Gutters and roofs are regularly cleared of leaves, debris and branches; and
- Water ponding in gutters is prevented as it can provide breeding sites for mosquitoes and could lead to eggs being washed into tanks.

Additional guidance on cleaning, testing and disinfection can be found in documents listed in **Section 5.9**.

Roof Materials

Roofs constructed from galvanised iron, Colourbond® or Zincalume®, slate or ceramic tiles provide acceptable water quality for potable use (Department of Health South Australia 2006; Parsons Brinkerhoff 2006).

However, the following should be taken into account when considering installation of a rainwater tank (Department of Health South Australia 2006):

- Rainwater should not be collected from roofs coated with lead or bitumen-based paints;
- Some types of new tiles and freshly applied acrylic paints may affect the colour or taste of rainwater, therefore the first few runoffs may need to be discarded;
- Chemically treated timbers and lead flashing should not be used in roof catchments;
- Rainwater should not be collected from parts of roofs incorporating flues from wood burners, if possible;
- Copper roofing or guttering materials should not be used upstream of aluminium or galvanised or Zincalume® steel products;
- Avoid corrosion caused by dissimilar metals (e.g. do not use stainless steel screws on steel or on aluminium pre-painted roofing materials); and
- Galvanised gutters should not be used in combination with materials such as Zincalume® or Colourbond® steel or terracotta tiles, as this can lead to accelerated corrosion of guttering.

Tank Materials

Rainwater tanks should be made of durable, watertight, non-reflective, opaque materials with a clean, smooth interior such as Colourbond®, galvanised iron, polymer or concrete. There are also a range of innovative products available which do not use the conventional tank design (see **Sections 5.4** and **5.9**).

Sunlight should not penetrate the rainwater tank to prevent the growth of algae.

System Configuration

Possible system configurations for the use of rainwater with mains supply back up include:

- Pressurised rainwater supply with mains supply back up (Figure 5.1);
- Gravity rainwater supply with mains supply top up to tank (Figure 5.2); or
- Pressurised rainwater supply with mains supply back up from a buried or partially buried tank (Figure 5.3).

Examples of each of these possible configurations are illustrated in the figures below.

For a new development, factors to consider include:

- Roof and gutters being designed so that runoff from the whole roof is collected in a single tank or in a series of tanks. In multi storey buildings this can be most effectively achieved through the use of symphonic drainage systems;
- Integrating the tank itself into the design of the building so that it is convenient, reduces the space required and is aesthetically pleasing (e.g. tanks can be buried); and
- Locating the tank close to the mains water inlet (for mains connected systems) or close to the point of use (for gravity fed systems).

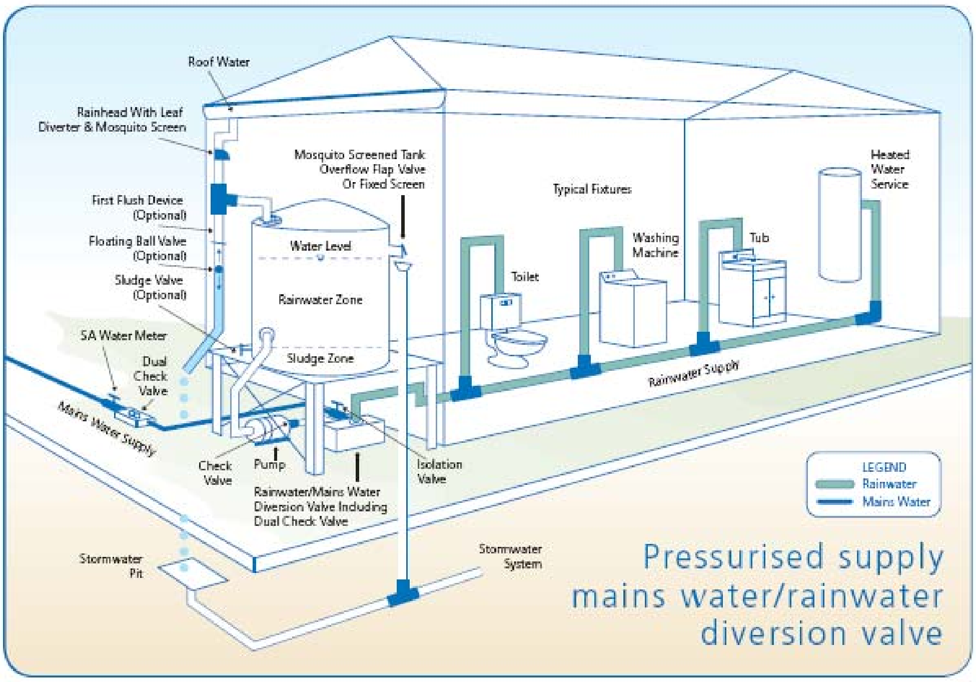


Figure 5.1 Pressurised Rainwater Supply with Mains Supply Back Up

Source: SA Water (2006)

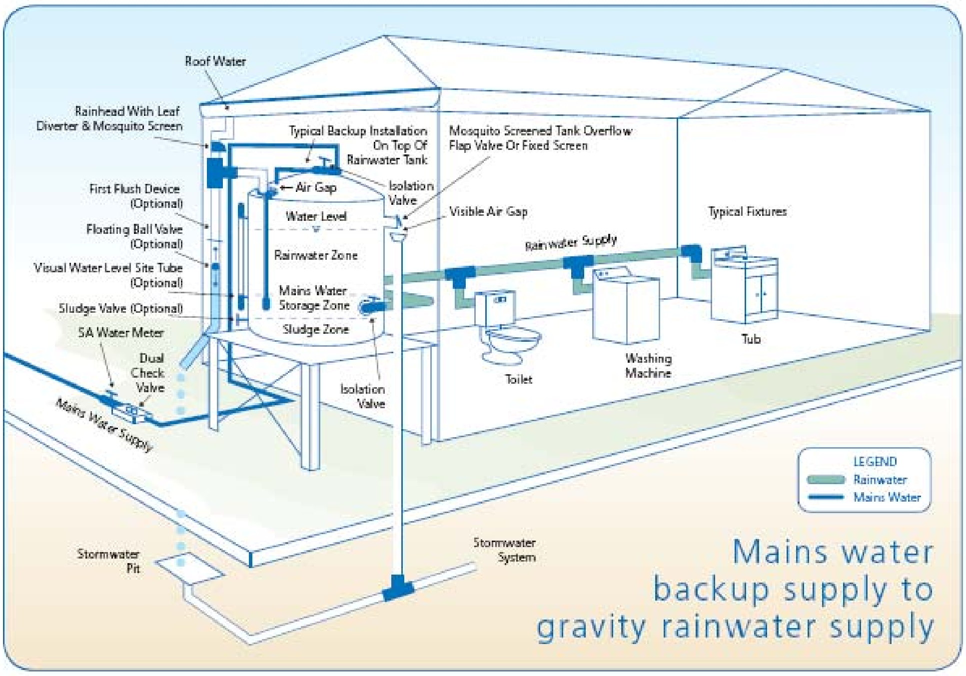


Figure 5.2 Gravity Rainwater Supply with Mains Supply Top Up to Tank

Source: SA Water (2006)

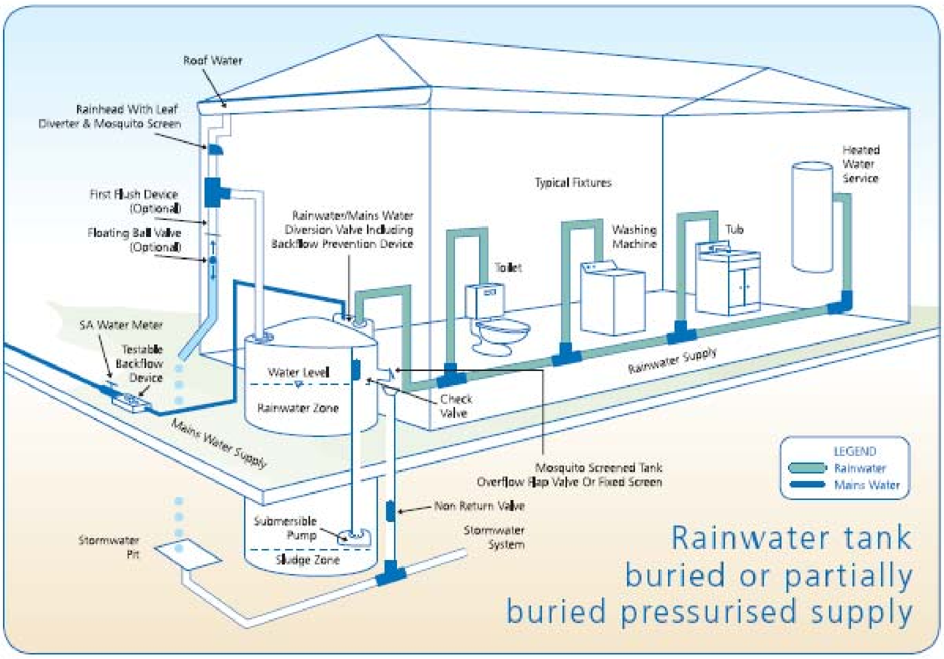


Figure 5.3 Pressurised Rainwater Supply with Mains Supply Back Up From a Buried or Partially Buried Tank

Source: SA Water (2006)

Embodied Energy and Greenhouse Gas Impact

The energy and materials impact of rainwater tank manufacture and operation are substantially higher, in percentage terms, than the energy equivalent for reticulated water supply, especially when a pump is used with the tank. However, the absolute impact of rainwater tanks is not large in proportion to other impacts. In terms of greenhouse gas emissions, the overall additional impact of a rainwater tank and pump is equivalent to 50 to 100 kilometres per year of car travel (ACT Planning and Land Authority 2007).

Water use is generally considered the most significant environmental indicator with respect to rainwater tanks. In respect to greenhouse gas emissions, steel tanks have the lowest impact, followed by concrete, with plastic tanks having the highest impact (ACT Planning and Land Authority 2007).

5.4 Design Process

Overview

The following key steps should be undertaken when considering the installation of a rainwater harvesting system:

- Assess site suitability;
- Identify objectives and targets;
- Meet with local council and other relevant authorities;
- Select a type of rainwater tank;
- Size the rainwater tank;
- Additional elements;
- Undertake approvals process (if required);
- Check the objectives; and
- Prepare a maintenance plan.

Several of the elements of the design process are discussed briefly below.

The WSUD design process is also discussed in general in **Chapter 3** of the Technical Manual.

Assess Site Suitability

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of site conditions is a fundamental part of designing a development that effectively incorporates WSUD.

Careful selection of where to place a rainwater tank is important – and is not only a matter of appearance.

The following factors should be considered when undertaking a site suitability assessment:

- The tank should be located in a cool place (to keep the temperature of the water low, reduce evaporation and reduce damage to the tank material);
- No tank should be fixed to the wall of a building unless certified by a practising structural engineer;
- All tanks should be placed on a structurally adequate base in accordance with the manufacturer's or engineer's details;
- Pumps must be located and operated so as not to cause offensive noise;

- Any overhanging foliage needs to be removed to decrease leaf litter, bird and possum droppings and other animal contamination;
- Location of existing downpipes;
- Location of mains water supply;
- Location of any easements and boundaries; and
- Space available.

Identify Objectives and Targets

Before the commencement of the design process, the objectives and targets for the rainwater harvesting system must be established.

An appropriate objective for rainwater harvesting on a site is to provide a 'reliable' supply of suitable quality water to meet the demand requirements of a stipulated preferred 'end use' (for example, toilet flushing, laundry use, and/or garden watering).

If the objectives for selecting a rainwater tank size are clearly defined, the task is simplified.

More general information on setting objectives and targets can be found in **Chapter 3** of the Technical Manual.

Meeting with Council or Other Relevant Authority

Before designing or installing a rainwater tank system, it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to rainwater tanks in your area. A discussion with a development assessment officer at your local council is recommended.

The council will also be able to advise whether:

- Development approval is required and, if so, what information should be provided with the development application;
- Any other approving authorities should be consulted; and
- Any specific council requirements need to be taken into consideration

Further information can be obtained in **Section 5.2**.

Selecting a Type of Rainwater Tank

There are many options available for rainwater tanks. The summary tables here outline the features of various above and below ground tanks.

Table 5.2 Metal Tanks

Type	Features	Considerations
Corrugated iron	The classic outback tank. Readily available and relatively easily transported. Galvanised steel performance can be improved with rust-resistant coatings such as Zincalume or Aquaplate. Easy to install, service and maintain.	Initial corrosion of galvanised steel normally creates a thin adherent film that coats the interior surface of the tank and provides protection against further corrosion. Cleaning should not disturb this film. Avoid copper or copper alloy fittings (brass and bronze) connected directly to steel tanks as this causes corrosion.
Aquaplate Colorbond	Aquaplate steel has a polymer skin bonded to a corrosion-resistant galvanised steel base. Colours can match roofs and fences. Easy to install, service and maintain.	The polymer coating is not resistant to prolonged exposure to sunlight so tanks must have a top cover in place at all times. Avoid copper or copper alloy fittings (brass and bronze) connected directly to steel tanks as this causes corrosion.
Stainless steel	High resistance to corrosion, staining and bacteria. Available as a garden design feature and in a range of shapes and sizes. Easy to install, service and maintain.	

Source: Australian Rainwater Industry Development Group (2007)

Figure 5.4 Example of a Metal Tank

Table 5.3 Concrete Tanks

Type	Features	Considerations
Above ground	Good for larger capacity tanks. Not usually used in urban settings. Lime from cement softens the water. Easy to install, service and maintain.	Heavy, so needs strong foundations. Tanks can be poured on site. Needs sealing for maximum water retention.
In ground	Inconspicuous large tanks. Lime from cement softens water. Sealed with latex or other lining.	Can be placed in traffic areas as they can be designed as load bearing structures.

Source: Australian Rainwater Industry Development Group (2007)

Figure 5.5 Example of a Concrete Tank

Table 5.4 Plastic Tanks

Type	Features	Considerations
Above ground	Light weight and easily transported – good for smaller tanks. Flexibility in shapes and colours. Easy to install, service and maintain.	Despite having UV inhibitors, best placed in shade.
In ground	Good choice of materials and clever design maximises strength, minimises depth and increases practicality. Anti-hydrostatic lift measures, such as good design features, anchoring or ballast will be needed as pressure from high groundwater can force it out of the ground. Also need to protect tank water from overflow surges running back into tank.	Load bearing can be limited. Need to be integrated into system which can include driveways etc.

Source: Australian Rainwater Industry Development Group (2007)

Figure 5.6 Example of a Plastic Tank

Table 5.5 Innovative Tanks

Type	Features	Considerations
Water walls	Generally plastic or metal, good for limited ground space.	Can be difficult to clean and maintain in protected areas when in exposed sites.
Bladders	Innovative under-deck or under-house bladder made from tough materials. Can collect from a number of drainpipes unobtrusively and utilise previously wasted space.	Ongoing maintenance and access needs to be considered.
In slab	Used like a waffle pod. A waffle pod is where the concrete slab is sitting on and around a series of boxes (or pods) set out in a grid pattern. Each in slab is approximately 600 litres.	Used in new homes or extensions; cannot be retrofitted. Ongoing maintenance and access needs to be considered.
Fibreglass	A food-grade coating on the interior surface is cured before the tanks are offered for sale. Lightweight and strong. Flexibility in shapes and colours. Relatively salt resistant so good in coastal locations. Relatively easy to repair.	Despite having UV inhibitors, better to be placed in shade.

Source: Australian Rainwater Industry Development Group (2007)

Figure 5.7 Example of a Bladder Tank

Sizing a Rainwater Tank

Variables that need to be considered in selecting the best size for a rainwater tank include:

- The size or area of roof directed to the tank;
- The purpose the tank will serve in reaching the desired targets and fulfilling the objectives;
- The quantity and nature of demand;
- Rainfall pattern of a particular area;
- Available space; and
- Budgetary constraints.

(Note: In an urban environment where the reticulated supply is always present as a back up, all collected water use is beneficial, so any size tank is preferable to none.)

Tanks come in a wide range of shapes and sizes. The typical size of rainwater tanks installed on residential properties within urban areas (that are connected to mains water) is between 1 kilolitre (1000 litres) and 10 kilolitres (10,000 litres).

Large store volumes can be made up of a number of smaller tanks.

The various factors regarding sizing a rainwater tank are discussed below.

Roof Area

The size of the roof that is drained to a rainwater tank is a key factor that governs the amount of water that can be harvested and reused.

If determining the roof size by measuring the outside of the building, allow for eaves overhang. Include garages, sheds, carports and verandahs only if runoff from them will go to the tank. More than one tank may be required to collect water from different areas of the roof. The slope (pitch) of the roof is unimportant, it is the flat or plan area that matters.

For proposed buildings, this area can be calculated from architectural plans.

Rainfall

Rainfall varies depending on where you are located. Factors which are important to consider include:

- The average annual rainfall;
- The pattern of distribution throughout the year; and
- The variation from year to year.

The mean annual rainfall varies from more than 1100 millimetres in the Adelaide Hills to around 400 millimetres near the sea. A rainfall distribution map can be used to determine the appropriate weather station for your location. Rainfall data is available from the Bureau of Meteorology (www.bom.gov.au). Some rainfall data is provided in **Figure A1** in **Appendix A**.

It should be noted that the majority of the Adelaide Plains receives 450–600 millimetres/annum of rainfall.

Maximum Volume

The maximum volume of water that you can obtain from a roof each year, on average is:

Water volume (kL) = average annual rainfall (mm) x coefficient of runoff x roof area (m^2)

A coefficient of runoff of 0.9 can be used to obtain a rough estimate (Department for Environment and Heritage 1999).

This formula does not allow for water that may be lost because the tank is already full, or the runoff is more than the tank can hold in a heavy storm.

Intended Use / Demand

How the collected rainwater is to be used is a fundamental question in the design of a rainwater harvesting system.

The demand varies enormously depending on the type of usage (e.g. domestic, commercial and industrial) and will vary from season to season depending on:

- Number of people;
- Water use habits;
- Uses to which the rainwater can be put; and
- Type of water using appliances (if any).

The use of stored rainwater for toilet flushing, laundry and lawn/garden watering will reduce water levels in the rainwater tank and create available airspace to capture further water during the next storm. Increasing the demands on a rainwater tank by attaching more internal and external uses saves more mains water.

To determine how rainwater harvesting may be used and what form it may take (i.e. what end uses will be connected to the tank, type of distribution system) an audit of the water usage at the site in question should be conducted. There are tools and services available to assist developers, existing businesses, industry, schools and householders to complete this process (see **Section 5.9**).

Average water use figures and previous water bills and usage information can be used to inform the auditing process (see **Chapter 4**).

Design tools that can be utilised to assist with sizing a rainwater tank are discussed in **Section 5.5**.

Additional Elements – Features and Fittings

The following system features and fittings should be considered when designing a rainwater collection system. Some features are not relevant for all design purposes:

- The tank is to be provided with suitable backflow prevention to the mains supply in accordance with Australian Standard AS3500.1.2 and the requirements of the relevant water authority (i.e. SA Water);
- Tanks are to be fully enclosed to prevent mosquitoes breeding and access by insects, animals and birds;
- Gravity tanks should be constructed with sufficient head to achieve required flows;
- Gutter mesh should be installed;
- A suitable trap or filter needs to be installed prior to the tank inlet to prevent contaminants entering the tank;
- A storage system should have an inlet above the top water level, a visible air gap complying with plumbing regulations, a means to scour and clean out accumulated sediment and an outlet positioned above the maximum level of sediment; and
- Overflow outlet.

Specific features of various rainwater tank systems are discussed in further detail below.

Pump

When selecting a rainwater pump, there are three aspects to consider – application, reliability and noise. The intended application(s) will determine the flow rate and water pressure that is required which will then allow the pump capacity to be determined.

To calculate the performance that is needed, work backwards from the number of appliances that will be run at the same time, add them up and calculate the required flow rate. The relevant pressure required is determined by the pipe size used, the length of pipe and the operating pressure of the appliance.

Pumps come in a range of models and with varied power, which is indicated by litres per minute (LPM) of water they can move.

The pressure requirements for the different demands to be serviced by the rainwater harvesting system need to be considered. Table 5.6 provides some indication of the flow rate pressure required for a range of demands. In a pressurised system a pump will be required.

Table 5.6 Indicative Flow Rate and Pressure Requirements for a Range of Demands

Application	Flow Rate Recommended	Water Pressure Recommended
Lawn sprinkler / garden hose	15 litres/minute	140 kPa (20 Psi)
Garden irrigation	60 litres/minute	400 kPa (55 Psi)
Internal use	15 litres/minute at last fixture	Min 50 kPa at last fixture
Washing machine	15 litres/minute	Min 100 kPa
Toilet flushing	10 litres/minute	Min 50 kPa

Source: Australian Rainwater Industry Development Group (2007)

Pump systems are available from leading suppliers and ensure a reliable water delivery system (see **Section 5.8**).

Unless you want to turn the pump on and off at the power point all the time, you will need some type of automatic pump controller fitted to the pump. Pump controllers automatically start and stop your pump, and selection will depend on a number of factors including:

- Frequency of use;
- Pump protection;
- Energy consumption; and
- Automatic mains back up.

There are four main types of pump controllers currently available:

- Pressure switch – a pressure switch is the simplest auto controller – it will turn the pump on when the system water pressure drops (a tap turned on) and will turn it off when the pressure becomes high (a tap is turned off). A pressure switch system can 'cycle' or switch on and off rapidly if the pipe work or taps leak.
- Constant flow – like a pressure switch, these start the pump on pressure drop, but turn off on low flow. They are usually electronic and may have moving parts in the water.
- Adaptive constant flow – these are the latest generation of constant flow units and as their name implies, they adapt to the conditions the pump system is experiencing.

- Automatic interchange – these provide automatic pump control for rainwater with mains water back up – they are ideal for toilet, laundry and garden irrigation applications in metropolitan areas which need to guarantee water supply to essential services.

The reliability of the rainwater pump can be influenced by several factors including suitability to the application and quality of water.

First Flush Device

All tanks must be fitted with a first flush device, which diverts the first volume of runoff from the roof in a storm event. To improve water quality it is recommended a minimum of 10 litres per 100 square metres of water is diverted/discarded before entering the rainwater tank (Water Services Association of Australia 2005).

Individual site analysis should be undertaken at locations where heavy air pollution is known or suspected to determine if larger volumes of first flush roof water are to be diverted. Similarly at locations subject to prevailing winds from the sea, higher first flush volumes may need to be increased.

The device is to include a primary litter/leaf mesh screen and a first flush containment storage with a small orifice to empty the storage between rain events. The first flush water is to be directed to another WSUD measure (such as an infiltration trench or rain garden) before discharging to the stormwater drainage system.

A first flush diverter can be fitted to each downpipe that supplies water to the tank, or a larger diverter can be installed that can handle multiple downpipes.

5.5 Design Tools

A range of design tools is available for the concept and detailed design of rainwater tanks as detailed in **Chapter 15**. The modelling tools which are able to assist include:

- Rain tank yield curves;
- Raintank Analyser;
- MUSIC;
- WaterCress; and
- Switch-2

A simple spreadsheet analysis can be used to assess rainwater tank performance or existing models such as Raintank Analyser or MUSIC are available to perform additional analysis. Allen et al. (2005) outlines a method for developing an Excel spreadsheet that enables the assessment of the performance of a rainwater tank.

Several of the modelling tools available are discussed briefly below.

Rainwater Tank Yield Curves – Greater Adelaide Region

A series of yield curves for the assessment of different rainwater tank sizes has been developed for the Greater Adelaide Region and is provided in **Appendix A**.

Four sets of curves for domestic and commercial application have been produced, using daily rainfall data from locations that cover the range of annual rainfall variation in the Greater Adelaide Region.

Each curve provides average annual supply for a fixed roof area for a range of specific tank sizes and average daily demands (see **Figure 5.8** as an example).

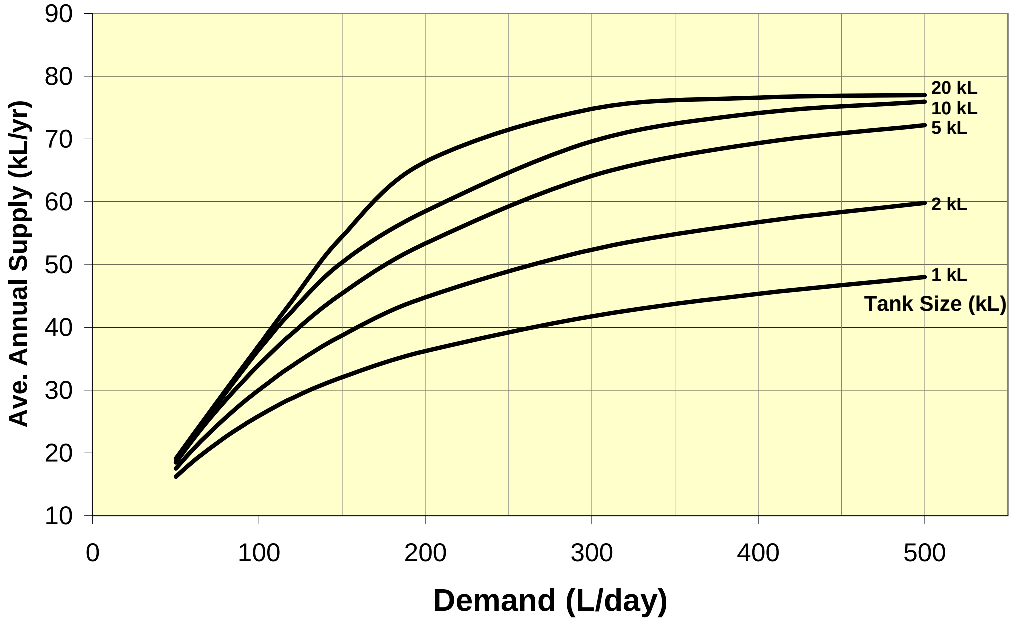


Figure 5.8 Rainwater Tank Yield Curves for a Roof Area of 150 square metres with an Average Annual Rainfall of 500–600 millimetres/year

Detail on how to use the curves and a case study are contained in **Appendix B**.

Rainwater Tank Yield Curves – City of Burnside

Modelling data based on rainfall in the Glen Osmond area has been developed to assist residents in the City of Burnside estimate tank yields with variables including connected roof area (based on 50, 100, 150, 200 square metres of connected roof area), daily consumption and tank size.

The information can be found on the City of Burnside website **www.burnside.sa.gov.au/site/page.cfm?u=958**

Rainwater Tank Yield Curves – South Australian Murray-Darling Basin Natural Resources Management (NRM) Board Region

Four rainwater use options have been modelled based upon the rainfall patterns for the major townships within the SA Murray-Darling Basin NRM region to help households select the appropriate sized rainwater tank for their needs.

The information can be found on the SA Murray-Darling Basin NRM Board's website **www.samdbnrm.sa.gov.au**

Raintank Analyser Software

In many cases, rainwater harvesting and use will be site-specific and a more detailed analysis will enable the performance of rainwater tanks to be determined.

The Raintank Analyser is a detailed spreadsheet that can be used for assessing rainfall harvesting including:

- Yields;
- Cost analysis; and
- Tank size selection.

This software is intended primarily for sizing rainwater tanks for domestic use of water – inhouse as well as outdoors, if required. The analysis considers roof material type, first flush losses, monthly irrigation demands, economic costs and security of supply. The analysis determines a suggested tank size based on an increasing and decreasing benefit approach. Economic assessments are limited to a storage volume of 20,000 litres.

The model can also be applied to commercial/industrial situations provided the 20,000 litres limit is recognised. In these situations where very large catchment roof areas are available, then a solution to the problem of sizing can be found by segmenting the catchment so that each segment requires a rainwater tank that has a capacity not exceeding 20,000 litres.

The analyser allows for the user to insert local rainfall data. A case study is provided in **Appendix B**.

The program is freely available and can be downloaded from **www.unisa.edu.au/water/UWRG/publication/raintankanalyser.asp**

5.6 Installation/Construction Process

When it is to be plumbed into a building, the rainwater tank must be installed by a licensed plumber.

It may be necessary to flush the tank before use; advice should be sought from the manufacturer.

If a non-submersible pump is to be installed, it should be located in a frost free position on a hard, dry and well drained site with good ventilation and protection from the weather. The pump should ideally be as close to the tank as possible.

Noise is increasingly becoming a cause of tension and aggravation between neighbours. Limits on pump noise are governed by the Environment Protection Authority and local government. Guidelines set maximum noise levels at the closest point to neighbouring properties (see **Section 5.2**). Housing the pump inside an acoustic pump cover or box reduces the noise, while a submersible pump will eliminate most noise.

5.7 Maintenance Requirements

Rainwater tanks should be considered a low maintenance system, not a no maintenance system. Maintaining the tank, catchment and distribution system will provide for better water quality. It is important to establish a general maintenance program to ensure the tank, its water quality and accessories will provide years of service.

Simple, pre-scheduled clearing of debris and cleaning will keep the system in good condition. An example Maintenance and Inspection Checklist is provided in **Appendix C**.

For rainwater tanks the following items should be inspected:

- Clogging and blockage of the first flush device;
- Clogging and blockage of the tank inlet leaf/litter screen; and
- Depth of sediment within the tank.

Inspections should be undertaken at the frequencies shown in the example Maintenance and Inspection Checklist for Rainwater Tanks in **Appendix C**.

The following maintenance activities should be undertaken:

- First flush device to be cleaned out;
- Leaves and debris to be removed from the inlet leaf/litter screen;
- Leaves and debris removed from roof gutters; and
- Sediment and debris removed from rainwater tank floor.

Adequate first flush systems and mesh screens on tanks inlets will reduce the amount of sediment and debris entering the tank, rendering cleaning only necessary approximately every 10 years.

5.8 Approximate Costs and Manufacturer Information

Approximate Costs

A rainwater collection system can be considered to be an investment and not a cost. When the costs of a rainwater tank and its accessories and connections are included, the cost per unit of water is initially higher than mains water but in the long-term the proportionate cost goes down until you are saving money and helping the environment.

The cost of rainwater tank systems depends on many factors including:

- The tank itself;
- Any necessary alteration to gutters and downpipes;
- A tank stand (in most cases);
- Plumbing to take water into the building;
- A device to reject initial runoff after dry periods (i.e. first flush device);
- A pump (if necessary); and
- Gutter guards (if necessary).

The cost for the supply of rainwater tanks will largely depend on the tank's fabrication material. The cost of installing a rainwater tank can vary considerably depending on site constraints.

Typically, the cost of rainwater tank installation for supplementary water source ranges from $1200 to $2000 for residential detached or semi-detached dwellings. Indicative costs are provided in **Table 5.7**.

Costs may increase with higher density development as space constraints could require more specialised tanks to be fitted.

Table 5.7 Indicative Rainwater Tank System Costs

Item	Approximate Cost for Each Tank Size			
Size	5 kL	10 kL	15 kL	20 kL
Round galvanised tank	$550	$850	$1110	$1800
Pump	$270	$270	$270	$270
Plumber and fittings	$500	$500	$500	$500
Float system	$200	$200	$200	$200
Concrete base	$200	$200	$200	$200
GST	$160	$180	$200	$230
Total	**$1800**	**$2020**	**$2210**	**$2490**

Source: Rainwater Tanks Information Sheet (based on 2001 costs from Coombes et al (2001))

A conservative estimate of annual maintenance costs incurred for a rainwater tank is approximately $70 per year (Upper Parramatta River Catchment Trust 2004).

The ongoing operating costs for the pump motor (if required) would be approximately $150/year (based on 13.53 cents per kWh for a 0.75 kW pump for an average four hour operating day) (Upper Parramatta River Catchment Trust 2004).

Manufacturer Information

A range of rainwater tank and accessories suppliers in the Greater Adelaide Region is provided in Table 5.8**.**

However, it should be noted that this is not a complete (or recommended) listing.

For more options visit **www.yellowpages.com.au**. Useful searches include:

- Tanks and tank equipment;
- Tank cleaning; and
- Plumbers.

Table 5.8 Rainwater Tank Equipment Suppliers in the Greater Adelaide Region

Supplier	Location	Products	Contact Details
Betta Tanks	Pt Wakefield Rd, Burton	Galvanised aqua plate and Colourbond tanks 450 litres to 29,250 litres	mbetta2006@yahoo.com.au Ph 8280 8069
Bushman Tanks	Agent in Adelaide is Stratco	Tanks and accessories, including pumps	www.bushmantanks.com
Butlers Pumps and Irrigation	Sturt Street, Adelaide	Pumps	www.butlersirrigation.com.au
Davey Water Products	Range of dealers	Pumps	www.davey.com.au
Denyer Tanks	Bacon Street, Hindmarsh	Tanks	Ph 8346 5081
Grundfos Pumps	Range of dealers	Pumps	www.grundfos.com
Leafshield Gutter Protection	Armiger Court, Holden Hill	Gutter guards	www.leafshield.com.au info@leafshield.com.au Ph 8265 2000
Master Tanks	Richmond Road, Marleston	Polyethylene tanks from 340 litres to 9000 litres, slimline tanks galvanised tanks (one, two and three)	Ph 8443 9061
Nylex	Various dealers	Tanks	www.nylex.com.au
Onga	Various dealers	Pumps	www.onga.com.au
RainReviva	Various dealers	Bladder tank	www.rainreviva.com.au www.newwater.com.au
Stratco	Various locations	Tanks, gutters	www.stratco.com.au
TankMasta	Various dealers	Tanks	www.tankmasta.com.au
Team Poly	Waddikee Road Lonsdale (and various agents – see website)	Tanks, pumps	www.teampoly.com.au
The Rainwater Tank Centre	South Road, Melrose Park	Tanks	Ph 8277 8655

5.9 Useful Resources and Further Information

Fact Sheets

www.unley.sa.gov.au/webdata/resources/files/Guidance_on_the_use_of_Rainwater_Tanks1.pdf

Guidance on the use of rainwater tanks

www.unley.sa.gov.au/webdata/resources/files/rainwater_tanksDHS2pager1.pdf

Use of rainwater tanks

www.unley.sa.gov.au/webdata/resources/files/RainwaterFactSheet_WCPP.pdf

Rainwater tanks

www.decs.sa.gov.au/docs/documents/1/WaterSmartRainWaterToilet.pdf

Rainwater tanks for toilet flushing – schools

www.waterforgood.sa.gov.au

Fact sheets

www.amlrnrm.sa.gov.au/Portals/1/Our_Plans/Docs/WAP/WesternMtLofty/DP_9.pdf

Adelaide and Mt Lofty Ranges Natural Resources Management Board Discussion Paper 9 – Roof Runoff

www.wsud.org/downloads/Planning%20Guide%20&%20PN%27s/04-Rainwater%20tanks.pdf

Rainwater Tanks Practice Note – WSUD in the Sydney region

http://library.melbournewater.com.au/content/wsud/sustainable_urban_design/Rainwater_Tanks.pdf

Rainwater tanks fact sheet – Melbourne Water

Regulations and Legislation

www.planning.sa.gov.au/go/building/sustainability-and-efficiency/rainwater-tanks/rainwater-tanks

Department of Planning and Local Government web site

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA Information – Environmental Noise

General Information

www.unisa.edu.au

University of South Australia

www.eng.newcastle.edu.au/~cegak/Coombes

University of Newcastle

www.lga.sa.gov.au/site/page.cfm

Local Government Association

www.bom.gov.au/climate/averages

Bureau of Meteorology

www.arid.asn.au/

Australian Rainwater Industry Group

www.arid.asn.au/images/stories/documents/rainwater2007.pdf

Rainwater 2007 Consumer Guide

www.watertanks.org.au

The Water Tanks Group

www.greenhouse.gov.au/yourhome/technical/fs22.htm

Rainwater tank information

www.stormwater.asn.au/tanks/tankresearch.html

Water tank research

www.stormwater.asn.au/sa/default.asp?id=74

List of links

Suppliers

www.atlantiscorp.com.au

Atlantis

www.rocla.com.au

Rocla Pipes

www.jameshardie.com.au

James Hardie Industries

www.rainharvesting.com.au/default.asp

Rainwater Harvesting

www.tankmasta.com.au

TankMasta

www.unley.sa.gov.au/webdata/resources/files/Tank_suppliers2.pdf

City of Unley – summary of suppliers

Development Information Guides

www.charlessturt.sa.gov.au/Portals/0/DIG%20G%209a%20Water%20Efficiency%20Rainwater%20Tanks.pdf

City of Charles Sturt – development information guide to rainwater tanks

Audits

www.sawater.com.au/SAWater/YourBusiness/SaveWaterInYourBusiness/Business+Water+Saver+Program.htm

SA Water – Business Water Saver Program

www.sawater.com.au/SAWater/YourHome/SaveWaterInYourHome/How+water+wise+is+your+home.htm

SA Water – Home Water Audit

www.murrayusers.sa.gov.au/water_audit_kit.php

Murray Care – Water Audit Kit

Plumbing

www.sawater.com.au/NR/rdonlyres/E49EA34C-3400-40C9-9634-1B6F7966E7FA/0/RainwaterPlumbingGuide.pdf

SA Water Rainwater Plumbing Guide

www.plumbingindustry.com.au/frmshowpage.aspx

Plumbing Industry Association

www.greenplumbers.com.au

Green Plumbers

Health Information

www.dh.sa.gov.au/pehs/PDF-files/rainwater-tank-factsheet06.pdf

Department of Health – rainwater tanks maintenance and water care

www.dh.sa.gov.au/pehs/PDF-files/rainwater-quality-testing-06.pdf

Department of Health – domestic rainwater quality testing

5.10 References

ACT Planning and Land Authority (2007). *Water Sensitive Urban Design General Code*. Canberra, ACT. July. http://www.actpla.act.gov.au/__data/assets/pdf_file/0013/5440/Waterways.pdf.

Argue, J. R. (Ed, 2009) *WSUD: basic procedures for 'source control' of stormwater - a Handbook for Australian practice.* Editor: Argue, J.R., Authors: Argue, J.R., Allen, M.D., Geiger, W.F., Johnston, L.D., Pezzaniti, D., Scott, P., Centre for Water Management and Reuse, University of South Australia, 5th Printing, February 2009, ISBN 1-920927-18-2, Adelaide.

Australian Rainwater Industry Development Group (2007). *Rainwater 2007 Consumer Guide*. July. http://www.arid.asn.au/images/stories/documents/rainwater2007.pdf.

Beecham, S. (2003). *Impacts of Rainwater Tanks on Stormwater Drainage Design: Rainwater Tank Modelling*. September.

Coombes, P. J., Frost, A., Kuczera, G. (2001). *Impact of Rainwater Tank and On-site Detention Options on Stormwater Management in the Upper Parramatta River Catchment.* Upper Parramatta River Catchment Trust. August. http://www.uprct.nsw.gov.au/sustainable_water/publications/Impact_Rainwater_tanks_&_OSD_SWMgt_UPRC,2001.pdf.

Department for Environment and Heritage (1999). *Rainwater Tanks ... Their Selection, Use and Maintenance.* Government of South Australia. May. http://www.dwlbc.sa.gov.au/assets/files/rainwater.pdf.

Department for Environment and Heritage (2005). *Water Conservation Handbook for Local Government.* Government of South Australia. Adelaide.

Department of Health South Australia (2006). *Rainwater Tanks Maintenance and Water Care.* Government of South Australia. Adelaide. August. http://www.health.sa.gov.au/PEHS/PDF-files/rainwater-tank-factsheet06.pdf.

Department of Natural Resources and Mines Queensland (2005). *Planning Guidelines for Water Supply and Sewerage* - Chapter 5 - Demand / Flow and Projections.

Government of South Australia (2005). *Water Proofing Adelaide: A Thirst for Change (2005 - 2025).*

Melbourne Water (2005). *WSUD Engineering Procedures: Stormwater*. CSIRO Publishing.

Parsons Brinkerhoff (2006). *Peel-Harvey Coastal Catchment Water Sensitive Urban Design Technical Guidelines.* Peel Development Commission. October.

SA Water (2006). *Rainwater Plumbing Guide.* Government of South Australia. April. http://www.sawater.com.au/NR/rdonlyres/E49EA34C-3400-40C9-9634-1B6F7966E7FA/0/RainwaterPlumbingGuide.pdf.

Upper Parramatta River Catchment Trust (2004). *Water Sensitive Urban Design, Technical Guidelines for Western Sydney.* Prepared by URS Australia Pty Ltd. http://www.wsud.org/tech.htm.

Upper Parramatta River Catchment Trust, Sydney Coastal Councils Group, Western Sydney Regional Organisation of Councils, Lower Hunter Central Coast Regional Environmental Management Strategy (2003). *Water Sensitive Planning Guide for the Sydney Region.* Upper Parramatta River Catchment Trust. Sydney. May. http://www.wsud.org/downloads/Planning%20Guide%20&%20PN's/WSPP%20Final.pdf.

Water Services Association of Australia (2005). *Integrated Rainwater Tank Systems - A Supplement to the Water Supply Code of Australia WSA 03-2002.* https://www.wsaa.asn.au/download/2005/IRTSSupplementV1_1.pdf.

Appendix A

Annual Rainfall and Rainwater Tank Harvesting Curves

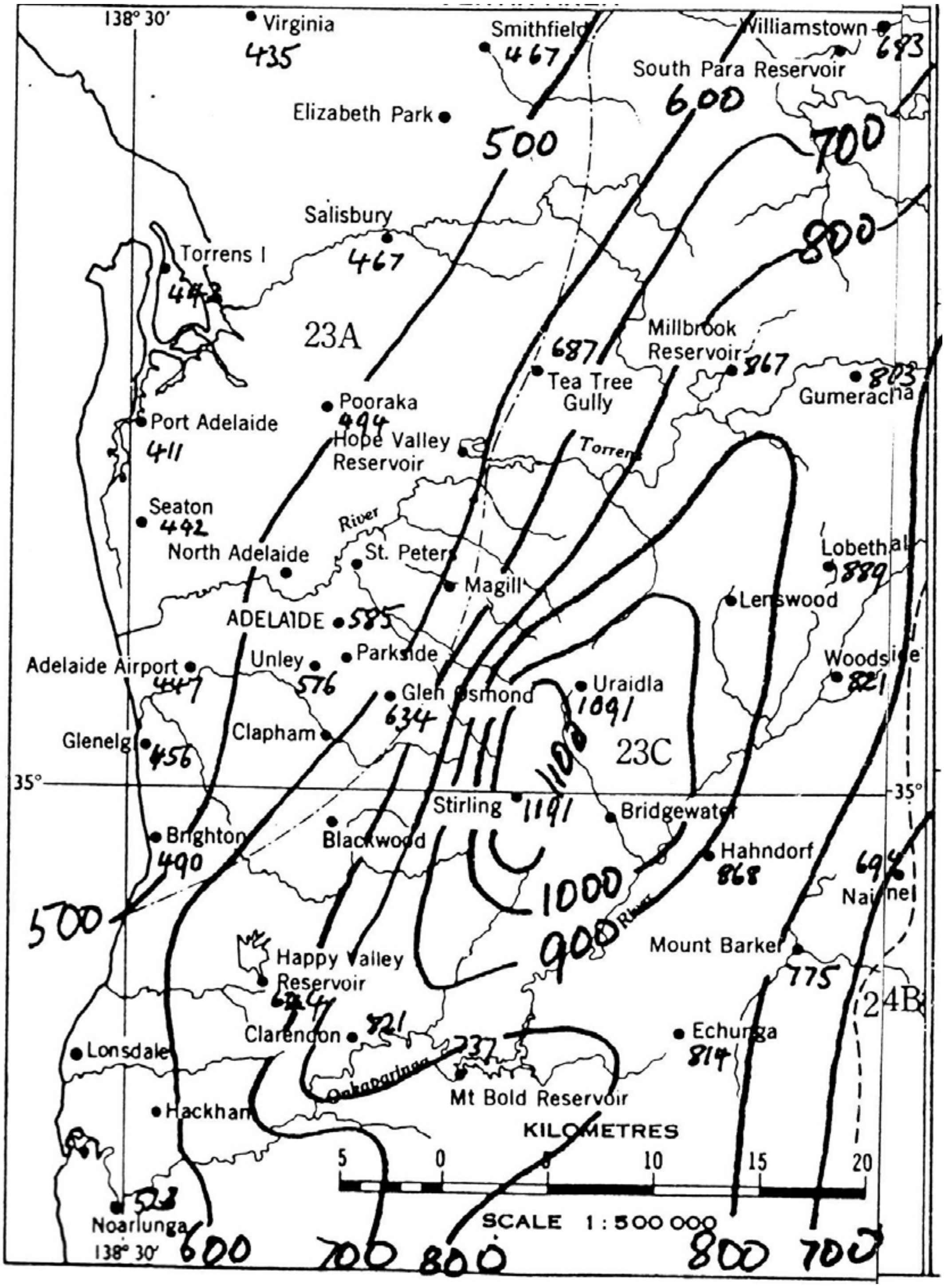


Figure A1 Average Annual Rainfall for the Greater Adelaide Region

Rainwater Tank Harvesting Curves

In order to utilise the curves outlined here, the following steps should be considered:

1. Determine the roof area that can be connected to the tank. In most situations it is not possible to gravity feed the runoff to the tank as the roof gutter slopes are flat and several downpipes are required to meet 20 year ARI flow capacity. It may be possible to drain the roof via a ‘wet’ system.
2. Determine your average daily demand characteristics. Refer to **Section 5.4**.
3. Select the appropriate yield curve graph according to the roof area and annual rainfall.
4. Locate the demand rate along the x-axis and project vertically until it meets the desired tank size. Then project left, horizontally to determine the average annual yield on the y-axis.

A case study is provided in **Appendix B**.

Note: In order to develop the curves, several assumptions were adopted, such as constant daily demand rate, no rainfall (depression or infiltration) losses, no first flush losses, etc.

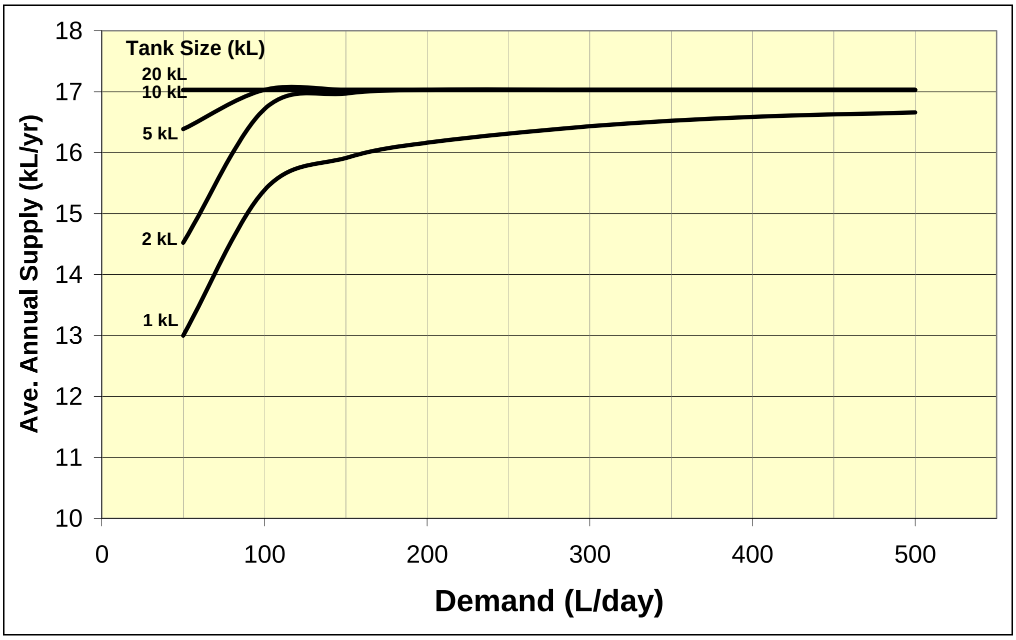
Historical rainfall data used to develop the set of curves was selected to represent the Greater Adelaide Region. The particular sites where the rainfall data was measured were:

- Largs Bay (341 millimetres/year) – for locations with annual rainfall between 300 and 400 millimetres/year;
- Adelaide Airport (445 millimetres/year) – for locations with annual rainfall between 400 and 500 millimetres/year;
- Kent Town (513 millimetres/year) – for locations with annual rainfall between 500 and 600 millimetres/year;
- Kersbrook (766 millimetres/year – for locations with annual rainfall between 600 and 800 millimetres/year; and
- For areas where the average annual rainfall is higher than 800 millimetres, the 600 – 800 millimetres/year curves should be adopted.

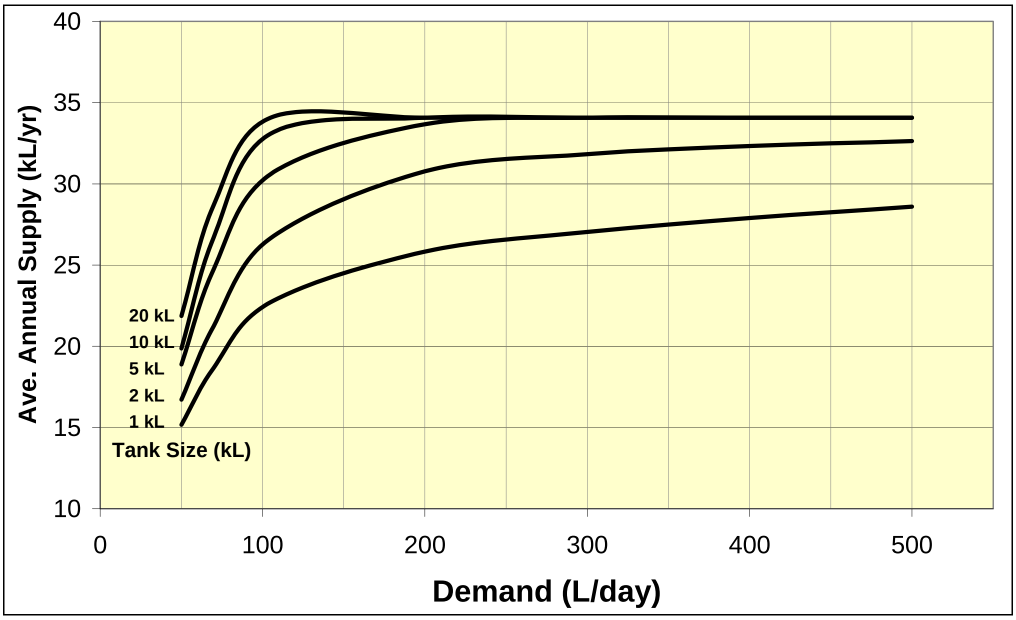
Curves for rainfall area of 300-400 millimetres per annum

Based on Largs Bay 6 minute rainfall data for 1998-2003. Average annual rainfall 341millemetres.

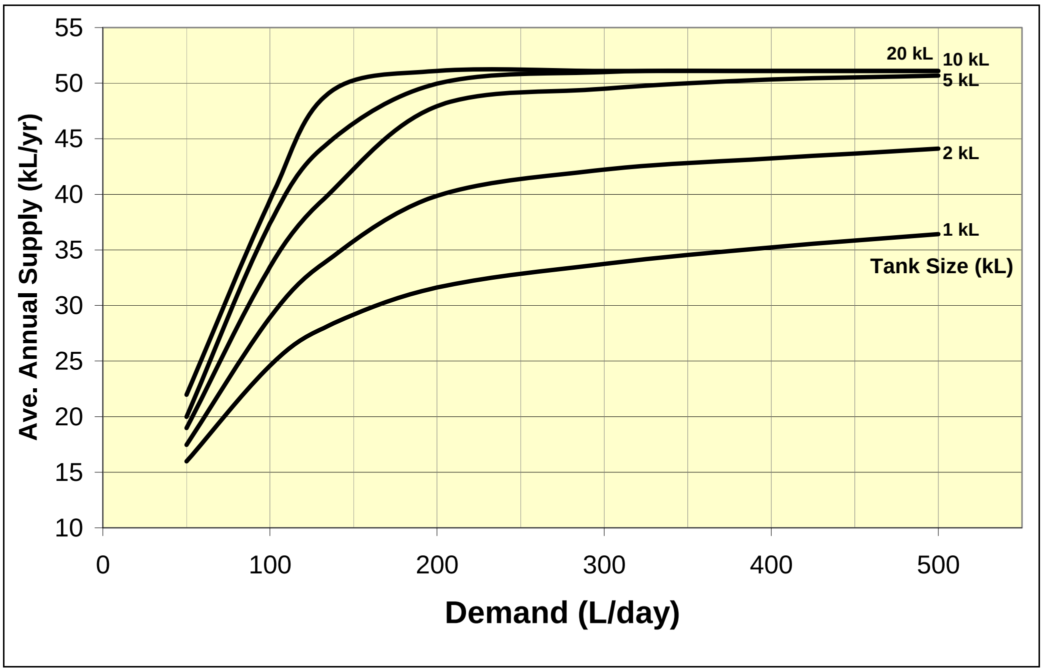
Roof area 50m² (Rainfall: 300-400 millimetres per annum)



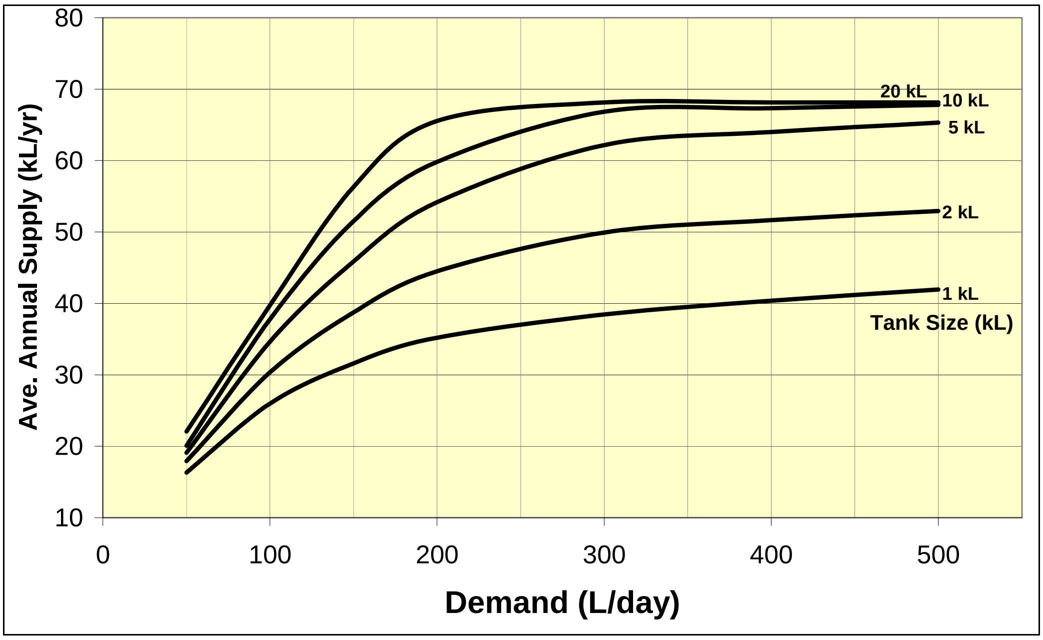
Roof area 100m² (Rainfall: 300-400 millimetres per annum)



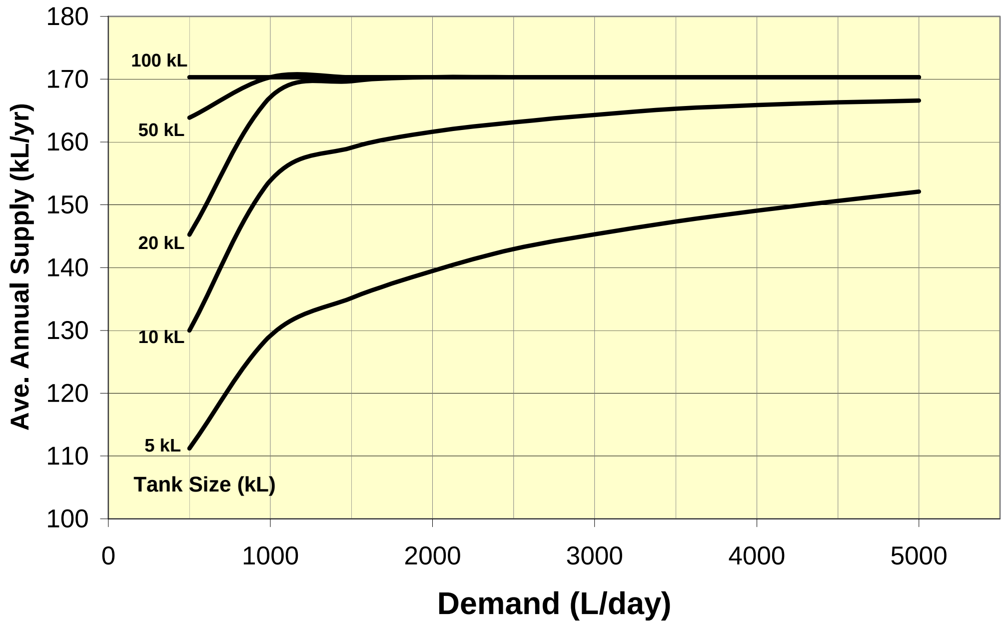
Roof area 150m² (Rainfall: 300-400 millimetres per annum)



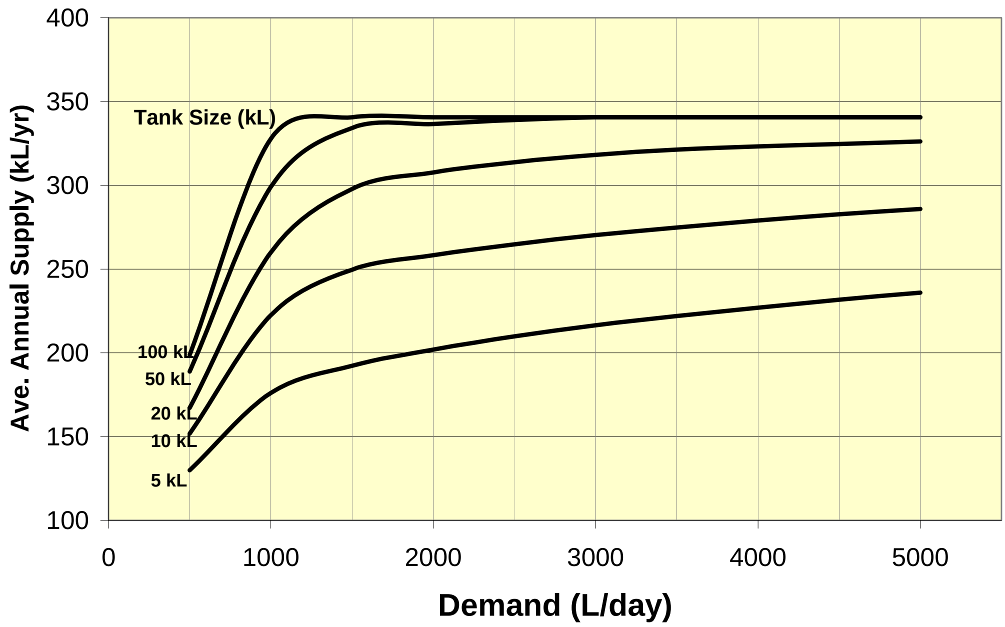
Roof area 200m² (Rainfall: 300-400 millimetres per annum)



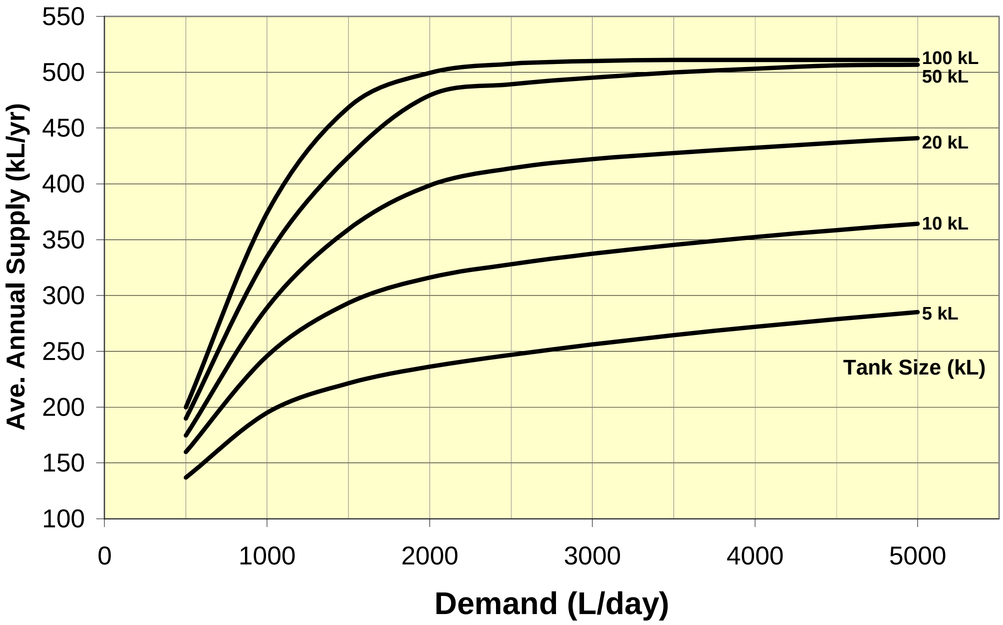
Roof area: 500m² (Rainfall: 300-400 millimetres per annum)



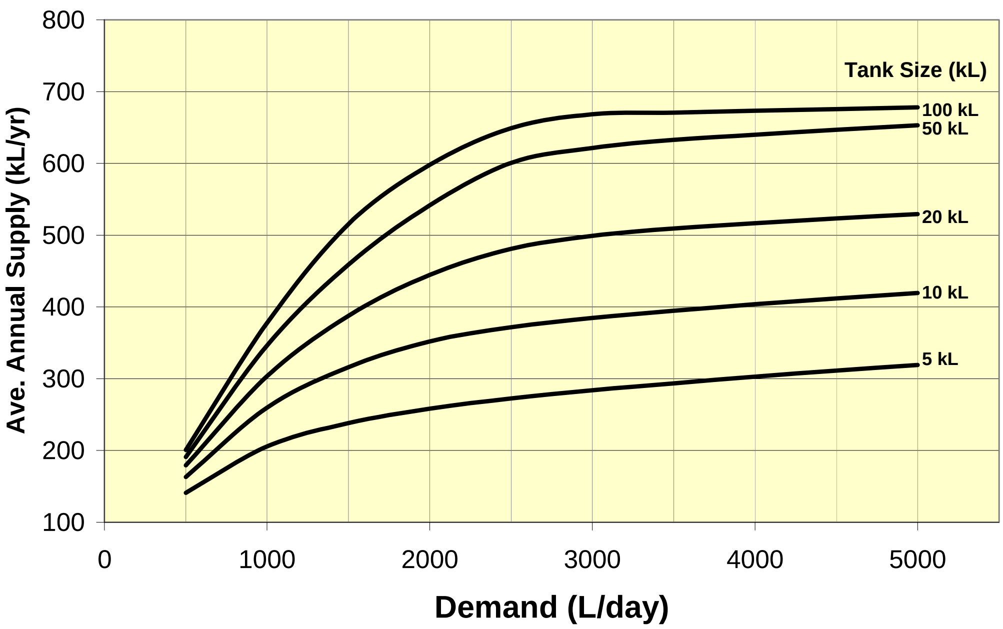
Roof area: 1000m² (Rainfall: 300-400 millimetres per annum)



Roof area: 1500m² (Rainfall: 300–400 millimetres per annum)



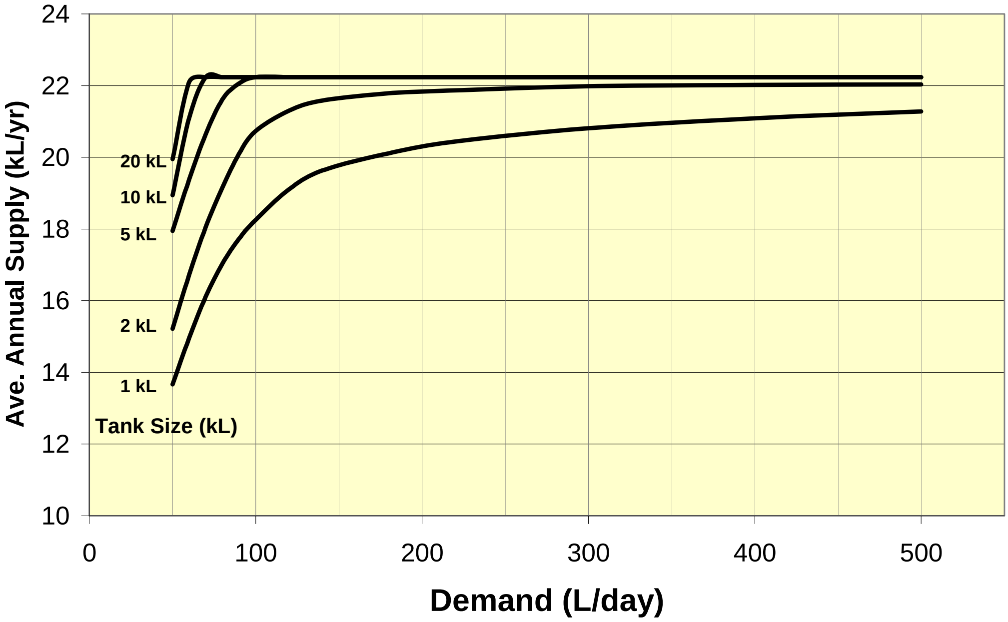
Roof area: 2000m² (Rainfall: 300-400 millimetres per annum)



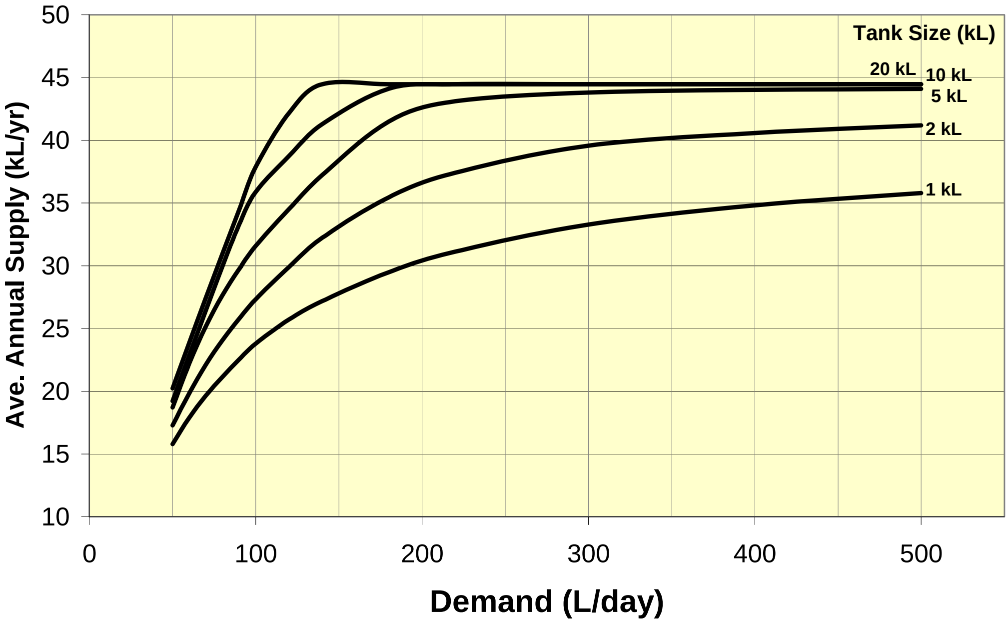
Curves for rainfall area of 400-500 millimetres per annum

Based on Adelaide Airport 6min rainfall data for 1996-2005. Average annual rainfall 445millemetres.

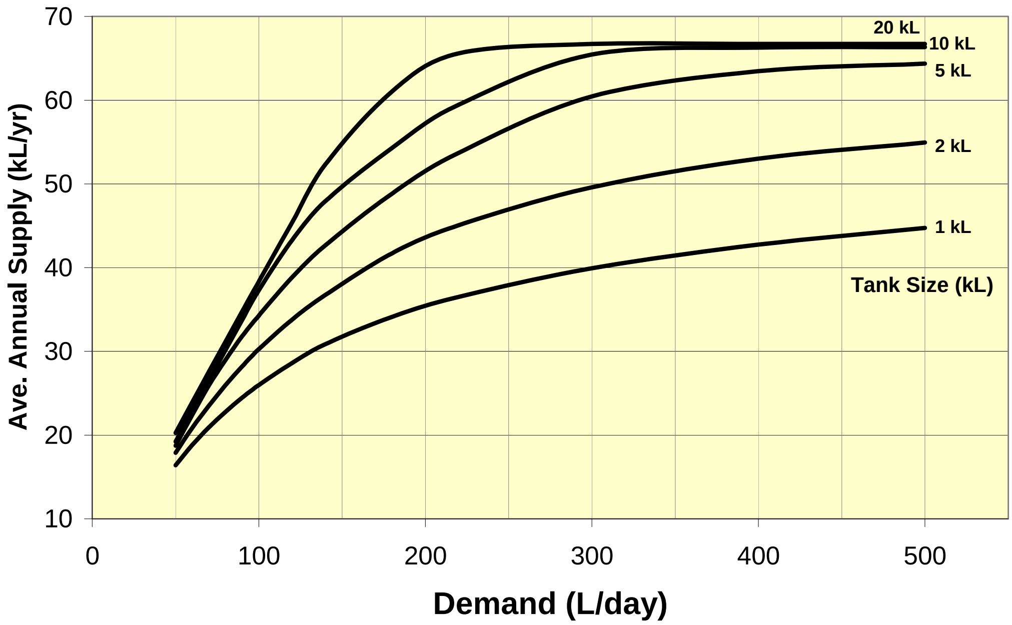
Roof area 50m² (Rainfall: 400-500 millimetres per annum)



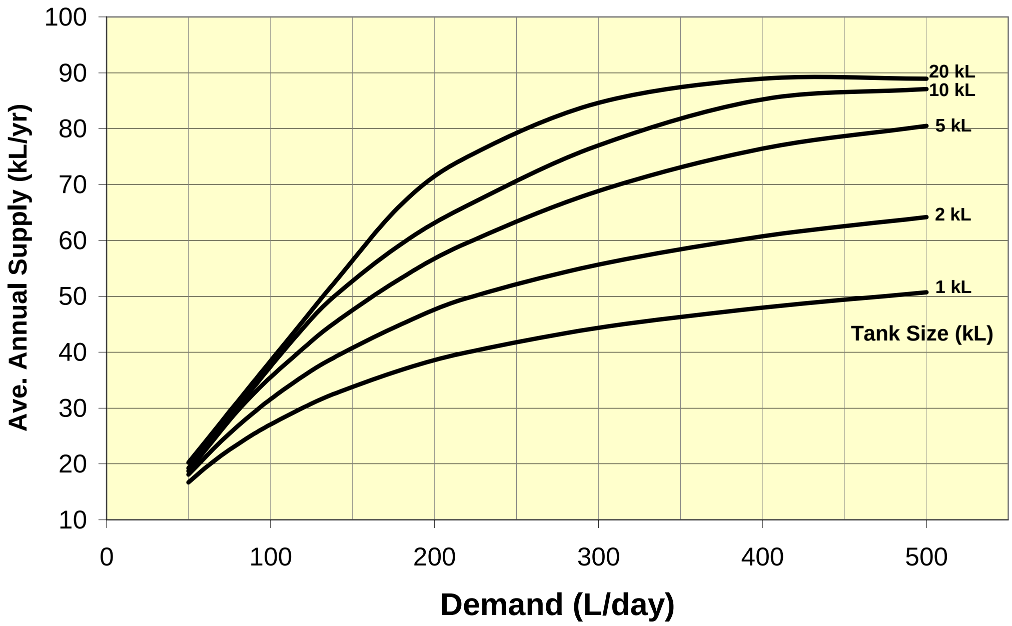
Roof area 100m² (Rainfall: 400-500 millimetres per annum)



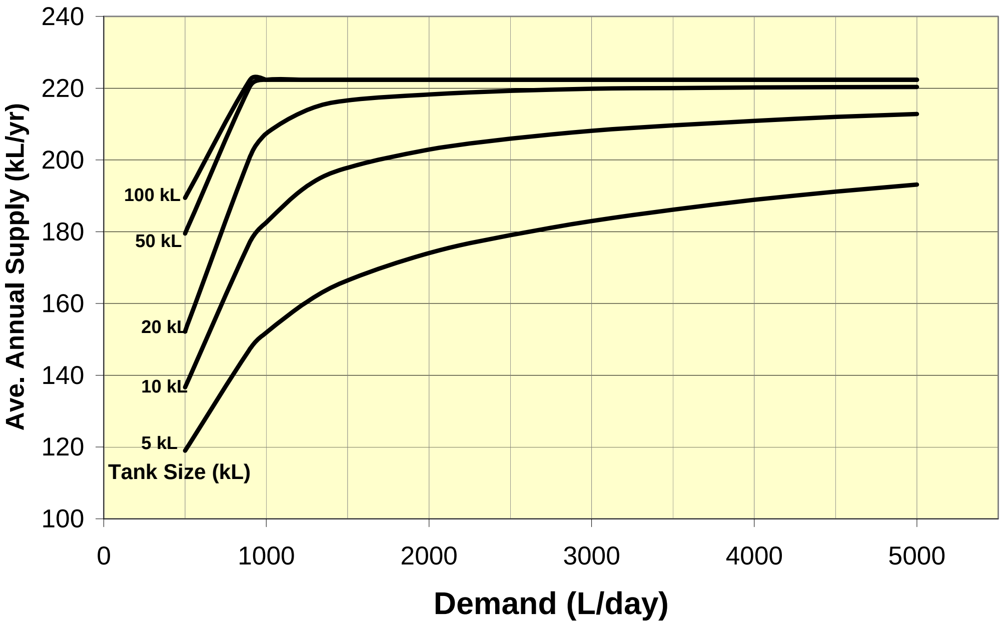
Roof area 150m² (Rainfall: 400-500 millimetres per annum)



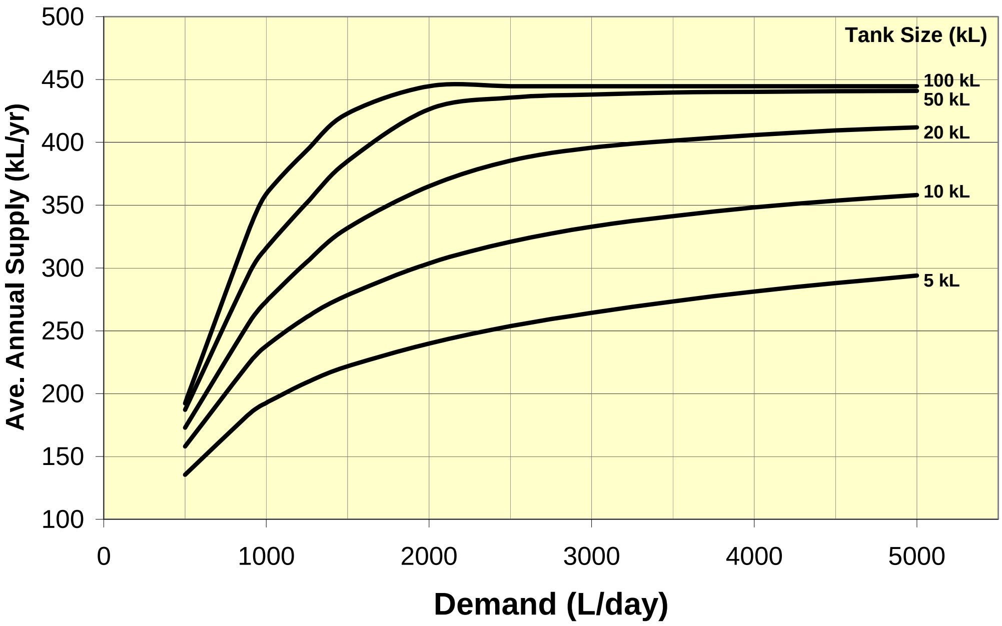
Roof area 200m² (Rainfall: 400-500 millimetres per annum)



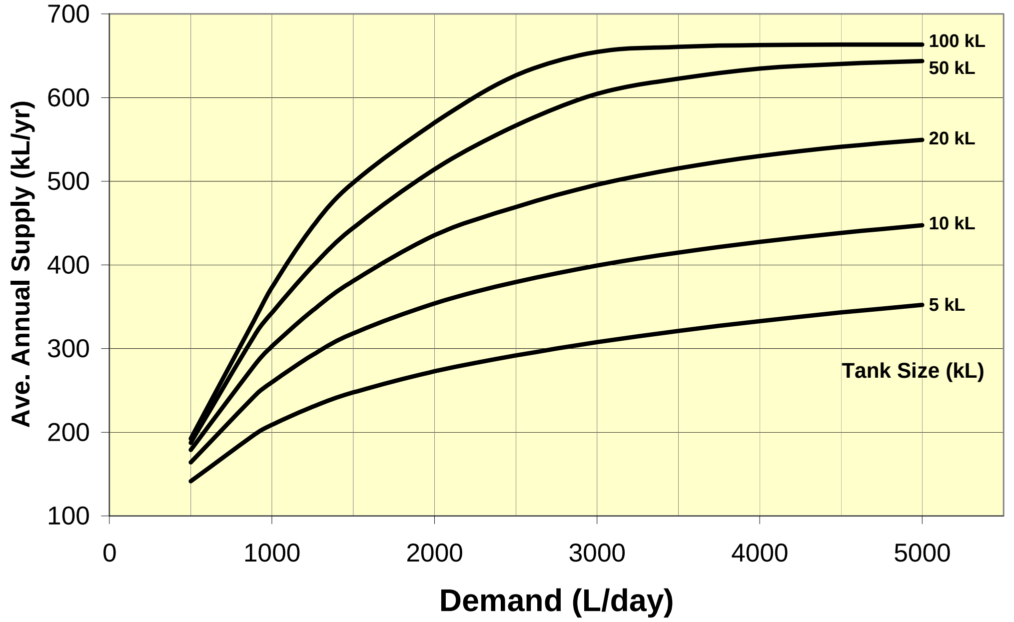
Roof area: 500m² (Rainfall: 400-500 millimetres per annum)



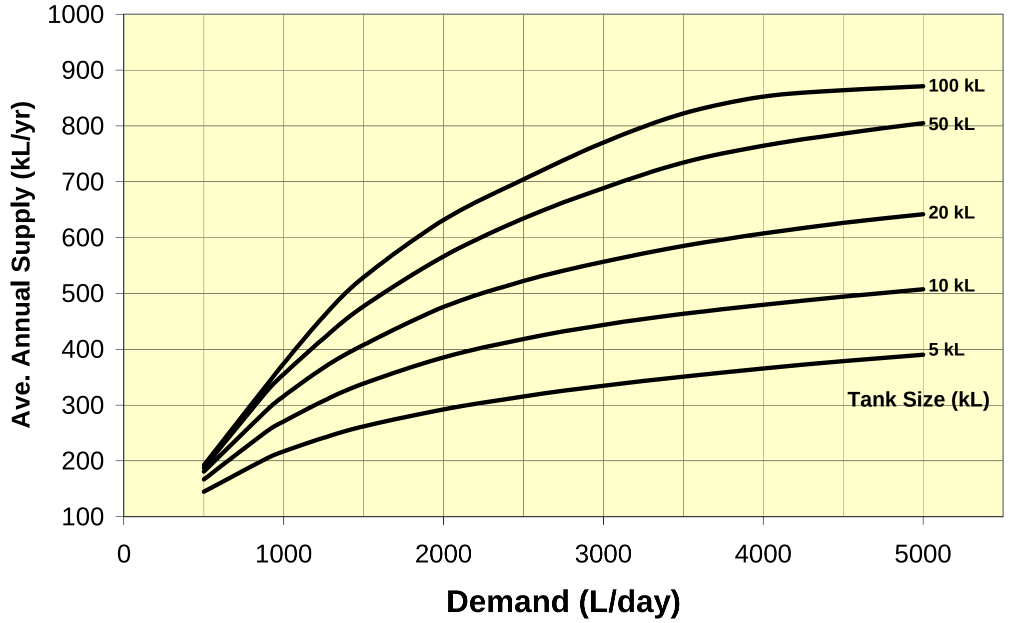
Roof area: 1000m² (Rainfall: 400-500 millimetres per annum)



Roof area: 1500m² (Rainfall: 400 – 500 millimetres per annum)



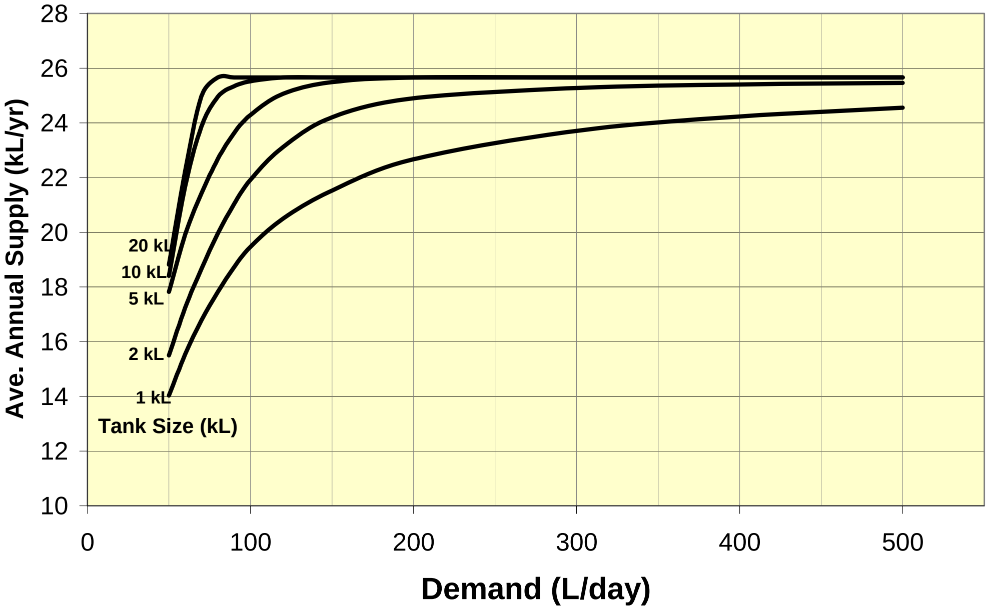
Roof area: 2000m² (Rainfall: 400-500 millimetres per annum)



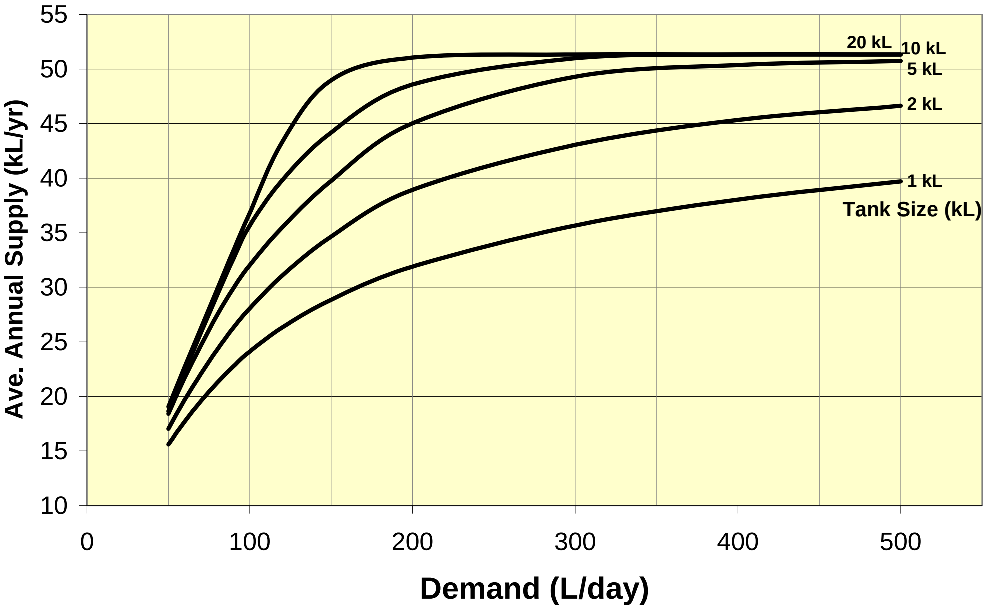
Curves for rainfall areas of 500-600millemetres per annum

Based on Kent Town 6min rainfall data for 1977-2002. Average annual rainfall 513 millimetres.

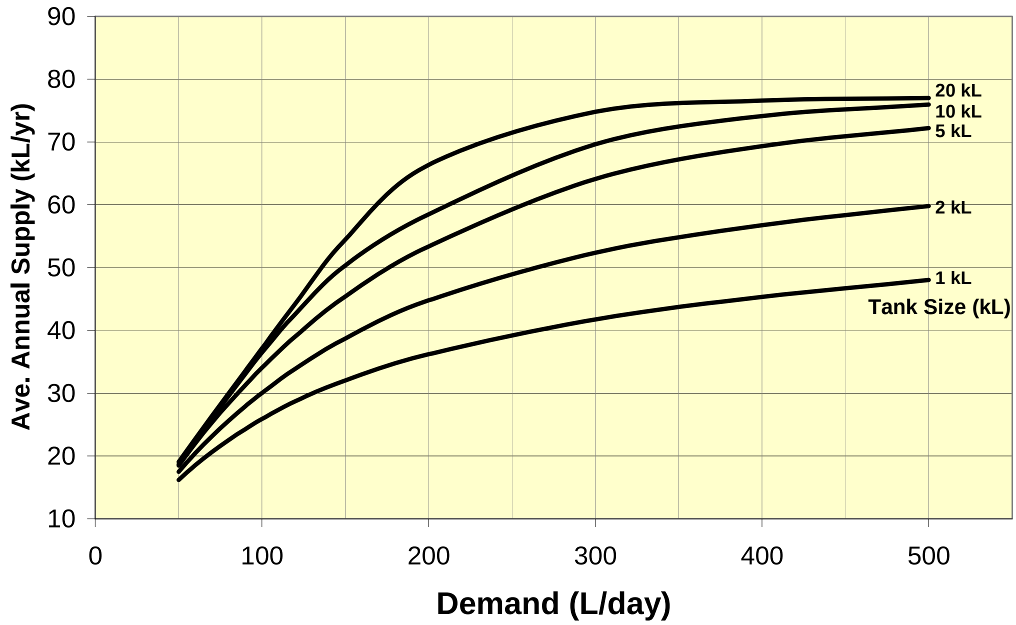
Roof area 50m² (Rainfall: 500-600 millimetres per annum)



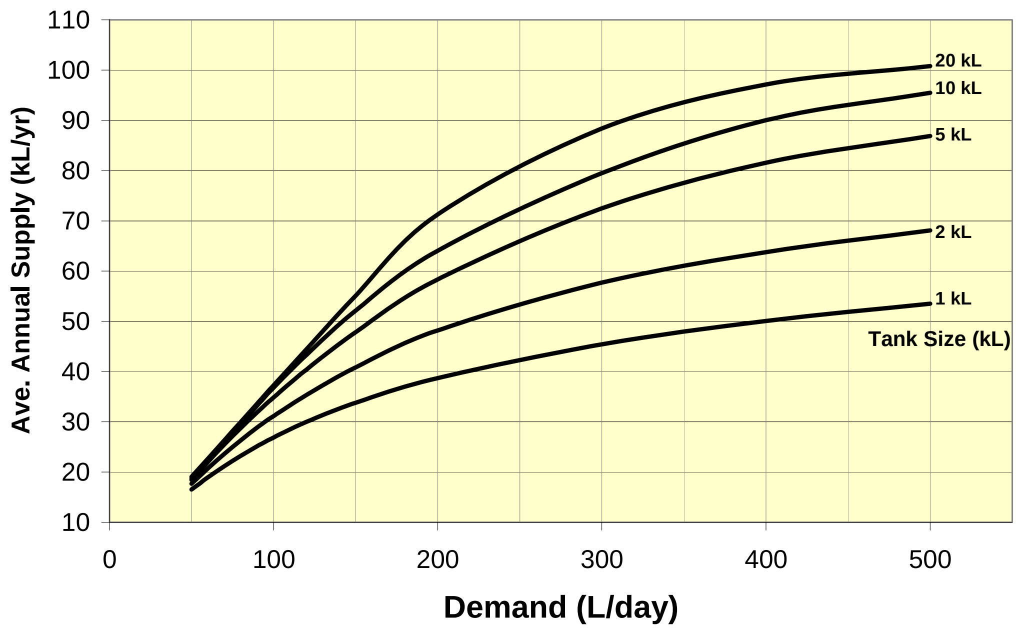
Roof area 100m² (Rainfall: 500-600 millimetres per annum)



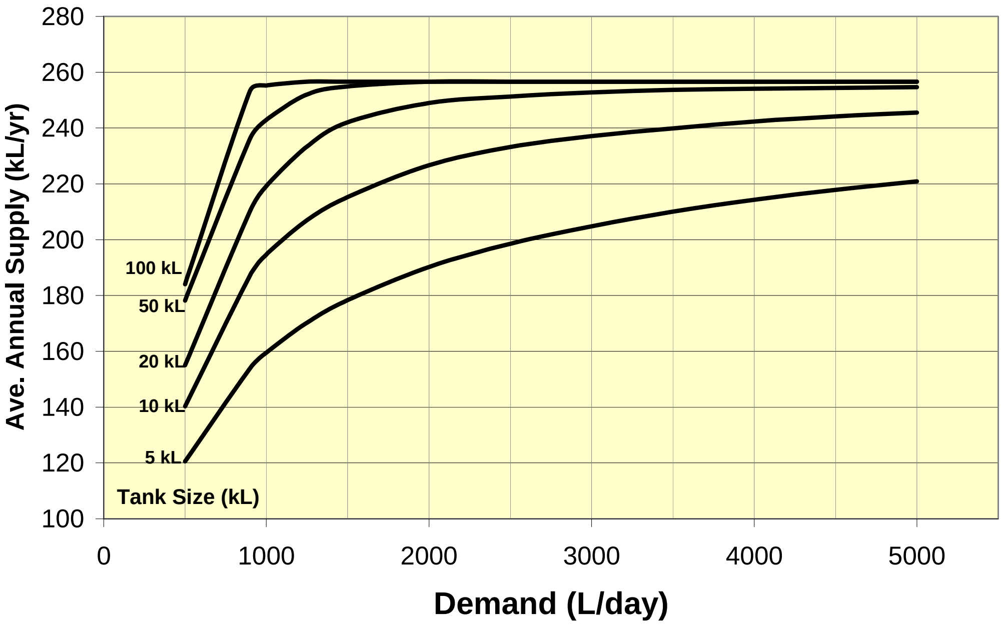
Roof area 150m² (Rainfall: 500-600 millimetres per annum)



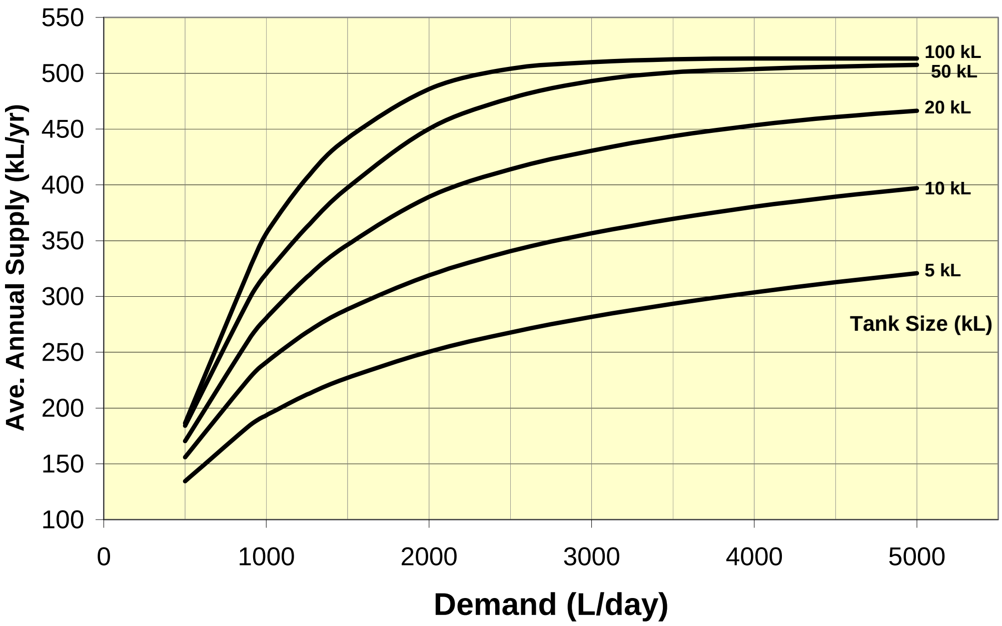
Roof area 200m² (Rainfall: 500-600 millimetres per annum)



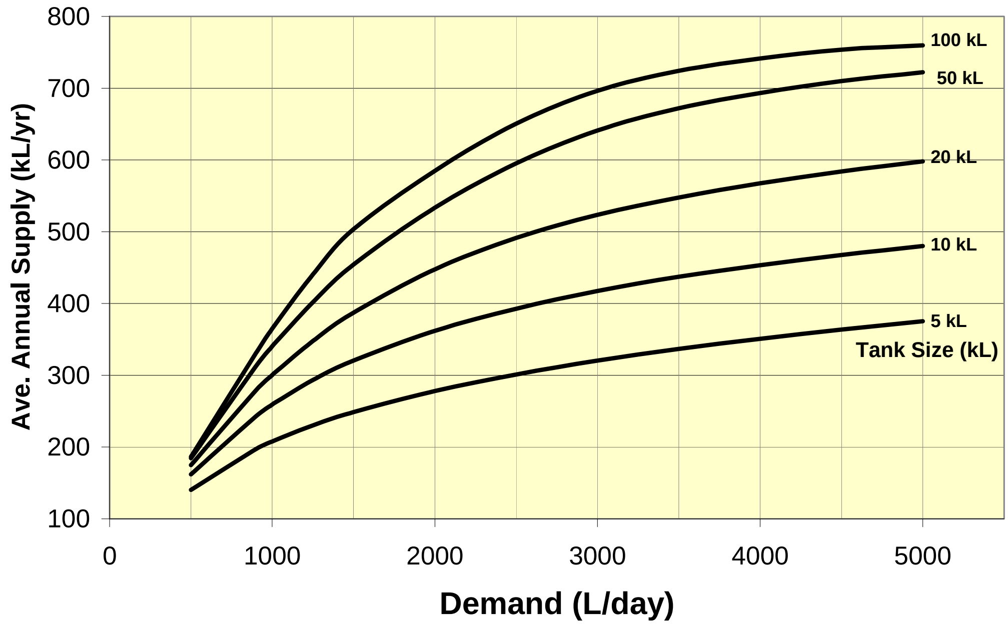
Roof area: 500m² (Rainfall: 500-600 millimetres per annum)



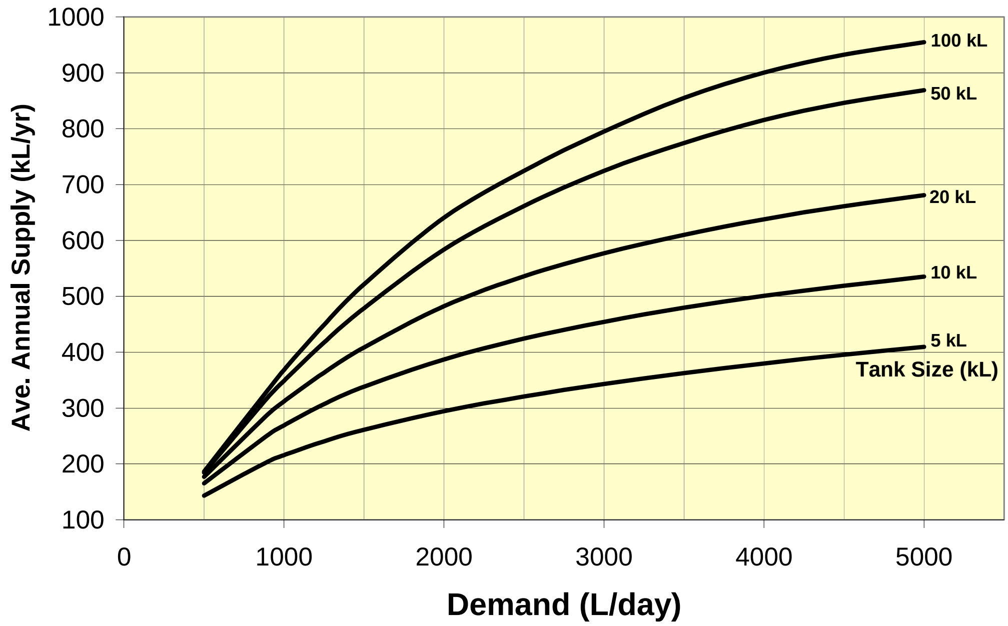
Roof area: 1000m² (Rainfall: 500-600 millimetres per annum)



Roof area: 1500m² (Rainfall: 500-600 millimetres per annum)



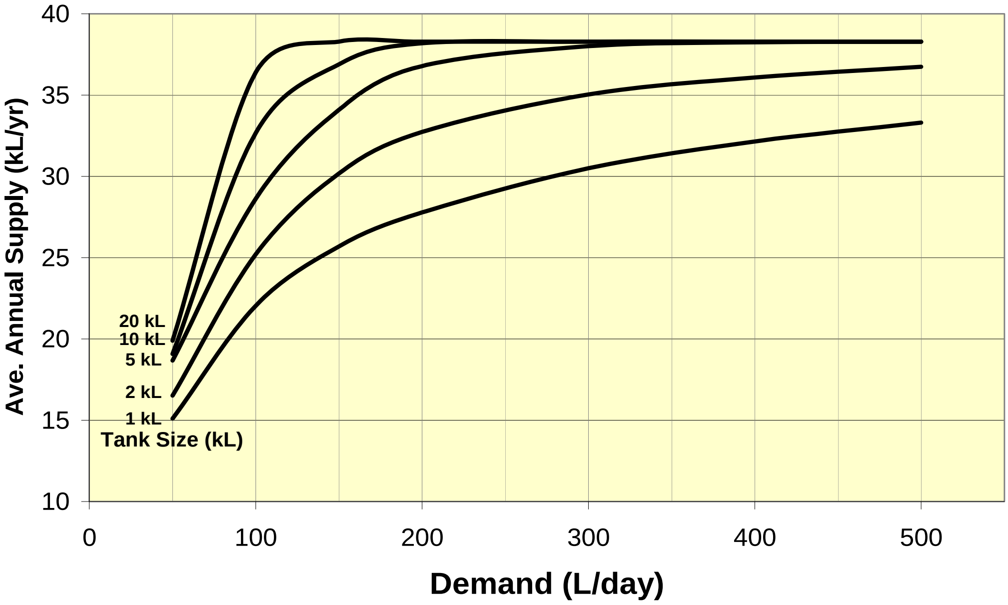
Roof area: 2000m² (Rainfall: 500-600 millimetres per annum)



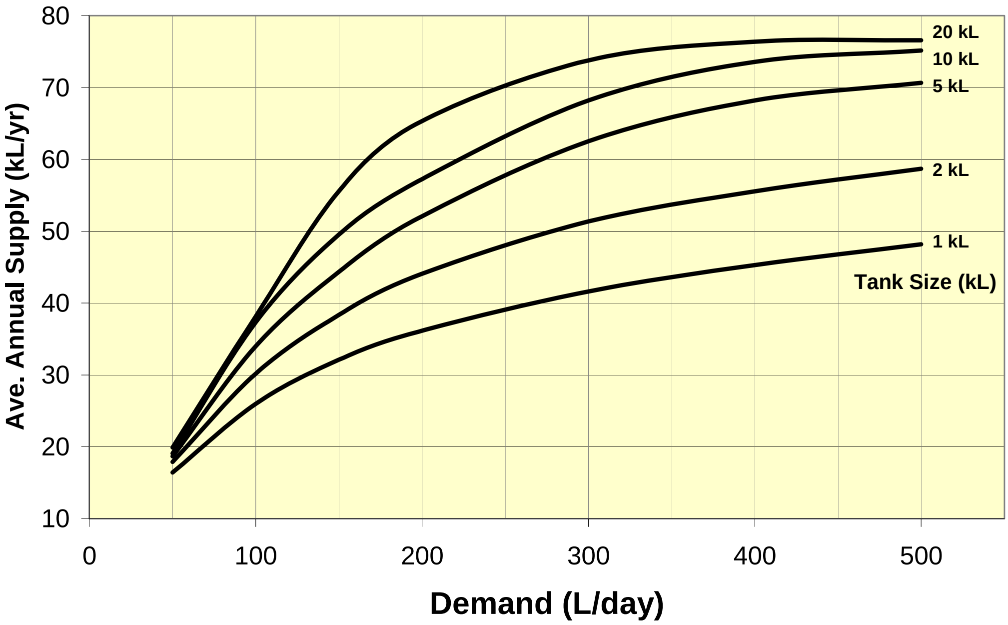
Curves for rainfall areas of 600-800 millimetres per annum

Based on Kersbrook 6min rainfall data for 1993-2005. Average annual rainfall 766 millimetres.

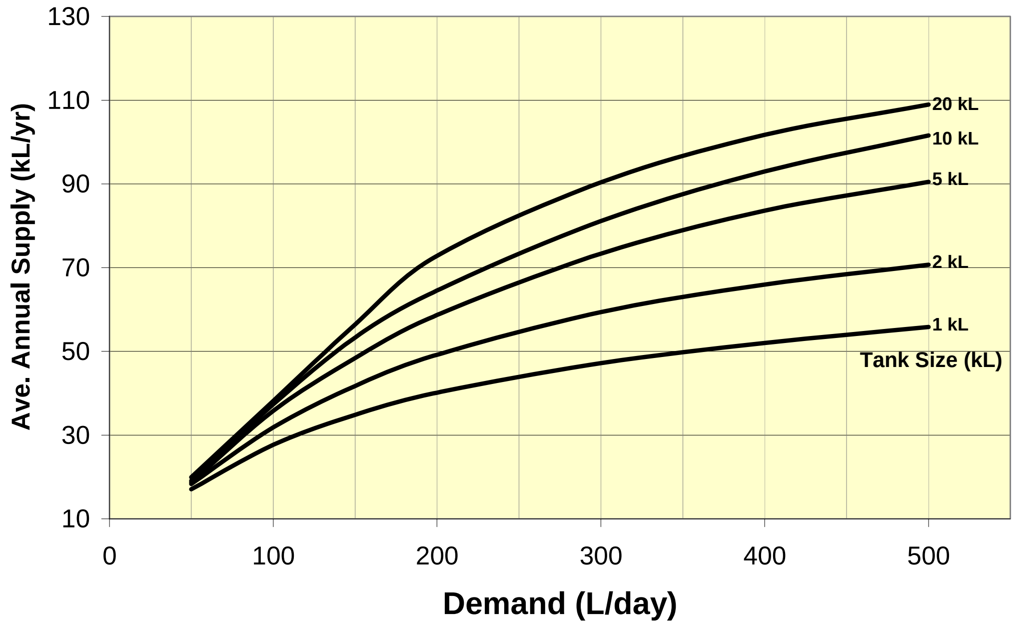
Roof area 50m² (Rainfall: 600-800 millimetres per annum)



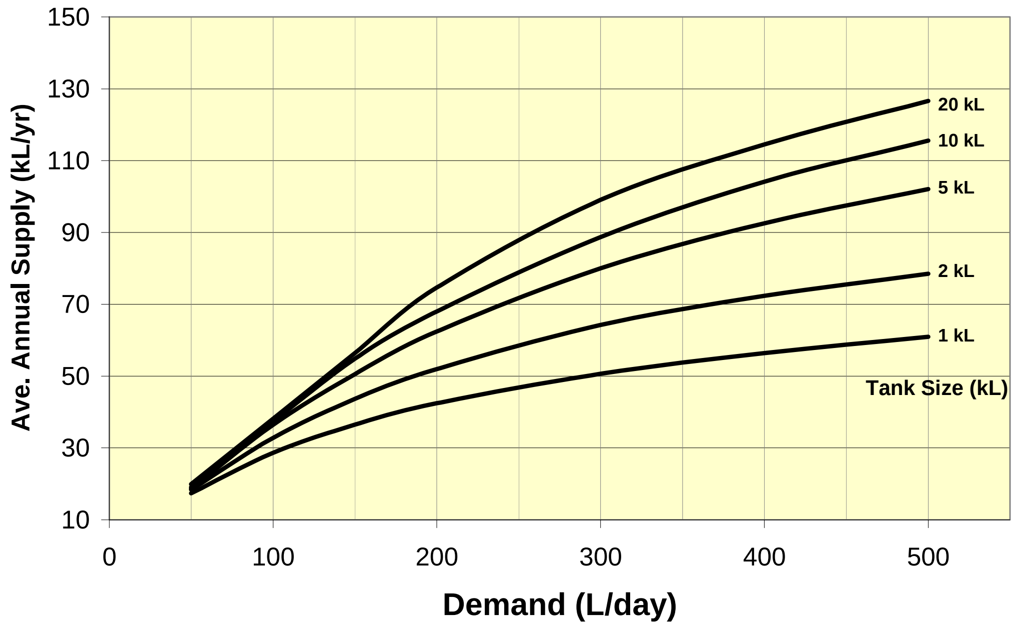
Roof area 100m² (Rainfall: 600-800 millimetres per annum)



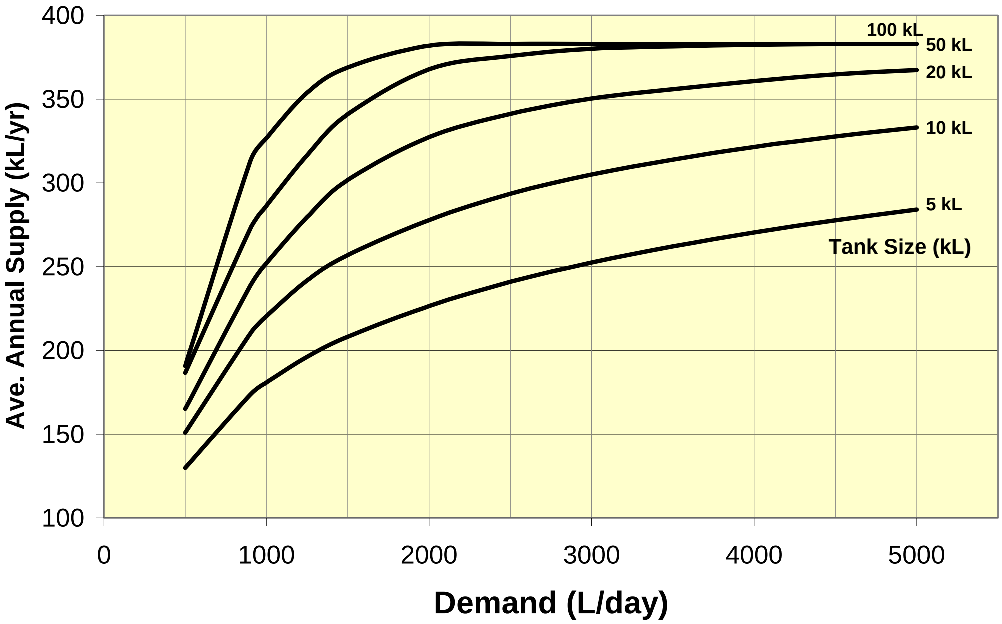
Roof area 150m² (Rainfall: 600-800 millimetres per annum)



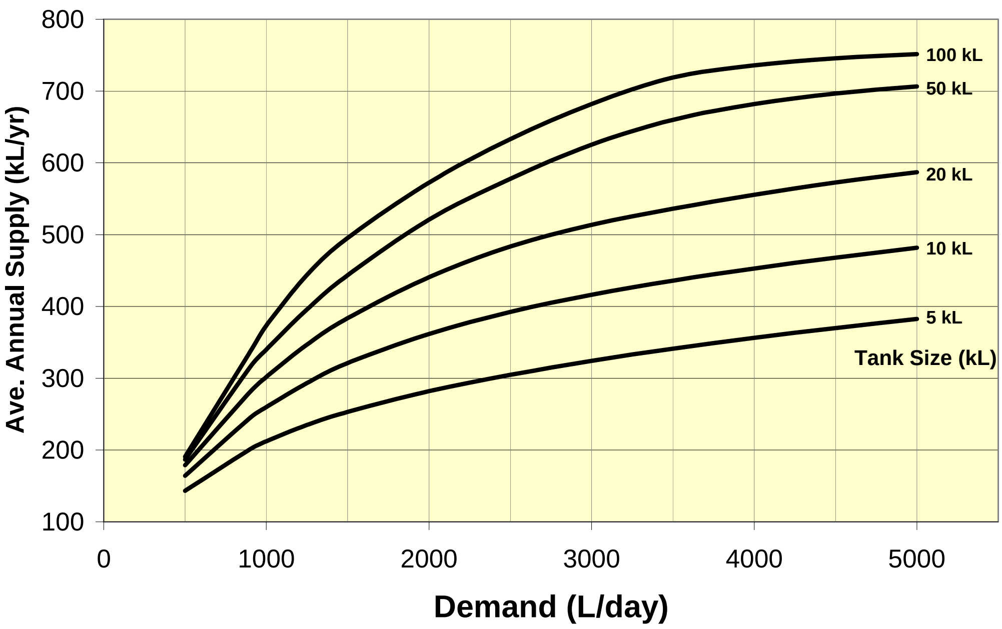
Roof area: 200m² (Rainfall: 600-800 millimetres per annum)



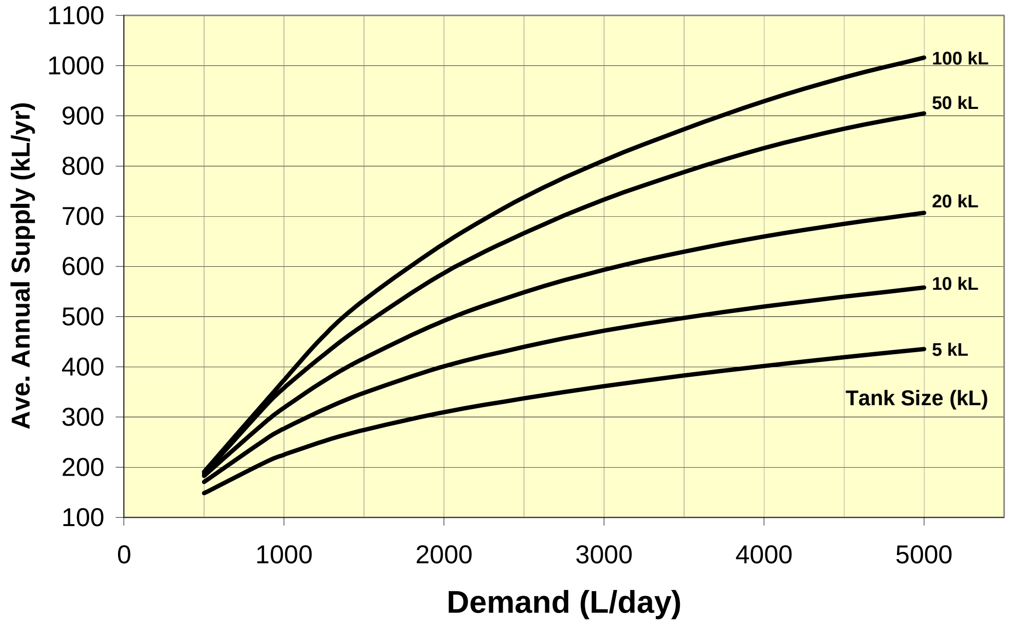
Roof area: 500m² (Rainfall: 700-800 millimetres per annum)



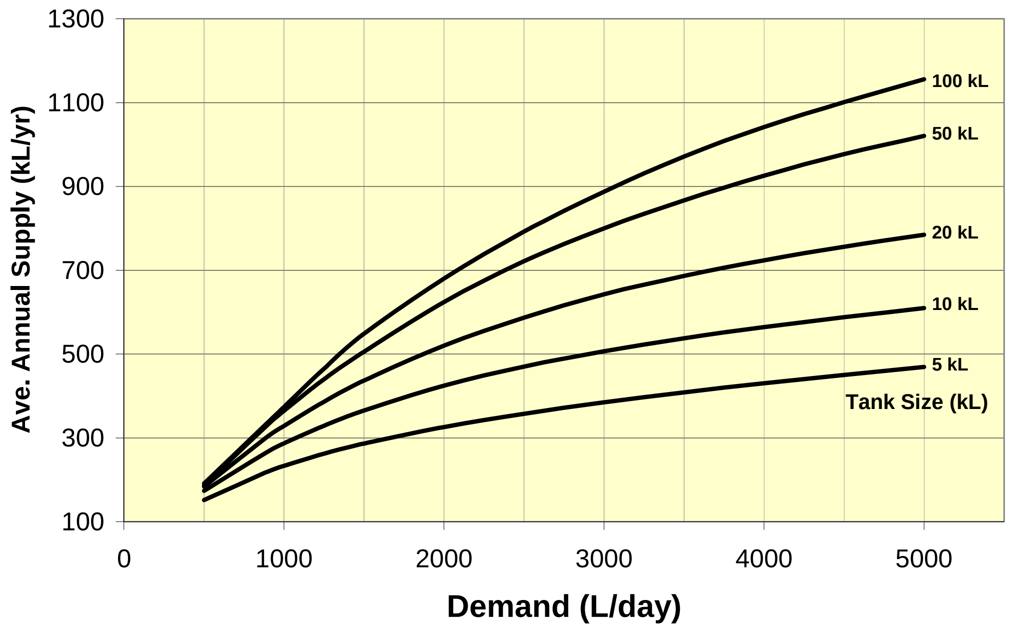
Roof area: 1000m² (Rainfall: 700-800 millimetres per annum)



Roof area: 1500m² (Rainfall: 700-800 millimetres per annum)



Roof area: 2000m² (Rainfall: 700-800 millimetres per annum)



Appendix B
Rainwater Tank Harvesting Case Study

Case Study

Task: Select appropriate rainwater tank size for a dwelling.

Details:

Location: West Beach.

Occupancy (normal): 4 persons.

Effective Roof Area: 200 square metres with one half connected via gravity system and the other half via a 'wet' system.

Demand: Inhouse demand only for laundry and toilet use.

Back Up Supply: Site has potable mains water supply.

Methodology (A): Using the Hydrological Type Curves

1. Determine average daily house demand from **Table B1** (see next page).

   For a dwelling with 4 persons daily demand for laundry and toilet is 100 and 145 litres/day respectively making a total daily demand of 245 litres/day or average annual demand of 89.4 kilolitres/year

2. Determine the average annual rainfall for the location.

   From **Figure A1** in **Appendix A** (the Average Rainfall Map) the map indicates an average annual rainfall of approximately 450 millimetres.

3. Determine the average annual yield.

   The appropriate yield curve graph for this case study is therefore the 400-500 millimetres/yr graph, with a roof area of 200 square metres. It can be seen in **Figure B1** that there are several tank size choices, as shown in **Table B2**.

   According to the yield results there is no obvious solution, however the result does show that all of the demand cannot be met in an average year and that there is a relatively small yield to storage benefit of going from a 5 kilolitre to the 10 or 20 kilolitre tanks. Selecting a tank size can sometimes be dictated by space limitations or cost and given that total demand can not be satisfied the selection can be subjective. On this basis, a 2 or 5 kilolitre tank would appear to be an appropriate size.

Table B1 Estimated Typical Household Water Demands (litres/day)

Water Use	Design Number of Occupants				
	1	2	3	4	5
Bathroom	65	107	145	189	223
Toilet	49	107	145	189	223
Laundry	38	54	100	137	174
Gardening	87	220	220	220	220
Kitchen	14	38	60	83	123
TOTAL	253	526	670	818	963

Source: Upper Parramatta River Catchment Trust (2004), Melbourne Water (2005)[1]

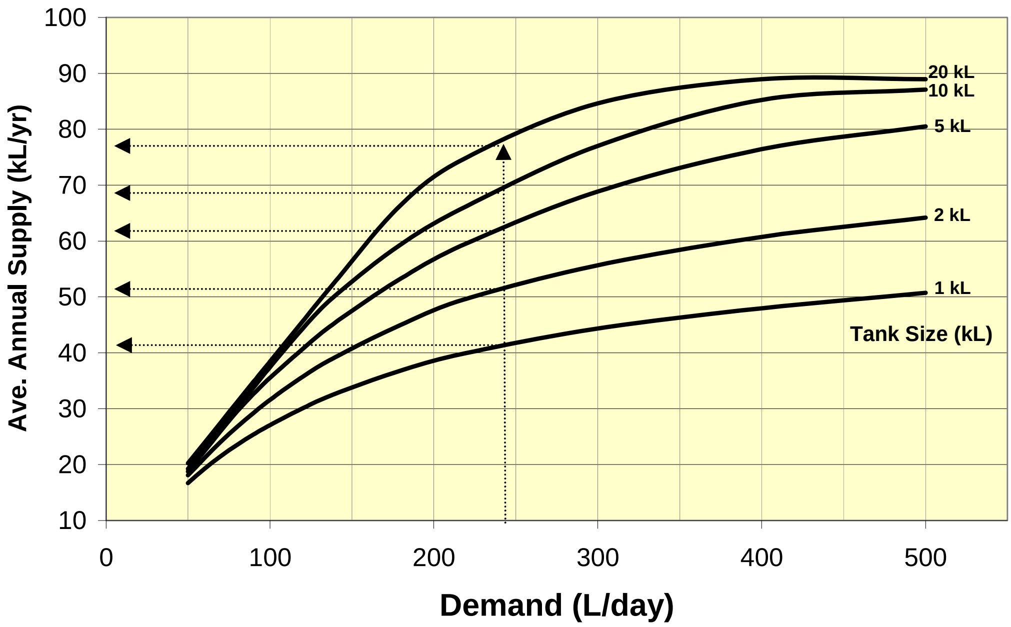


Figure B1 Yield Curves for Roof Area 200 square metres and Rainfall of 400-500 millimetres per annum

[1] Data from Melbourne Water has been used for the 1 person scenario and the remainder of information in the table is sourced from Upper Parramatta River Catchment Trust

Table B2 Yield Performance for Each Tank Size

Tank Size (kL)	Ave. Yield (kL/yr)	% of Demand Met by Rainwater Tank Water
1	42	47.0
2	52	58.2
5	63	70.5
10	69	77.2
20	8	87.2

Methodology (B): Using the Raintank Analyser

(www.unisa.edu.au/water/UWRG/publication/raintankanalyser.asp)

Using the Raintank Analyser program (see **Section 5.5**), additional variables can be considered and they include:

- Roof type and associated rainfall loss;
- First flush losses; and
- Irrigation demand.

The analyser provides additional outputs (see **Figures B3 and B4**) that allow the user to consider costs and security of supply (days without rainwater tank supply).

For this case study the program suggested a tank size based on decreasing and increasing benefit with respect to yield/storage characteristics. The tank size suggested in this case is approximately 5 kilolitres with a yield of 60 kilolitres/year. For this size tank the discounted cost of the water supplied is about $5.70 per kilolitre and the number of days without supply is 112.

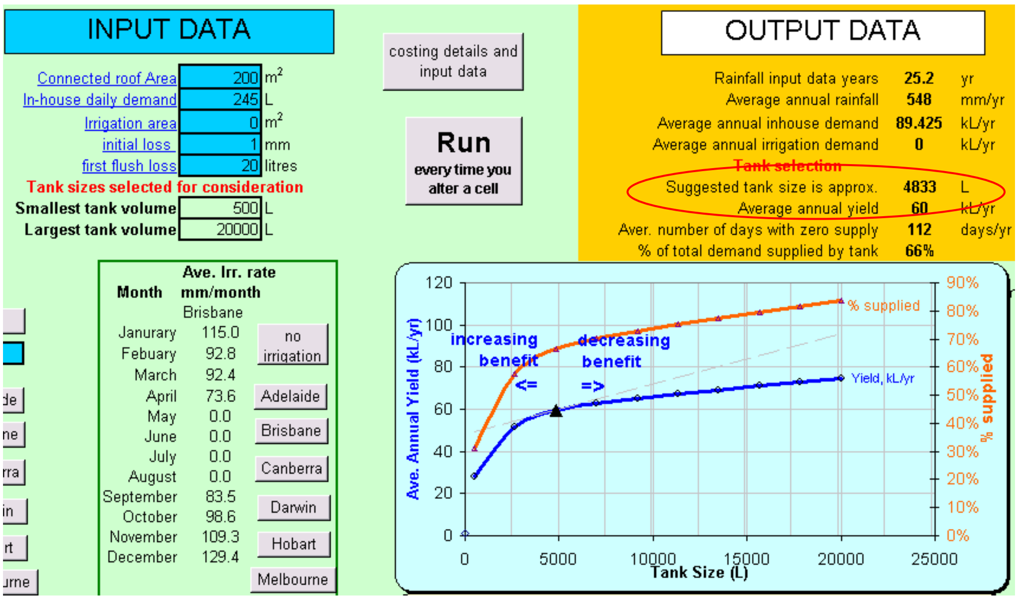


Figure B3 **Raintank Analyser Results**

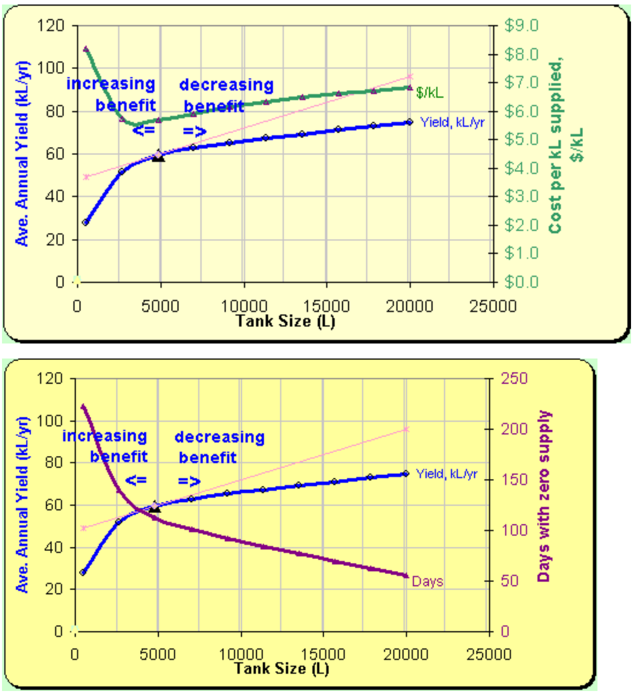


Figure B4 Raintank Analyser Results

Appendix C
Checklists

Rainwater Tanks

Design Assessment Checklist

Design Feature	Checked		Satisfactory	Unsatisfactory	Comments
1. Minimum rainwater tank efficiency	Y	N			
2. Design number of occupants	Y	N			
3. Demand use	Y	N			
4. Design demand	Y	N			
5. Roof catchment area	Y	N			
6. Rainwater tank capacity for reuse	Y	N			
7. Site storage requirement	Y	N			
8. Total rainwater tank volume	Y	N			
9. Overflow system	Y	N			
10. First flush device	Y	N			
11. Maintenance plan	Y	N			
12. Required approvals obtained	Y	N			

Source: Upper Parramatta River Catchment Trust (2004)

Rainwater Tanks

Maintenance and Inspection Checklist

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
	Y	N	Y	N	
First Flush Device/Pump					3 months
1. First flush device clear of debris and not blocked					
2. Remove acoustic cover from pump and clean in and around where leaf litter and dust can build up between the two					
Debris Cleanout					6 months
3. Inlet area clear of debris					
4. Overflow pipe clear of debris					
Inlet Screen					6 months
5. Leaves and debris on surface					
Roof Gutters/Tank Access					6 months
6. Leaves and debris in gutters					
7. Roof catchments clean and clear of moss and lichen					
8. Prune overhanging tree branches and foliage					
9. Check for evidence of animal, bird or insect access to tank, including larvae					
Sediment Level In Tank					2 years
10. Sediment level					
Tank Structure					2 years
11. Check for corrosion					
12. Check footings					

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
	Y	N	Y	N	
13. Check tank for defects (dints)					
Outlet Pipe					Annual
14. Pipe condition					
15. Evidence of blockage					
Below Ground Tanks					Annual
16. Back flow prevention valves checked by a licensed plumber					
Overflow Area					6 months
17. Area where overflow is directed is not showing signs of erosion					

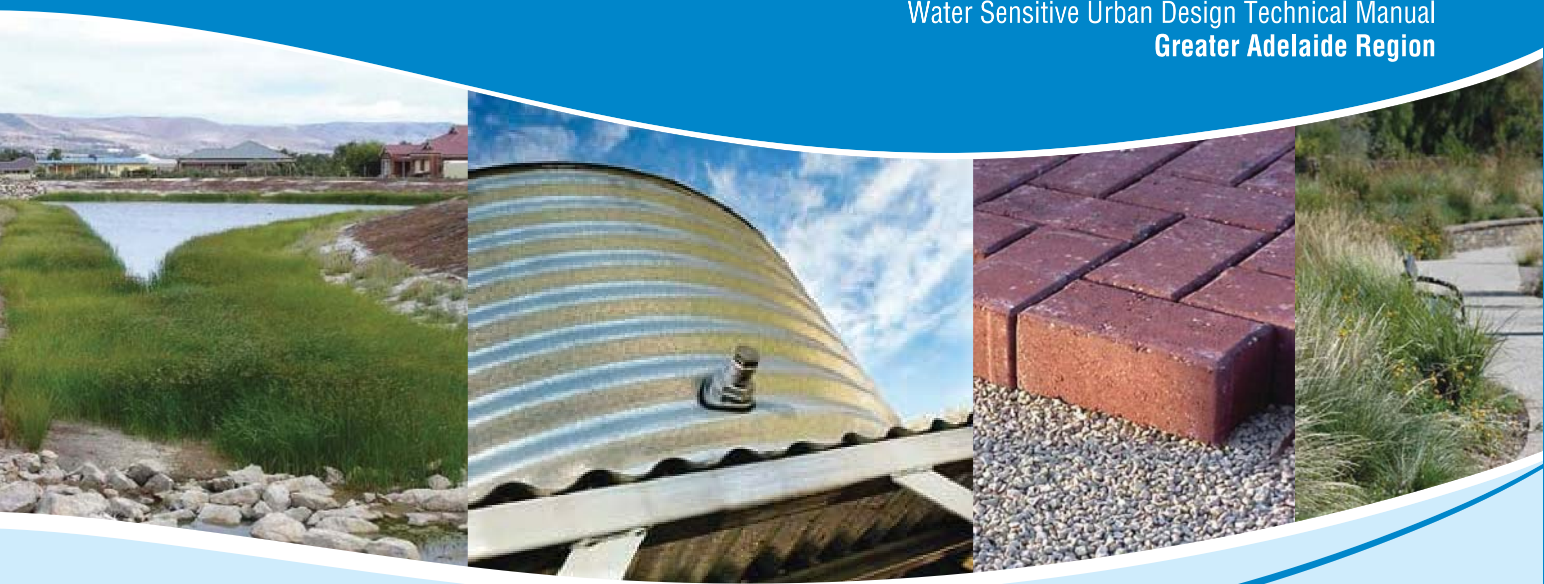
Source: Adapted from Upper Parramatta River Catchment Trust (2004) and Australian Rainwater Industry Development Group (2007)

July 2009

Chapter 6

Rain Gardens,Green Roofs and Infiltration Systems

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Appendix A Annual Rainfall in the Greater Adelaide Region

Appendix B Hydrological Effectiveness Curves for the Greater Adelaide Region

Appendix C Example of Utilising the Hydrological Effectiveness Curves to Design a Rain Garden

Appendix D Infiltration System Maintenance and Inspection Checklist

Chapter 6
Rain Gardens, Green Roofs and Infiltration Systems

6.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment).

Source control is one of the most effective ways of managing runoff in an urban catchment. Managing runoff at the source provides more opportunities to achieve a hydrological cycle that is closer to the pre-development (natural) regime.

WSUD measures that can be implemented at the site level include:

- Rain gardens;
- Green roofs; and
- Infiltration systems.

The purpose of this chapter of the WSUD Technical Manual for the Greater Adelaide Region is to provide an overview of these three measures, which each have the ability to intercept runoff, treat it and promote infiltration.

Rain gardens and green roofs are both vegetated WSUD systems. A particular challenge in Adelaide is to provide sufficient water to maintain the vegetation during the long interstorm dry periods commonly experienced in South Australia. In summer, in particular, the vegetation not only suffers from water shortage but often heat stress as well. Chapter 10 describes how to incorporate design features into vegetated streetscape WSUD systems to ameliorate these effects. For lot-scale vegetated WSUD systems, such as raingardens and green roofs, there is often less space available in which to incorporate significant storage volumes.

6.2 Legislative Requirements and Approvals

A thorough investigation of required permits and approvals should be undertaken as part of the conceptual design of any rain garden, green roof or infiltration system.

Consideration also needs to be given to what, if any, risks and/or financial obligations would be transferred to council if it operates the scheme (e.g. operations, maintenance, monitoring and reporting costs).

A proposed rain garden, green roof or infiltration system needs to meet the requirements of the following legislation:

- *Development Act 1993*;
- *Environment Protection Act 1993*;
- *Natural Resources Management Act 2004*;
- *Local Government Act 1999*; and
- *Public and Environmental Health Act 1987*.

Further information regarding legislative requirements and approvals should be sought from your local council.

6.3 Rain Gardens

Description

Rain gardens are shallow planted depressions designed to take the excess rainwater runoff from a house roof or other building, assisting runoff to infiltrate the underlying soil, recharge the groundwater, and reduce peak flows from the site. The rain garden concept can be expanded to incorporate an entire garden or a city streetscape, but of particular interest is its small scale application in the domestic, commercial and industrial garden, where there is potential for a very significant impact on runoff management at the source.

Rain gardens are different to other bioretention systems in that they allow the water to infiltrate the underlying soil to recharge the groundwater.

Rain gardens are typically planted with native plants or sustainable species that are adapted to local climate conditions. Rain gardens are an example of WSUD that can be easily integrated into the landscape to achieve an attractive low maintenance solution.

Purpose

Rain gardens use the technique of retaining runoff for infiltration back into the soil. Through the chemical, biological and physical properties of plants, microbes and soil, the water is filtered before it enters the groundwater, with some degree of pollutant removal occurring.

In addition to retaining and filtering water on site, rain gardens have a number of other attractive benefits for the garden. The promotion of more planting rather than paved surfaces increases the proportion of pervious areas in the built environment. Biodiversity is increased as habitat opportunities are increased for small animals, birds and insects. Rain gardens also provide visual interest through the introduction of ephemeral water features into the garden. The cooling effect of this water can improve the microclimate of the whole garden.

The main functions of rain gardens are water quality control, water conservation and increased amenity. They provide limited flood control, mainly because of their small volume. The low voids ratios of soils used in these systems (a typical value is 0.2) and their limited infiltration rates (typically 150 to 350 millimetres/hour) limits their potential to provide flood control. An approximation of the available flood storage volume is a combination of 20% of the soil volume plus the above lying water ponding volume, although in practice the available soil storage is unlikely to be fully utilised during a high intensity storm event.

Where both the minor and major flood flows must be conveyed over the rain garden surface, velocities should be kept preferably below 0.5 metres/second to avoid scour.

Application / Scale

Rain gardens are a measure that may be implemented at a variety of scales, from domestic through to commercial and industrial sites.

Rain gardens are an especially useful tool that can be implemented and managed by homeowners. Their simplicity and low maintenance functioning, once established, make them an inexpensive WSUD measure applied at the domestic level.

Design Considerations

The following sections provide an overview of the key design issues that must be considered when conceptualising and designing a rain garden.

Plant Species

A wide range of plants are suitable for rain gardens, in particular many local native species. Professional advice should be sourced either from a landscape architect or qualified horticulturalist to provide guidance on the design and installation of appropriate plants for the Greater Adelaide Region.

The following points should be followed when choosing plants for a rain garden:

- In Adelaide plant species can be subjected to periods of inundation followed by longer dry periods;
- Plants should be chosen that naturally occur in wetlands or soaks, such as the sedge and rush families. These species will assist in biological treatment performance, improve the soil structure, and promote good surface and subsurface infiltration properties;
- Perennial rather than annual species are most effective in a rain garden; and
- Plants with deep fibrous root systems promote infiltration but have the potential, if planted extremely close to buildings, to affect the building. Only low shrub and groundcover plantings are recommended.

Since Adelaide has a modified Mediterranean climate with long periods of dry weather in summer and a significant wet weather period in winter it is important to recognise that plants need to be able to withstand this extreme seasonal rainfall condition. Some internet resources regarding plant species selection may not be appropriate for the climate conditions in Adelaide. Appropriate resources include:

- SA Water, Tune Your Garden to Our Climate:

  www.sawater.com.au/NR/rdonlyres/90B3E7E2-A938-4291-A443-8ADC2BAFD364/0/Tuneyourgarden.pdf

- Adelaide Botanic Gardens – Relevant information can be found at links to the SA Water Mediterranean Garden and the Sustainable Landscapes Project. These contain advice on appropriate plants in the Adelaide region:

  www.environment.sa.gov.au/botanicgardens/adelaide.html

Mosquitoes

The concept of rain gardens is to collect and infiltrate the water into the soil as quickly as possible as in the pre-development landscape and not to encourage a semi permanent water body. To prevent breeding of mosquitoes, ensure ponding of water in the garden is limited to no longer than four days. This can be achieved in a number of ways:

- Soils should be selected such that they have an adequate hydraulic conductivity – greater than $1x10^{-6}$ metre/second or matched to the maximum design pond depth to suit the infiltration properties of the soil; and
- Provide overflow piping to reduce excessive ponding in high runoff events.

Minor and Major Rain Events

It is possible to design rain gardens to manage minor and major rain events. The most important drainage element is the overflow path, which allows flows (greater than garden capacity) to be conveyed further along the stormwater runoff management chain.

Infrastructure

Depending on soil types, especially heavy clay soils, excessive wetting and drying cycles associated with rain gardens may cause the soil to expand and contract, as it did in pre-development conditions. Significant soil movement can result in damage to buildings and nearby subsoil infrastructure; therefore the location of the rain garden in heavy soil type areas is important.

If space is a constraint it is possible to place an impermeable liner between the building structure and the rain garden. The liner/water barrier would need to extend into the soil twice the depth of the rain garden, or a minimum of 1 metre. This acts as a bond breaker between the footing and soil movement.

Where infiltration to the native soil is not required, an impermeable liner can be placed beneath the rain garden base and side. This will not be a rain garden but will become a micro wetland or a bioretention system that is connected to the stormwater chain.

Design Process

The key elements of the design process for rain gardens are outlined below.

Design Objectives and Targets

The implementation of WSUD in a development seeks to achieve a range of outcomes relating to water quality, hydrology, conservation and amenity. Design objectives and targets should be determined before the design process commences. **Chapter 3** of the Technical Manual provides guidance on setting objectives and targets.

Selection of a Location

Areas of the property should be identified where rainwater runs from downpipes or from paved areas. Runoff from these areas represents potential sources of water for a rain garden.

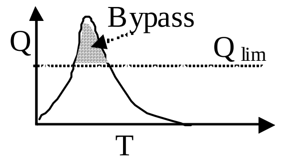
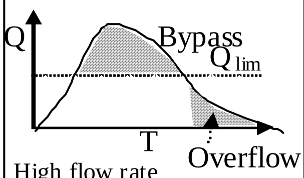
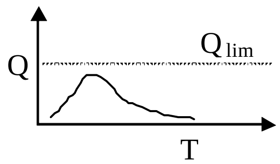
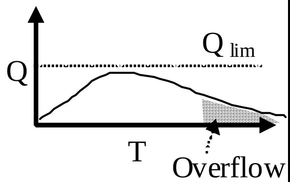
The size of a rain garden will depend on the amount of runoff it receives. For a typical downpipe, 1 or 2 square metres should be enough garden area at the domestic scale (Melbourne Water, 2007). A design for larger gardens may want to consider referring to the size requirements for a bioretention system (refer to **Chapter 10** – Bioretention Systems for Streetscapes).

Gardens may also collect water from driveways, roadways or carparks. This is accomplished using downpipes, or graded kerbs with cutaways.

Design Approach

Many rain gardens are designed without any specific hydraulic capacity but rather to integrate into the landscape design or the space available. This approach is acceptable provided that adequate overflow piping or overland flow is designed into the system. However, a detailed design approach is often required to calculate the required areas for the garden. If this is the case then the hydrological effectiveness curve approach to design may be applied to rain gardens.

The performance of storage systems with a discharge (infiltration or via pipe) can be described (quantified) in terms of hydrological effectiveness, which takes account of EIA (equivalent impervious catchment area), historical rainfall series, storage, infiltration (outflow), bypass and overflow, as illustrated in Figure 6.1.

Runoff event type	Loss mode: bypass and/or overflow
 High flow rate Low runoff volume	**BYPASS and NO OVERFLOW***
 High flow rate High runoff volume	**BYPASS and OVERFLOW ****
 Low flow rate Low runoff volume	**NO BYPASS and NO OVERFLOW ***
 Low flow rate High runoff volume	**NO BYPASS and** *OVERFLOW***

R = unshaded area in Figure 6.1 hydrographs/area under each hydrograph expressed as a percentage

Note: Hydrological Effectiveness is identical to the term Retention Efficiency, R used in Argue (Ed., 2009).

Figure 6.1: Hydrological event processes

Equivalent impervious area, A_{EIA} for systems discussed involves use of runoff coefficients that are significantly less than those used to determine this parameter in flood control design. The reason for this is the high proportion of small runoff events – incorporating greater (relative) losses – that provide the database of these systems. A_{EIA} should therefore be calculated for use in the hydrological effectiveness graphs applying a factor of 0.83 to the conventional C_{10} values in flood control practice.

It is possible, using sets of hydrological effectiveness curves, to determine the storage requirement or discharge rate necessary to achieve a target efficiency for particular circumstances. Storage requirement is expressed in terms of mean annual runoff volume (% MARV); discharge refers to the flow rate leaving the device whether it be through, for example, infiltration or slow drainage to an aquifer, or a combination of both. Each set of hydrological effectiveness curves takes account of all independent variables, as explained above. Therefore, a unit discharge rate, q, is introduced as a function of flow rate leaving the device and effective impervious area (EIA).

Most of the curves are based on simulation using more than 20 years of historical rainfall series at 6 minute intervals. The following assumptions were made:

- Equivalent impervious catchment area, A_{EIA} is determined, incorporating an appropriate volumetric runoff coefficient;
- All runoff is directed to storage and the facility excludes a bypass passage;
- Overflow occurs when the storage component fills; and
- Infiltration rate (or supply to harvesting systems) is considered to be constant throughout the period of storage.

An example of the utilisation of the hydrological effectiveness curves for the design of a rain garden is contained in **Appendix C**.

Construction Process

The following is a guide to implementing rain gardens on a domestic, commercial or industrial property. It is important to ensure that, where noted in this procedure, a licensed tradesperson is engaged to connect overflow pipes to the site stormwater drainage system.

Excavation

The area of the rain garden should be excavated as a shallow basin to a depth of about 40-80 centimetres into the soil. It is important to ensure this basin has a gentle slope away from any adjacent building, toward the bottom of the garden.

To prevent the transport of water toward building foundations, a root and water barrier sheet of waterproof material is placed in a trench between the rain garden and adjacent buildings.

Water Supply

Conventional runoff disposal systems will have to be arranged to supply the rain garden.

Where downpipes are used, water can be redirected to a rain garden using a flow distributor attached to the end of the downpipe, or through a shallow trench or pipe attached to the end of the downpipe. It is important to ensure that the pipe has a flow spreading mechanism to prevent scouring at the point where it delivers water to the garden. Alternatively, rocks can be embedded near the inflow point to dissipate the energy of the high velocity discharges entering the garden.

Where water is sourced from hard standing surfaces, scouring may still represent a problem and should be discouraged with flow spreading mechanisms in cutaway sections allowing for the entry of runoff. This may be achieved using simple techniques like roughened surfaces on the cutaway.

Pipework will also be required to collect the overflow or excess runoff that occurs in heavy storms and long periods of rainfall.

A vertical standpipe should be installed at the bottom end of the garden which will intersect with the piping that is connected to the conventional stormwater disposal pipe.

It is important to note that the services of a licensed plumber are required to connect this standpipe to the stormwater pipe.

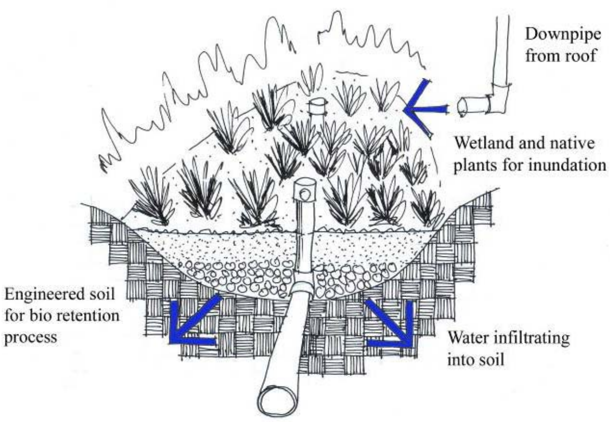


Figure 6.2 Typical Rain Garden Drainage Arrangement

Source: Fifth Creek Studio

Soil Medium Layers

There are several options for the construction of rain gardens. The most important aspect is the use of a soil with adequate drainage qualities.

Firstly, a layer of gravel should be laid into the base surrounding the overflow connecting pipe.

The rest of the garden can be filled with layers of well draining sandy soil (given the recommended infiltration rate). Local landscape suppliers may be able to assist in the choice of an appropriate soil mix (given the infiltration rate) for the planted section of the garden.

It is recommended to leave a 10-15 centimetre shallow depression at the surface of the rain garden to allow water to pond on the surface before it infiltrates into the garden soil. This excess water can be expected to drain away via the overflow pipe. Note that the overflow pipe should extrude from the surface of your rain garden and collect water that ponds beyond the surface.

The final step in installing a rain garden is the installation of adequate plants and the application of adequate mulching. Pebbles are the best way to achieve this as other mulch mixtures may contain organic matter that pollutes overflow runoff, and may compact over time to inhibit infiltration.

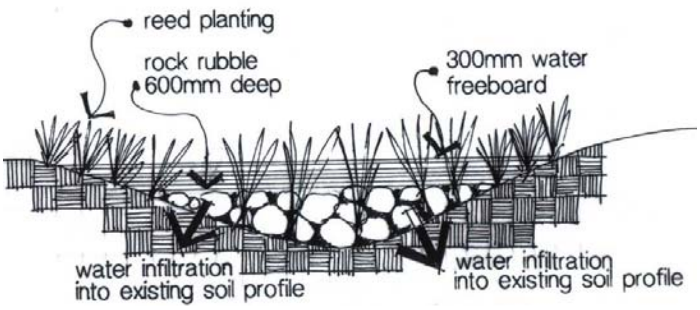


Figure 6.3 Typical Rain Garden Section

Source: Fifth Creek Studio

Opportunities for Retrofitting

Rain gardens represent low cost opportunities for implementing WSUD measures in new and existing sites.

Rain gardens may be easily retrofitted to existing domestic dwellings, commercial and industrial buildings with downpipes connected to subsurface water drains. The required installation procedures are well within the capability of most people to complete by themselves and at their own cost. The only exception to this is the connection of overflow mechanisms, where undertaken, to the street stormwater network. This work must be undertaken by a licensed plumber.

Larger scale rain gardens are an effective way to ensure new, or existing, developments have an attractive, low maintenance landscape tailored to local conditions in the Greater Adelaide Region.

Maintenance Requirements

Rain gardens are a low maintenance, small scale WSUD measure when appropriate vegetation is planted. Under typical climate conditions they should not need to be watered, mowed or fertilised.

Some guidance is provided to ensure rain gardens operate effectively as runoff management tools and aesthetic landscape features:

- If it does not rain, rain gardens should be watered (in accordance with water restrictions and water conservation measures) until plants have sufficiently established;
- Rain gardens should be covered with some form of mulch to retain moisture. A variety of different types of mulch is available, but stone types are recommended as they do not leach nutrients into ponded water and will not form a potential clogging layer at the surface of the rain garden;
- Rain gardens may require regular weeding until plants have matured;
- Ensure no areas of extended ponding develop that will facilitate breeding of mosquitoes;
- It is essential to evenly distribute the flow of runoff into rain gardens to limit erosion from significant flows that follow heavy rainfall;
- Rain gardens should be inspected regularly. Plants may require replacement, or erosion may need to be addressed where it was not expected; and
- Provide 'plant indicators' for identifying substrate infiltration rate changes, especially the silting up of the substrate. There are many species that do not tolerate waterlogging over an extended period of time. These species can be incorporated into the planting plan.

Rain gardens are not tolerant of traffic and may require maintenance following accidental abuse or vandalism in public areas.

6.4 Green Roofs

Description

Green roofs are a series of layers consisting of living vegetation growing in substrate over a drainage layer on top of built structures, either new or retrofitted. In this document the inclusion of living walls and green facades will be treated as having similar characteristics and behaviour patterns as green roofs.

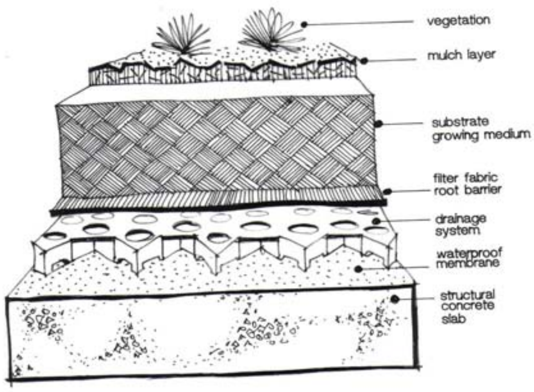


Figure 6.4 Typical Green Roof Construction

Source: Fifth Creek Studios

A green roof is built upon a roof structure, whether new or existing, which is protected by a high quality waterproofing and root repellent system, a drainage layer, a filter cloth and/or root repellent layer, a lightweight growing medium and plants, and finally a mulch layer.

There are four types of green roofs: extensive, semi-intensive, intensive, and elevated landscape. The primary difference between the four types is the depth of the substrate, which in turn has a direct relationship to the runoff holding capacity of each system:

- **Extensive roofs** are generally lightweight systems with low prostrate vegetation and are often inaccessible. These roofs have between 50-150 millimetres substrate depth.
- **Semi-intensive** combines the best features of extensive and intensive, are partially accessible and have greater plant diversity. The depth of the substrate is 150 millimetres +/– 50 millimetres.

- **Intensive** has a substrate depth greater than 150 millimetres, usually accessible for greater use, provides better insulation properties and stormwater management, and has greater biodiversity potential.
- **Elevated landscape** has 600 millimetres or greater depth substrate and creates a new ground plane. This has the greatest potential for biodiversity and topography shaping, and has similar insulation and runoff management potential as the existing ground surface.

Currently in Adelaide, extensive green roofs have not been proven as a successful system, given the available proprietary systems that have been used. The extremely dry humidity and heat in summer creates issues with the root systems of the plants in the shallow substrate. The most appropriate green roof for the Greater Adelaide Region would be the intensive type, which also performs better for runoff management given the increased depth of substrate.

Living walls and green facades provide similar functions to green roofs. Green facades are systems with climbers on vertical support systems grown from planters or inground planting. Living walls are systems where plants are grown in a vertical medium based on the principle of hydroponics for moisture and nutrients.

Figure 6.5 Extensive Roof Example

Source: Fifth Creek Studios

Figure 6.6 Semi-intensive Green Roof Example

Source: Graeme Hopkins, Department of Planning and Local Government

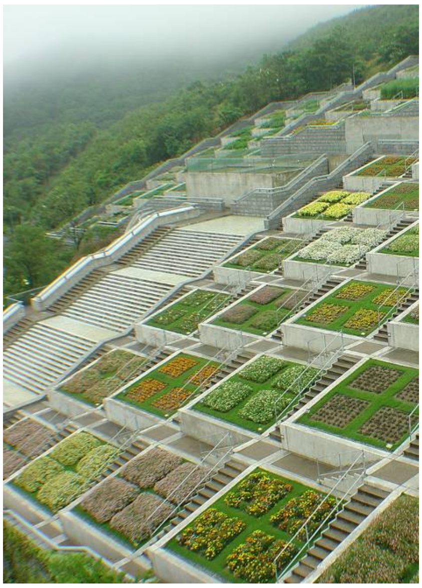


Figure 6.7 Elevated Landscape Example, Awaji Resort, Japan

Source: Graeme Hopkins, Department of Planning and Local Government

Figure 6.8 Intensive Green Roof, Hocking Place, Adelaide

Source: Fifth Creek Studio

Purpose

Green roofs have many benefits to the building, both inside and out, as well as many environmental benefits to the surrounding environs. One of the major drivers for green roofs in North America and Europe is reducing runoff volume and improving runoff quality. This will also be a driver for the Greater Adelaide Region as runoff is a major element of WSUD.

Benefits include:

- Runoff management;
- Improved water quality;
- Reduced impervious areas;
- Reduced heat island effect;
- Reduced air pollution;
- Improved biodiversity;
- Increased insulation;
- Increased carbon dioxide/oxygen exchange; and
- Additional living space.

All of these benefits are equally important in the holistic view but for this particular purpose the elements of water quality, runoff management and the reduction of impervious areas will be dealt with in more detail.

Overall the main function of green roofs is water quality control; they provide limited flood control. Effectively they increase the initial losses in a storm event primarily by increasing the depression storage and vegetation interception losses. These are typically small compared to infiltration losses. The low voids ratios of soils used in these systems (a typical value is 0.2) and their limited infiltration rates (typically 150-350 millimetres/hour) further limits their potential to provide flood control. An approximation of the available flood storage volume is 20% of the soil volume, although in practice the available soil storage is unlikely to be fully utilised during a high intensity storm event.

Reduced Impervious Areas

As cities become more dense, including Adelaide with infill programs, the area of impervious surfaces also increases. Rooftop areas as a percentage of total impervious area can range from 30-35% in suburban developments to as much as 70-75% in business districts. This may even be as high as 80% in some warehouse/semi-industrial districts. If partial usage of rooftops for green roofs were to be implemented, then a considerable reduction in overall runoff volumes could be achieved.

Runoff Management

Green roofs can be an important element in an integrated water sensitive design and planning approach, as the roof is often the first point of contact in the stormwater chain. By intercepting the rain runoff at the source, the green roof eliminates the potential multiplying effect further downstream of the runoff chain. Vegetation assists the management of runoff by reproducing many of the hydrological processes normally associated with the natural environment.

Elements that contribute to this process include:

- Rainwater landing on plant surfaces and then evaporating away;
- Rainwater that falls on the roof substrate can be absorbed by the substrate pores or taken up by the absorbent material in the substrate, and even evaporate back into the atmosphere;
- Rainwater taken up by the plants is either stored in the plant or transpired back into the atmosphere; and
- Rainwater can also be stored and retained within the roof's drainage system.

Storage detention or retention rates for green roofs depend on many variable factors, but as the Greater Adelaide Region, or indeed Australia, does not have any detailed research we can only rely on current observations of existing green roofs and general trends in research in North America and New Zealand as a guide. Overseas studies have found considerable seasonal variations for rainwater retention between summer and winter due to the greater amount of water being returned to the atmosphere in summer through evaporation and transpiration. Retention rates in summer can be between 70-100%, but in winter may be 40-50%.

In a more recent study (Hutchinson et al. 2003) involving stormwater monitoring of two ecoroofs in Portland, Oregon, it was found that the summer retention rate can be up to 100%, and down to 69% at other times of the year for a 100-150 millimetre thick green roof. These studies also showed that for small to moderate storms, the green roofs virtually retained all the rain that fell on them. In large rain events, once the substrate water holding capacity was reached, any extra water would simply run off, therefore reducing the overall percentage of retention.

A further development in technology is the installation of a layer of water-absorbing material within the soil profile. A green roof that has installed this technology in Adelaide has displayed evidence of 100% retention in summer and near that for the rest of the year. Given these outcomes it can be used as a design tool for achieving whatever retention rate is desired.

The graph below in **Figure 6.9** shows the green roof delayed runoff and reduced runoff rate and volume.

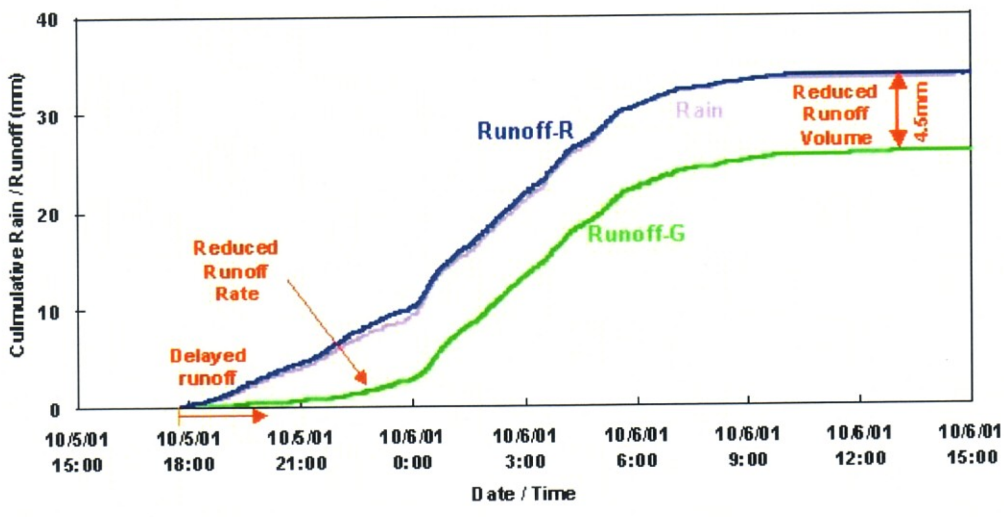


Figure 6.9 Cumulative Runoff Graph

Demonstrating the reduction in runoff volume, delayed and reduced rate of runoff caused by the green roofs. Runoff-G is a 150 millimetre grass covered green roof. Runoff- R is a membrane covered reference roof.

Source: National Research Council for Research in Construction

Water Quality

Green roofs not only retain rainwater, but also moderate the temperature of the water and act as a natural filter for any runoff. This occurs through infiltration and the bioretention process in the substrate.

A recent innovative development in green roof design is to install constructed wetlands as an integral part of the green roof system. Taking the known benefits of constructed wetlands and adding this element to the runoff management role of green roofs is an important WSUD technique.

A demonstration case is the John Deere Works in Mannhein, Germany where it was decided to begin treating the wastewater from the company's manufacturing and assembly operations with a constructed wetland on the factory roof. The wetland includes a combination of sedges, rushes and irises grown hydroponically in 50 millimetres of water. It breaks down carbon and nitrogen compounds present in the wastewater while sequestering phosphates and heavy metals (Earth Pledge 2005).

Figure 6.10 Constructed Wetland, John Deere Works, Germany

Source: Graeme Hopkins, Department of Planning and Local Government

Application / Scale

Green roofs are appropriate for commercial and industrial structures as well as residential buildings. They can be installed on flat roofs but also can be built on slopes up to 30 degrees. They can be incorporated into new construction or retrofitted into existing buildings.

Design Considerations

This section provides an overview of the key design issues that should be considered when conceptualising and designing a green roof for runoff management. The factors that need to be taken into consideration for the design of storage detention/retention rates include:

- Season of the year;
- Number and type of layers used in the system;
- Depth of substrate;
- Angle of slope of the roof;
- Physical properties of the growing media;
- Type of plants incorporated in the roof;
- Intensity of rainfall; and
- Local climate.

The design of the green roof system has typical components as follows:

- Waterproof membrane over structural roofing system;
- Root protection barrier (often incorporated in the waterproofing membrane);
- Drainage layer;
- Filter layer (prevents fine particles in the growing medium from interfering with the drainage layer);
- Water storage system (optional);
- Growing medium;
- Mulch layer; and
- Vegetation layer.

Structural considerations

Structural considerations for the design of green roofs include:

- The green roof needs to be designed to carry the load of a totally saturated substrate (growing medium), drainage system and the foliage weight of all the plants;
- Heaviest loads should be located over structural supports such as columns or walls;
- Lightest or thin substrates should be located at the midspan of the concrete slab or roof beam;
- Always consult a qualified structural engineer for structural suitability, whether for a new or existing structure.

Landscaping Considerations

A wide spectrum of plants from coastal or arid areas of Australia may be suitable for use on green roofs having adapted to extreme environmental conditions, including temperature extremes, high UV load, drought, salt laden winds in coastal areas, shallow nutrient depleted soils, or in some cases pure sand (Mibus 2006).

Plant selection is a critical element in green roof success, and advice from a professional landscape architect or horticulturist who is experienced in green roof design should be obtained. Green roof microclimate is an extreme environment for plants to survive and careful selection of well proven species is required.

Factors that must be considered for plant selection include:

- The higher the green roof, the harder or harsher the environment, therefore the choice of plant species becomes critical and the smaller the plant pallet;
- The orientation of roof or roof slope – whether it is a north facing roof with full sun exposure, or south facing with shading;
- The roof context – if it is overshaded by other buildings all day or part of the day;
- Plant layout – using sustainable landscape principles to maximize benefits;
- Do not use species that have the potential to become 'garden escapees' or weeds.

A useful guide for plant selection is the "Rooftop Gardens Fact Sheet" produced by Adelaide City Council, which provides plant lists for local native sustainable green roofs and for sustainable green roofs. This Fact Sheet is available from Adelaide City Council and provides proven species for Adelaide's climate (see **Section 6.6**).

It is important to consider the topography of the green roof surface, as even small undulations can create microclimates that may benefit many different habitats and greater biodiversity. The greater the biodiversity in the soil the greater the capacity of the soil substrate layer for improving the water quality; also the greater the depth of substrate the greater the retention ability of the green roof.

It should be noted that the timing of planting is critical to optimum establishment of plants on a green roof. Poor timing can result in excessive erosion, plant losses and additional costs.

Figure 6.11 Typical Native Plant Species for Adelaide, Hocking Place, Adelaide

Source: Fifth Creek Studio

Maintenance Requirements

Aside from initial watering and occasional fertilisation, a properly designed green roof does not require much maintenance. Initially the plants will need regular watering until they are fully established (usually within six months). The occasional weeding in the beginning and regular fertilisation of the soil layer are the only other maintenance requirements. Applying a slow release fertiliser twice a year is sufficient.

If the green roof is designed with water retention capacity then additional irrigation is not required once establishment has occurred. If extreme heat wave conditions occur then the use of subsoil dripper irrigation will be required over this period. In extensive roofs the vegetation layer does not grow vertically but the plant species habit is to spread horizontally because the thin soil layer does not support tall vertical growth.

6.5 Infiltration Systems

Description

Infiltration systems generally consist of a shallow excavated trench or 'tank', designed to detain (and retain) a certain volume of runoff and subsequently infiltrate the stored water to the surrounding soils. They reduce runoff volumes by providing a pathway for treated runoff to recharge local groundwater aquifers.

There are four basic types of infiltration systems:

- Soakaways;
- Infiltration trenches;
- Infiltration basins; and
- Leaky wells.

Infiltration systems typically consist of a storage that is made up from void spaces in media such as single size gravel or manmade structures.

The storage is usually wrapped up in geotextile type fabric and 'clean' water is allowed to infiltrate to the native surrounding soil. It is important that infiltration systems only receive 'clean' water; even runoff from roofs often requires some form of pre-filtering.

Infiltration trenches typically hold runoff within a subsurface trench prior to infiltrating into the surrounding soils. They usually comprise a shallow, excavated trench filled with reservoir storage aggregate. Infiltration trenches are similar in concept to infiltration basins, however trenches store runoff water below ground within a pit and tank system, whereas basins utilise above ground storage.

Soakaway systems (refer **Figure 6.12**) are similar, but simply allow water to "soakaway" with minimal storage. They can be below (as illustrated) or above ground systems. Leaky well systems consist of large diameter perforated or pervious pipes or wells that again have limited storage volumes. Both systems rely on the permeability of surrounding soils to disperse inflows. Leaky wells and soakaways are ideally suited to sandy soils which have inherent higher permeability and provide a passive irrigation mechanism for increasing soil moisture within close proximity (metres) of the infiltration area. They can be very effective in managing runoff as well as irrigating gardens and community landscapes.

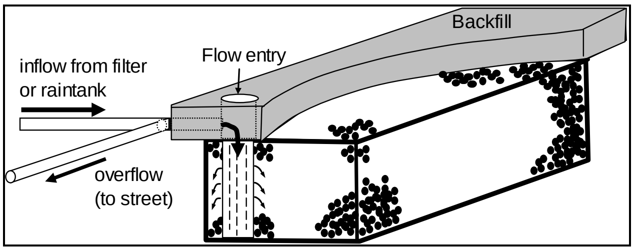


Figure 6.12 Simple Soakaway with Overflow Example

Source: IE Aust. (2006)

Purpose

Infiltration systems are an effective tool to achieve three primary goals:

- Runoff reduction;
- Pollution reduction; and
- Harvesting and retention of runoff.

The primary purpose of infiltration systems is to capture and infiltrate flows (not treat them).

Infiltration systems are designed to infiltrate runoff on site, thereby reducing the overall volume of water that runs off a site to the urban drainage network. This also reduces the impact of development on peak flow volumes.

Infiltration systems are usually applied with the aim of achieving a specific reduction in the annual runoff volume. Some local government authorities do not permit the use of infiltration systems in locations where they are deemed to be unsuitable.

When applied to promote infiltration, it is important to recognise that the infiltration system is not a primary method of flood mitigation, but a way of taking pressure off conventional urban drainage systems. It is considered appropriate to adopt a design process based on hydrological effectiveness curves where this is the case.

Infiltration systems may also be used as a flood mitigation measure. It is important in this case to design infiltration systems using the design storm method in this case. The design storm method is outlined in Section 11.6 of IE Aust. (2006). It is important that all systems designed using the design storm method also adhere to the requirements of the *Development Act 1993,* Ministers Specification SA 78AA (Planning SA 2003).

Infiltration systems reduce pollution in urban waterways in two ways. By minimising the conveyance of runoff from urban catchment surfaces to waterways, the accompanying volume of pollutants is prevented form entering the urban drainage network. Infiltration systems also cleanse runoff via a variety of processes, primarily filtration, which improves the quality of water leaving the system.

Water harvesting schemes can be undertaken with the application of infiltration systems. Collection of water after infiltration using subsurface storages, or a combination of pervious pipes and offline storages, can be undertaken. They therefore present an opportunity to address the pressing needs of the community to employ other sources of water for fit for purpose use.

Infiltration systems effectively strip a proportion of the runoff from urban areas and infiltrate this to underlying soils and groundwater. They also provide limited water quality control, primarily through mechanical filtration processes. Other treatment processes can be enhanced using engineered soils or geofabrics.

Application / Scale

Infiltration systems are limited to soils with good infiltrative capacity.

They should also be sited with adequate buffer distances from foundations, neighbouring properties and existing inground infrastructure.

Infiltration systems can be operated at a variety of scales, from receiving the overflow from a rainwater tank, to regional scale systems receiving treated runoff from large catchments.

Infiltration trenches are best suited to small (< 2 hectare catchment) residential, commercial and industrial developments with high percentages of impervious areas, including parking lots, high density residential housing and roadways.

Infiltration trenches are commonly used with overlying pervious pavements as an effective water treatment chain.

Infiltration basins are best suited to medium to large (5 to 50 hectare catchment) residential, commercial and industrial developments with high percentages of impervious areas, including parking lots, high density residential housing and roadways (Upper Parramatta River Catchment Trust 2004).

Design Considerations

The following sections provide an overview of the key design issues that should be considered when conceptualising and designing an infiltration system. A typical infiltration strategy is illustrated in **Figure 6.13**.

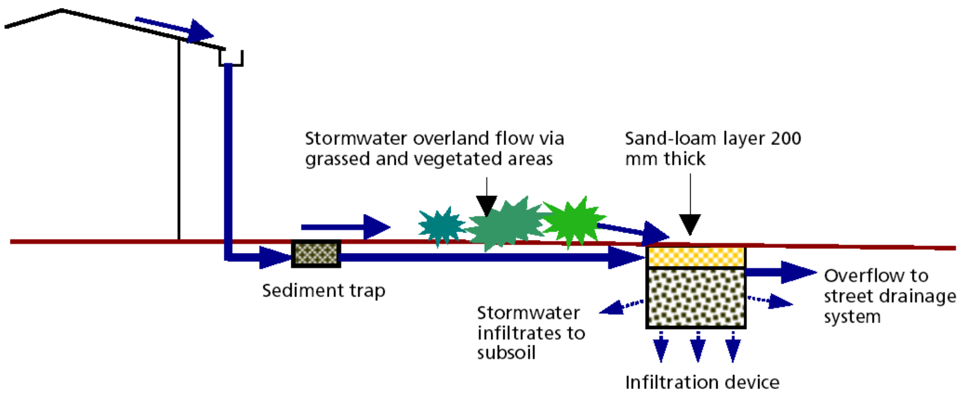


Figure 6.13 Typical Infiltration Strategy

Source: Water Sensitive Urban Design in the Sydney Region Practice Note 5 – Infiltration Devices

The *Development Act 1993* Ministers Specification SA 78AA (Planning SA 2003) contains a variety of considerations that must be adhered to in the design of infiltration systems. These include tables on the required size of infiltration systems and positioning of infiltration systems on a site.

A number of these design considerations are discussed briefly below.

Depth

The *Development Act 1993* Ministers Specification SA78AA (Planning SA 2003) has limited excavation depth for an infiltration system to 1.5 metres due to the restrictions imposed on excavations greater than 1.5 metres by the South Australian Occupational Health, Safety and Welfare Regulations 1995.

A permit is required to construct an infiltration system greater than 2.5 metres under the requirements of the *Natural Resources Management Act 2004*.

Site Setback Distances

In accordance with the *Development Act 1993* Ministers Specification SA 78AA (Planning SA 2003) the use of infiltration systems is restricted to soil types A and S or Class M-D where the characteristic surface movement (or ys value) is equal to or less than 25 millimetres, as defined in the document AS 2870 Residential Slabs and Footings – Construction, and where the following conditions exist:

- The slope of the natural ground does not exceed 1 in 10;
- The depth to rock is 1.2 metres or greater; and
- The groundwater table is permanently below 1.5 metres from the natural ground surface or the final ground surface, whichever is the lowest.

The design of infiltration systems must take into consideration their proximity to existing structures and boundaries. The *Development Act 1993* Ministers Specification SA 78AA (Planning SA 2003) specifies that:

- Retention devices shall be located a minimum of 3 metres from all property boundaries, (excluding front boundaries and/or reserves) and 3 metres from footings of all structures located on the allotment; and
- A minimum clear spacing of 1 metre between the sides of the retention device and any service trench is required.

Further recommendations are provided by Argue (Ed., 2009) on the appropriate setback of infiltration systems with respect to different soil types.

Design Process

The key elements of the design process for infiltration systems are outlined below.

Design Objectives and Targets

The implementation of WSUD in a development seeks to achieve a range of outcomes relating to water quality, hydrology, conservation and amenity.

Each of these outcomes is met by ensuring development complies with the appropriate objectives and targets identified for the site. Before any other activities are undertaken with respect to site planning, the objectives for the infiltration system should be clearly established.

For example, infiltration systems can be designed to achieve a range of objectives, including:

- Minimising runoff volume;
- Preserving pre-development hydrology; and
- Enhancing groundwater recharge.

Selection of Type of Infiltration System

As outlined above, a range of infiltration systems are available. In general, selection of the type of infiltration system is determined by the size of the contributing catchment.

Design Methods

There are two approaches to the design of infiltration systems. These are:

- The design storm method; and
- Design using hydrological effectiveness curves.

Design Storm Method

The design storm method should be applied where an infiltration system is being used for flood mitigation. In this case, the infiltration system may be considered the primary tool for flood mitigation.

A primary consideration in the design process of infiltration systems is the requirements set out in the South Australian *Development Act 1993* Ministers Specification SA 78AA – On-Site Retention of Stormwater (Planning SA 2003).

The design storm method for flood mitigation by infiltration systems is outlined in Section 11.6 of IE Aust. (2006).

A more comprehensive outline of the design storm method is also available in Argue (Ed., 2009).

Hydrological Effectiveness Curves

The hydrological effectiveness curve approach to design may be applied where the infiltration system is being utilised to promote infiltration only. In this case, the infiltration system must bypass flow in excess of its infiltration capacity to another flood mitigation system. An example of this situation may be in the case of retrofitting existing sites or to address local requirements for on-site retention.

The design methodology using hydrological effectiveness curves is outlined in **Chapter 11** of IE Aust. (2006).

Construction Process

In accordance with the *Development Act 1993* Ministers Specification SA 78AA (Planning SA 2003) all gutters and pipe work required to direct roof runoff to the infiltration device and pipe work from the infiltration system to the off-site system shall be designed and installed in accordance with AS/NZS 3500.3.2 Plumbing and Drainage – Stormwater Drainage.

It is important to note that blockage of infiltration systems can be an issue where infiltration systems are presented with a high sediment load. As indicated by Argue (Ed., 2009) the performance of infiltration systems applies to 'established residential neighbourhoods'.

Poor on-site management of runoff during the construction phase can lead to complete blockage of infiltration systems. Simple measures, such as scheduling infiltration system construction to the final phase of construction or preventing runoff from entering the system during the construction phase, are recommended.

Maintenance Requirements

Infiltration systems, by their very nature, trap and retain sediment in their structure for the term of their effective life. This characteristic makes them susceptible to clogging, especially in situations where they are exposed to high sediment loading.

Maintenance for infiltration systems is therefore aimed at ensuring the system does not clog with sediments and that an appropriate infiltration rate is maintained and pre-treatment measures are operating properly.

In accordance with the *Development Act 1993* Ministers Specification SA 78AA (Planning SA 2003):

- In addition to the installation of filtration devices to the on-site runoff retention system, retention trenches and wells should be inspected and cleaned on a regular basis; and
- Overflow, discharge or bleed off pipes from roof-mounted appliances such as evaporative air conditioners, hot water services and solar heaters should not discharge onto the catchment area.

Argue (Ed., 2009) recommends regular inspection and corrective maintenance, such as desilting, be undertaken. The issue of their widespread use, according to Argue (Ed., 2009), hinges upon the lifespan which can be expected for installations.

An example Infiltration System Maintenance and Inspection Checklist is provided in **Appendix D**.

Approximate Costs

The construction costs for infiltration systems depend largely on the surface area/width and depth and the volume of excavation required.

Excavation costs would also depend on subsurface ground conditions, with rates varying from $20/cubic metre in light soils to over $50/cubic metre in soft, rippable rock (Upper Parramatta River Catchment Trust 2004).

The estimated unit rate construction costs for a typical 1 metre wide x 1 metre nominal infiltration trench is summarised in **Table 6.1**.

Table 6.1 Estimated Unit Rate Construction Cost of Infiltration Trench

Works Description	Quantity	Unit	Rate	Cost ($/m)
Excavate trench (1 m x 1.25 m) and stockpile	1.25	m3/m	20	25
Supply and install geofabric liner	4.0	m2/m	5	20
Supply and place perforated pipe (100 mm diameter)	1.0	m/m	13	13
Supply and place gravel storage layer	1.0	m3/m	65	65
Supply and place filter layer (150 mm minimum thick)	0.15	m3/m	45	7
Supply and place topsoil layer (100 mm minimum thick)	0.1	m3/m	70	7
Supply and apply grass seed, fertiliser and watering	1.0	m2/m	1.0	1
TOTAL				138

Source: Upper Parramatta River Catchment Trust (2004)

Maintenance costs will differ depending on the scale of the device. No approximate costs regarding maintenance of infiltration systems are available at present.

6.6 Useful Resources and Further Information

Fact Sheets

www.waterforgood.sa.gov.au

Water For Good fact sheets – Stormwater Use and Wastewater Recycling

www.melbournewater.com.au/content/library/publications/fact_sheets/drainage/how_to_build_a_rain garden.pdf

How to Build a Rain Garden fact sheet

www.brisbane.qld.gov.au/bccwr/lib184/stormwater_factsheet_sml.pdf

Stormwater Garden fact sheet

www.adelaidecitycouncil.com/adccwr/publications/guides_factsheets/fact%20sheet%20-%20rooftop%20gardens.pdf

Adelaide City Council Rooftop Gardens fact sheet

www.wsud.org/downloads/Planning%20Guide%20&%20PN%27s/05-Infiltration.pdf

Water Sensitive Urban Design in the Sydney Region Practice Note 5 – Infiltration Devices

www.brisbane.qld.gov.au/bccwr/lib184/wsud%20practice%20note%2007%20infiltration%20measures.pdf

Practice Note 7 Infiltration Measures, Brisbane City Council

Legislation Information

www.epa.sa.gov.au/pdfs/info_construction.pdf

Construction Noise information sheet, EPA

www.epa.sa.gov.au/pdfs/info_noise.pdf

Environmental Noise information sheet, EPA

www.epa.sa.gov.au/pdfs/bccop1.pdf

Stormwater Pollution Prevention Code of Practice for the Building and Construction Industry, EPA

http://dataserver.planning.sa.gov.au/publications/654p.pdf

Guide for Applicants, Department of Planning and Local Government web site

http://dataserver.planning.sa.gov.au/publications/948p.pdf

Development Act 1993 Ministers Specification SA 78AA

General Information

www.brisbane.qld.gov.au/bccwr/lib184/stormwater_gardentechnical.pdf

Stormwater Gardens – Bioretention Basins for Urban Streets, Brisbane City Council

http://greenroofs.wordpress.com/

Green Roofs Australia

www.urbanecology.org.au/christiewalk/roofgarden.html#main

Christie Walk Rooftop Garden

www.lasa.org.au/

The Landscape Association of South Australia

www.lid-stormwater.net/greenroofs_maintain.htm

Low Impact Development Urban Design Tools – Green Roofs

www.greenroofs.com

Greenroof industry portal

www.edcmag.com/

Environmental Design and Construction

www.fytogreen.com.au/products/roofgarden/index.html

The Fytogreen Roof Garden System

6.7 References

Argue, J. R. (Ed, 2009) *WSUD: basic procedures for 'source control' of stormwater - a Handbook for Australian practice.* Editor: Argue, J.R., Authors: Argue, J.R., Allen, M.D., Geiger, W.F., Johnston, L.D., Pezzaniti, D., Scott, P., Centre for Water Management and Reuse, University of South Australia, 5th Printing, February 2009, ISBN 1-920927-18-2, Adelaide.

Earth Pledge (2005). *Green Roofs: Ecological Design & Construction*, Schiffer Publishing, USA.

Hutchinson, D., Abrams, P., Retzlaff, R., Liptan, T. (2003). *Stormwater Monitoring for Ecoroofs in Portland, Oregon, USA*. Greening Rooftops for Sustainable Communities, Chicago.

IE Aust. (2006). *Australian Runoff Quality: A Guide to Water Sensitive Urban Design*. New South Wales.

Mibus, R. (2006). *Green Roofs in the Changing Australian Landscape.* Melbourne.

Planning SA (2003). *On-Site Retention of Stormwater*. Government of South Australia. Adelaide. September. http://dataserver.planning.sa.gov.au/publications/948p.pdf.

Upper Parramatta River Catchment Trust (2004). *Water Sensitive Urban Design, Technical Guidelines for Western Sydney.* Prepared by URS Australia Pty Ltd. http://www.wsud.org/tech.htm.

Appendix A
Annual Rainfall in the Greater Adelaide Region

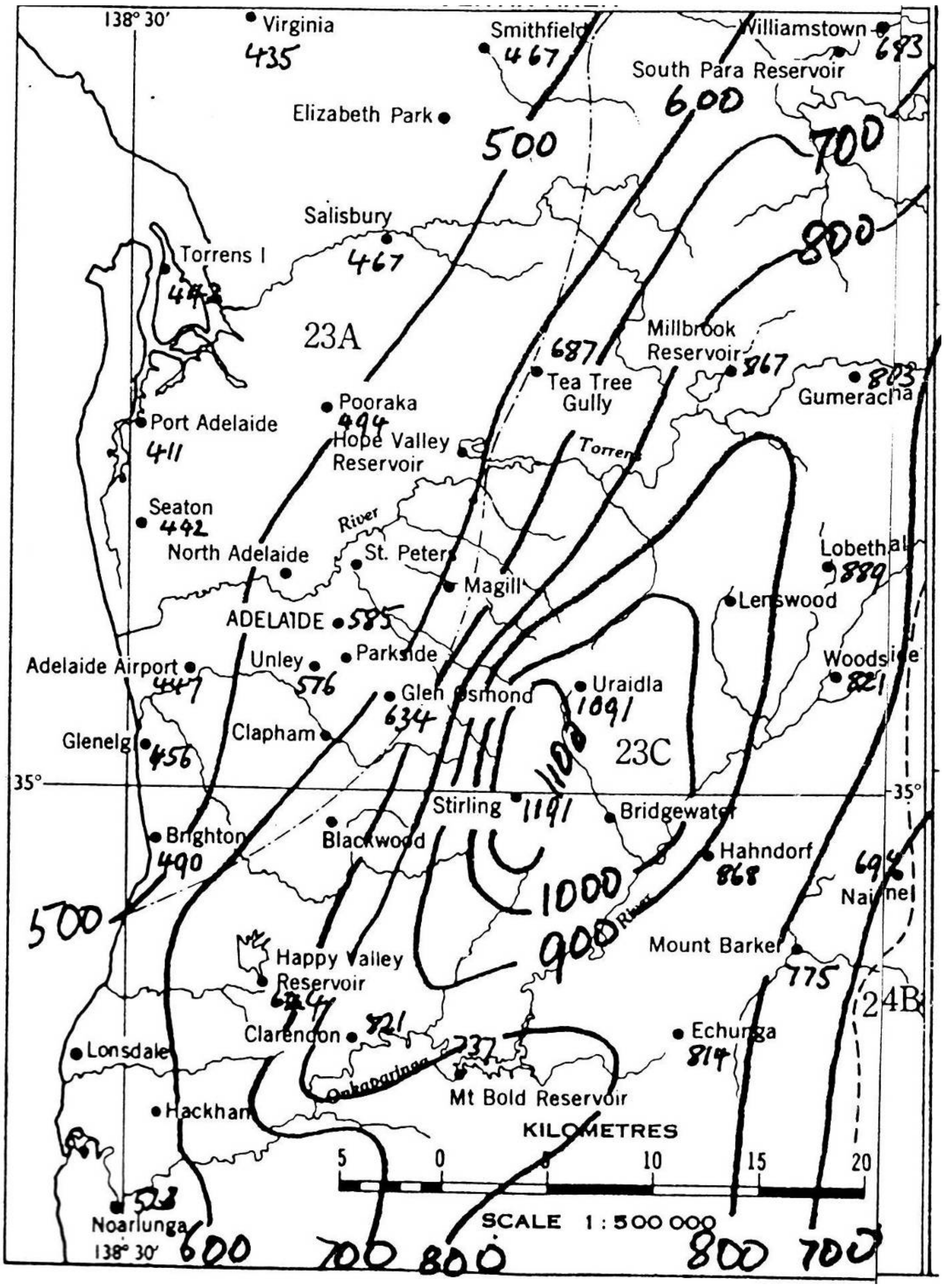
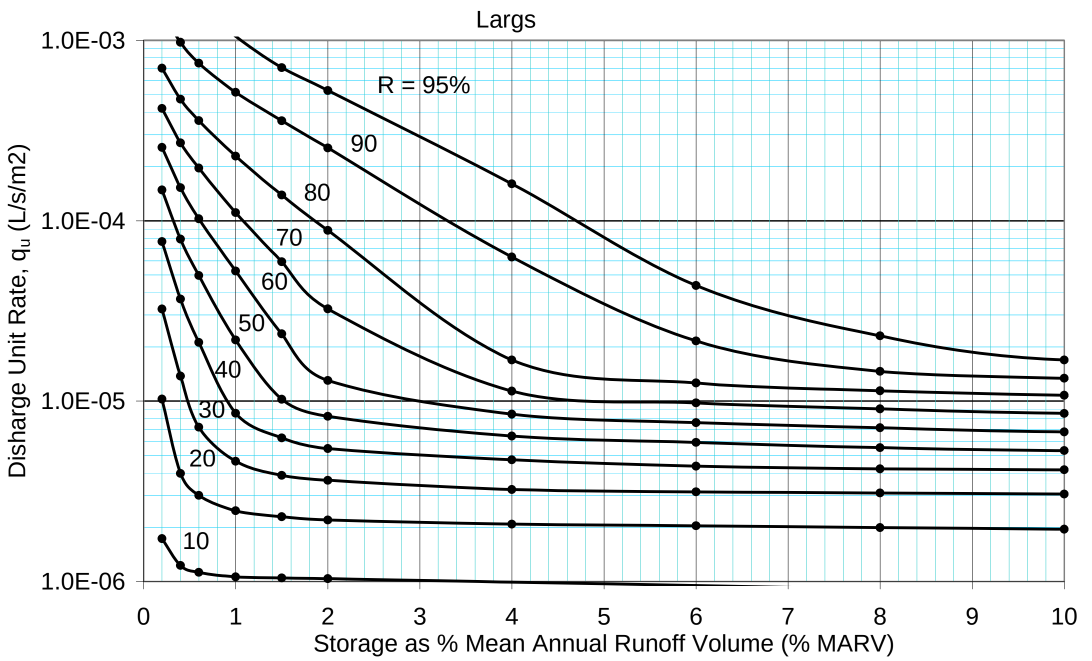


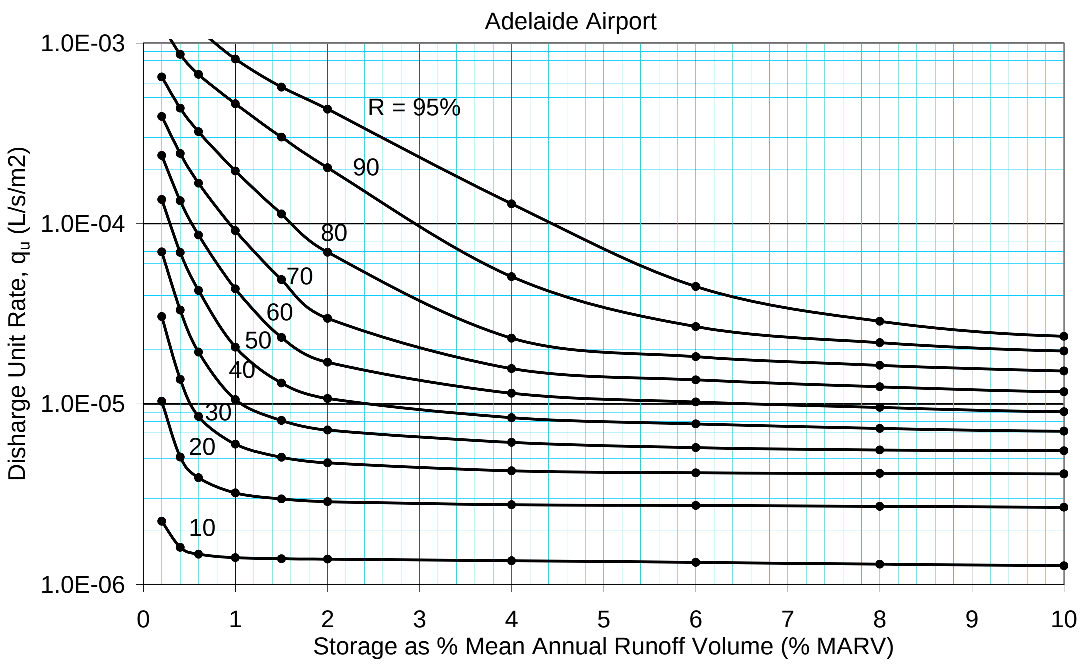
Figure A1 Annual Rainfall in the Greater Adelaide Region

Appendix B
Hydrological Effectiveness Curves for the Greater Adelaide Region

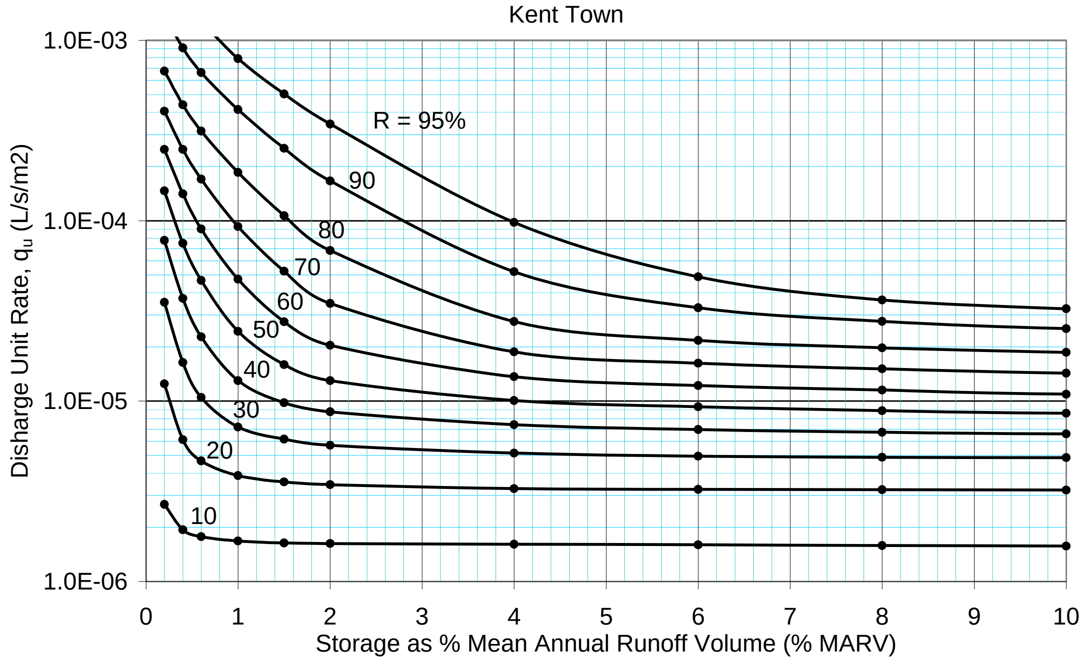
300-400 millimetres per annum



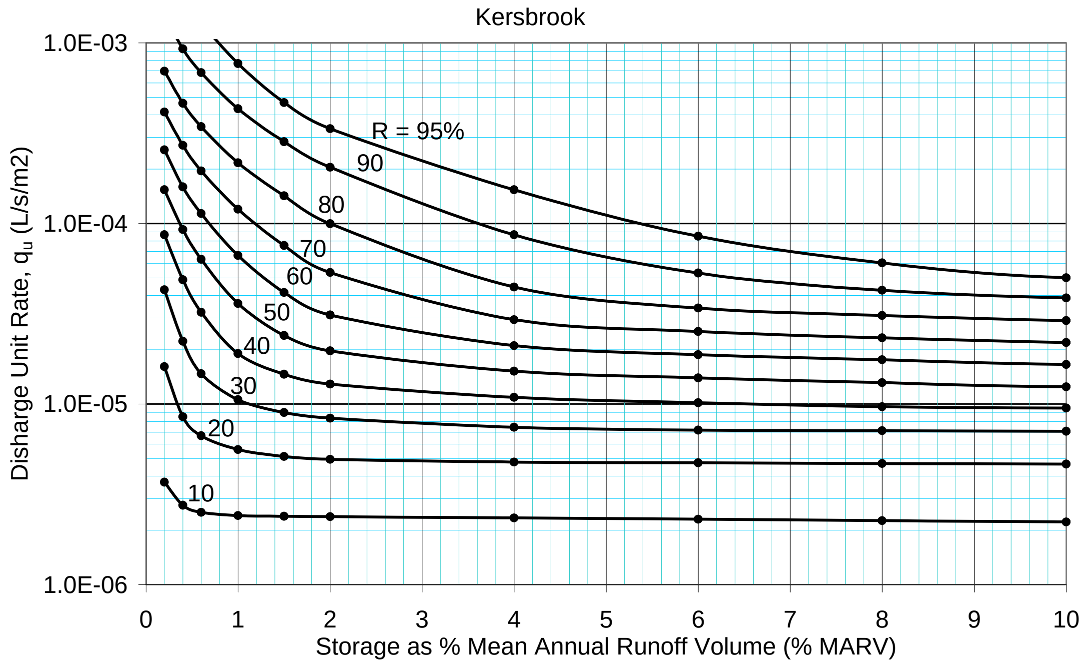
400-500 millimetres per annum



500-600 millimetres per annum



600-800 millimetres per annum



Appendix C

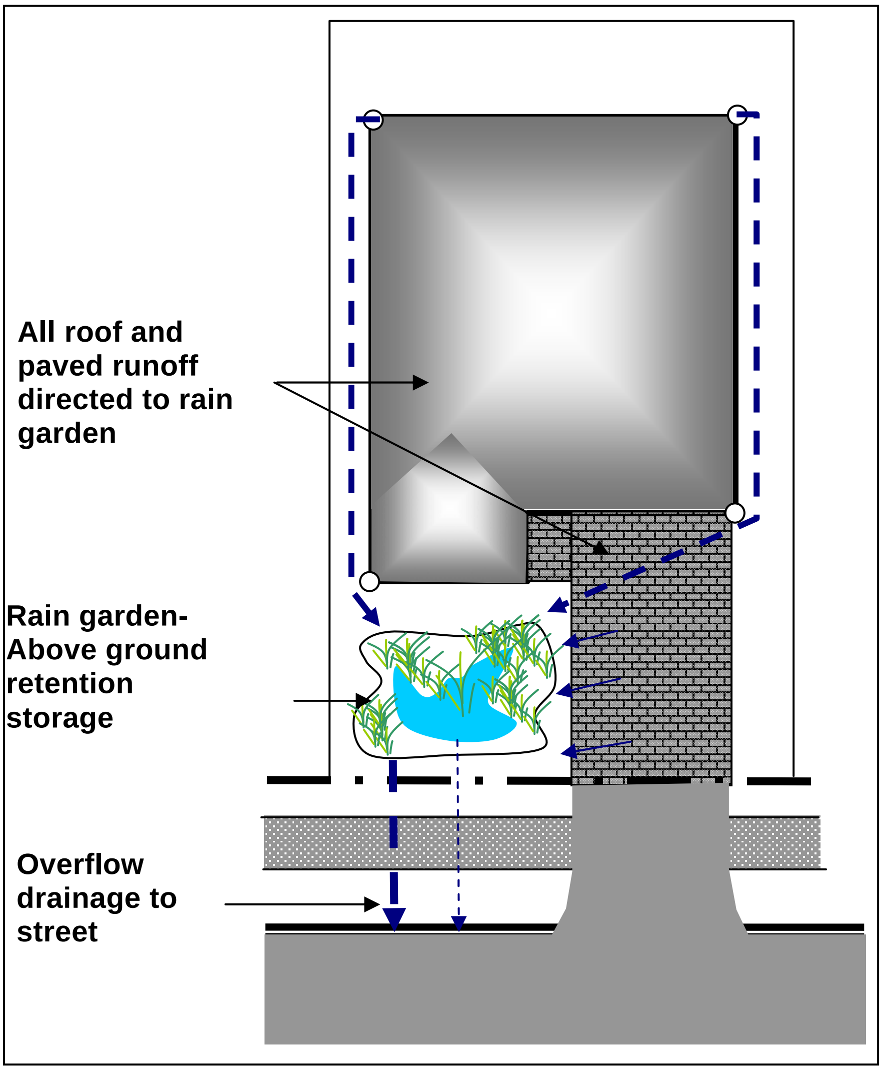
Example of Utilising the Hydrological Effectiveness Curves to Design a Rain Garden

Example: Rain garden ('natural' drainage)

Task:

Determine storage volume of the rain garden needed to manage 95% of the average annual runoff.

If required depth exceeds maximum allowable, determine slow drainage necessary to limit depth to maximum allowable.



Location: Adelaide (see Figure in Appendix A).

Average annual rainfall:

X = 545 millimetres/year.

Soil: medium clay, k_h = 1.0×10^{-5} metre/second.

Moderation factor, U = 1.0

Contributing Catchment:

Roof area A_{EIA} = 200 square metres

Paved area A_{EIA} = 30 square metres

Space available for garden = 25 square metres

Storage: Surface ponding e_S = 1.

Hydrological (treatment) effectiveness, R = 95%

Step 1: Determine infiltration rate and unit discharge rate

According to Allen et al (2005) five soil permeability categories are provided:

Sandy soil :	$k_h > 5\times10^{-5}$ m/s
Sandy clay :	k_h between 1×10^{-5} and 5×10^{-5} m/s
Medium clay and some rock :	k_h between 1×10^{-6} and 1×10^{-5} m/s
Heavy clay :	k_h between 1×10^{-8} and 1×10^{-6} m/s
Constructed clay :	$k_h < 1\times10^{-8}$ m/s

Where k_h is the value of hydraulic conductivity determined by Jonasson's (1984) 'falling head' augerhole method.

When the hydraulic conductivity results from the small volume infiltration test are compared with field data from infiltration systems, it is found that field hydraulic conductivity is different. This observation has led to the introduction of a correction factor, moderation factor, U, which should be applied to hydraulic conductivity, k_h, in the formulae which follow Allen et al (2005):

Clay soils, U = 2.0;

Sandy clay soils, U = 1.0;

Sandy soils, U = 0.5.

Hence,

Infiltration discharge unit rate, q,

$$q = \frac{k_h \times U \times A_{avail}}{A_{EIA}} \text{ L/s/m}^2 \text{ of EIA}$$

$$q = 1.0 \times 10^{-5} \times 25/230$$

$$= 1.1 \times 10^{-6} \text{ L/s/ m}^2$$

Step 2: Determine mean annual runoff volume (MARV)

Locate q on **Figure C1**.

It can be seen that it is not possible to achieve 95% hydrological effectiveness. Maximum possible pond depth above low flow discharge point is 150 millimetres. This translates to a storage of 3 cubic metres.

Mean annual runoff volume (MARV) is (230+25) x 545 mm/yr = 144.0m^3

The storage ratio β (%MARV) is 2.2%

Step 3: Determine unit discharge rate, q

Locate β on Figure C1.

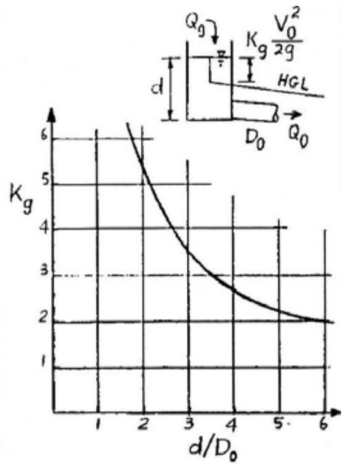
It can be seen that to achieve 95% hydrological effectiveness a unit discharge rate, $q = 3.0 \times 10^{-4}$ L/s/m² (EIA) is required, hence a slow release discharge is required.

Step 4: Determine required discharge rate to street drainage

Total discharge is made up of infiltration and piped flow, hence the slow discharge rate required is:

$$q_{pipe} = q_{total} - q_{infiltration} = 3.0 \times 10^{-4} - 1.1 \times 10^{-6} = 3.0 \times 10^{-4} \text{ L/s/m}^2 \text{ (EIA)}$$

$$Q_{pipe} = q_{pipe} \times EIA = 3.0 \times 10^{-4} \times 255 = 0.7 \text{ L/s}$$



Discharge coefficient relationship

Step 5: Determine the pipe size required to discharge 0.7 L/s.

Using the velocity head equation with an average upstream water depth of 100 millimetres above the pipe invert and a pond depth to pipe diameter ratio of 6, an initial discharge coefficient of 2.0 is selected.

$H = k(v^2/2g)$……………….Velocity head equation

$A_{pipe} = Q / (Hx2g/k)^{-0.5} = 0.0007$

Hence diameter of pipe or orifice required d_{pipe} = 30 mm

The pond depth to diameter ratio is 3.3 and from the discharge coefficient graph, k_g should be about approximately 3. Using k = 3, the revised diameter is 33 millimetres.

This is a low flow rate that would provide a residence time (rain garden volume/discharge rate) of more than 10 days. A hose or orifice with a 30 millimetre diameter will provide necessary discharge rate. It will be important to protect the discharge outlet from blockage (e.g. with leaves). This can be achieved by placing coarse gravel around the outlet.

Solution

A rain garden with a surface storage of 3 cubic metres and with a low flow discharge via a garden hose or discharge opening (e.g. orifice) of 33 millimetres diameter will enable greater than 95% of the average annual runoff to be managed.

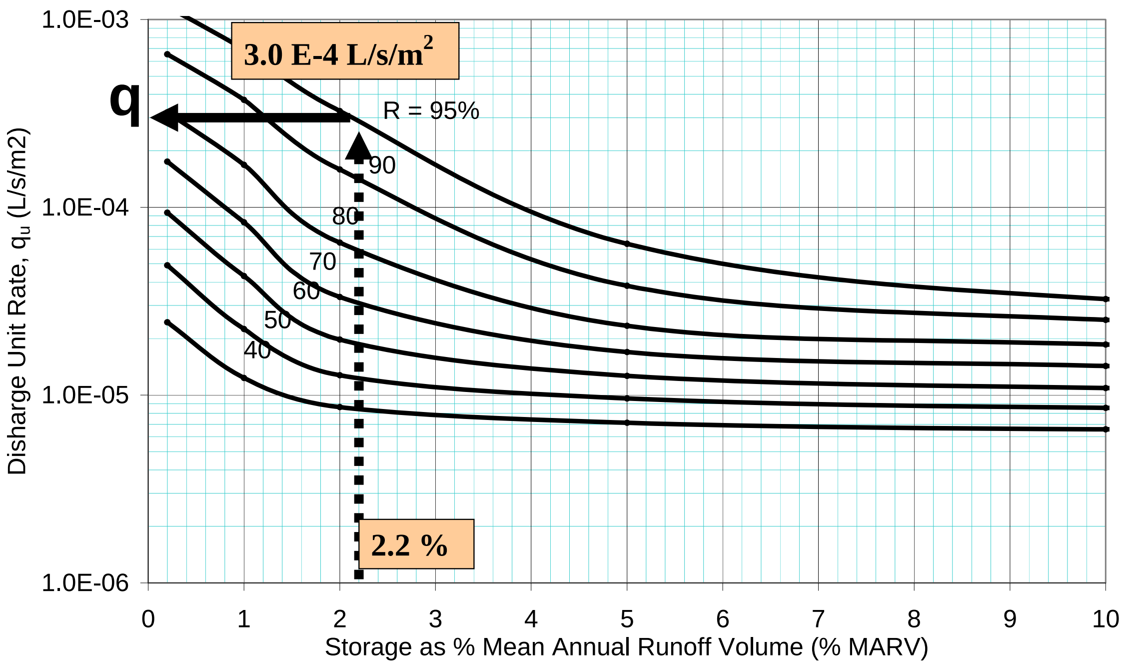


Figure C1 Hydrological Effectiveness Graph, Adelaide (Kent Town)

Appendix D

Infiltration System Maintenance and Inspection Checklist

Infiltration System

Maintenance Checklist

Asset ID:		**Date of Visit:**	
Inspection Frequency:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Weather:			

Items Inspected	Checked		Action Required (Details)	
	Y	N	Y	N
Debris Cleanout (every 6 months)				
1. Surface clear of debris				
2. Inlet area clear of debris				
3. Overflow clear of debris				
Sediment Traps, Forebays Or Pre-treatment (every 6 months)				
4. Trapping sediment effectively				
5. Facility not more than 50% full of sediment				
Surface (every 6 months)				
6. Evidence of surface erosion / scouring				
Surface Vegetation (if applicable) (every 6 months)				
7. Vegetation condition				
8. Vegetation trimming / maintenance				
9. Weed infestation				

Dewatering (every 3 to 6 months)				
10. Dewatering between storms				
11. Top aggregate layer / geofabric need replacing				
12. Entire aggregate requires replacing				
Outlet / Overflow (every 12 months)				
13. Outlet / overflow condition				
14. Evidence of erosion downstream				
Comments on Inspection				
Actions Required				
1.				
2.				
3.				
4.				
5.				

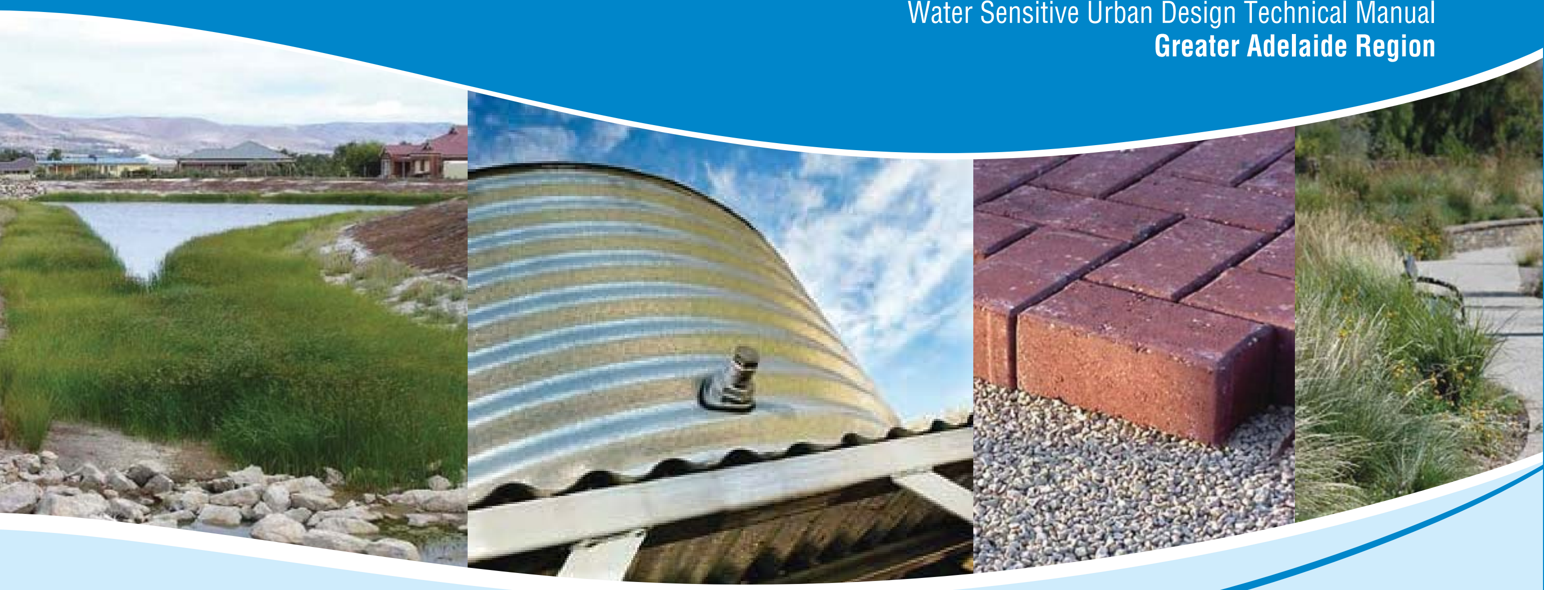
Source: Upper Parramatta River Catchment Trust (2004)

July 2009

Chapter 7

Pervious Pavements

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 7
Pervious Pavements

7.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Using pervious pavements is one of those measures.

This chapter of the Technical Documents for the Greater Adelaide Region is aimed at providing an overview of pervious pavements and how they can be utilised to assist in achieving the objectives and targets of WSUD.

Description

Pervious pavement (otherwise known as permeable and porous pavement) is a load bearing pavement structure that is permeable to water.

There is a wide variety of pervious pavement types, each with advantages and disadvantages for various applications.

Pervious pavements fall into two broad categories:

- Porous pavements, which comprise a layer of highly porous material; and
- Permeable pavements, which comprise a layer of paving blocks, typically impervious, specially shaped to allow the ingress of water by way of vertical ′slots‘ or gravel-filled ′tubes‘. There are generally large gaps between impervious paved areas for infiltration.

The common features of pervious pavements include a permeable surface layer overlying an aggregate storage layer. The surface layer of pervious pavement may be either monolithic (such as porous asphalt or porous concrete) or modular (clay or concrete blocks). The reservoir storage layer consists of crushed stone or gravel which is used to store water before it is infiltrated to the underlying soil or discharged towards a piped drainage system.

An example cross section through a pervious pavement is provided in **Figure 7.1**.

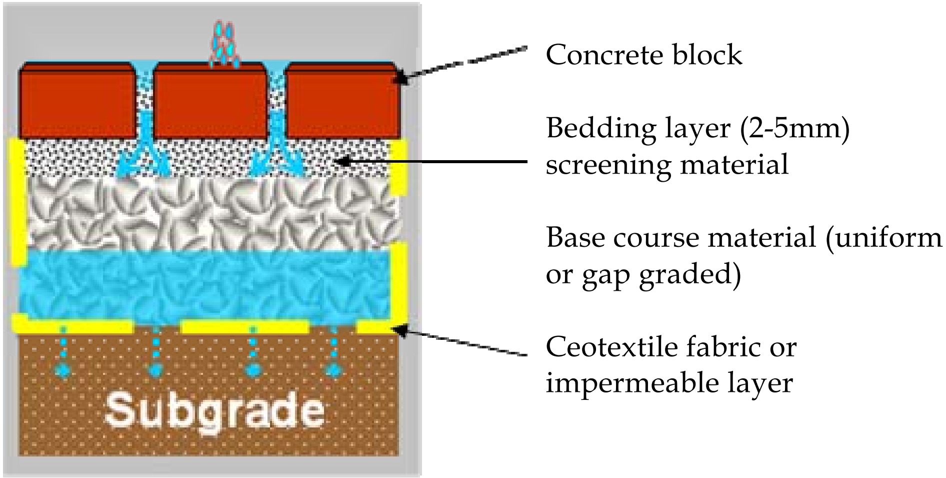


Figure 7.1 Example Cross Section Through a Pervious Pavement

Purpose

Urbanisation causes a significant increase in the area covered with paved (or impervious) surfaces, such as roads, driveways, parking bays and courtyards. Paved surfaces can have significant adverse impacts on the water cycle. They contribute to increased volume and peak runoff discharges, potentially resulting in downstream flooding, streambank erosion, sewer surcharges and the need to increase expensive drainage infrastructure capacity. Paved areas also reduce infiltration to the subsoil which also can result in reduced flow inputs to groundwater systems, upper soil moisture for dependent vegetation and increased downstream pollution of waterways and aquatic habitats.

Pervious paving has many runoff management benefits and can be utilised to promote a variety of water management objectives, including:

- Reduced (or even zero) peak discharges (runoff volumes) from paved areas (by infiltration to the subsoils);
- Delaying runoff peaks by providing retention/detention storage capacity and reducing flow velocities;
- Increased groundwater recharge;
- Potential to harvest runoff for reuse (e.g. storage capacity in the base-course layer can be designed to intercept significant rain fall events);
- Improved runoff quality by removing some sediments and attached pollutants by infiltration through an underlying bedding and base course media ;
- Reduced area of land dedicated solely for runoff management; and
- Being more aesthetically pleasing than conventional paving areas.

Pervious pavements effectively strip a proportion of the runoff from urban areas and infiltrate this to underlying soils and groundwater, thereby providing flood control. They also provide limited water quality control, primarily through mechanical filtration processes. Other treatment processes can be promoted in pervious pavements through appropriate design.

In terms of flood control, the main advantage that pervious pavements have over a bioretention system is their increased infiltration rate. The design infiltration rate for a bioretention system is usually limited to a range of 150 to 350 millimetres/hour. Borgwardt (1994) reported that pervious paving constructed with gravel chips with 2 to 5 millimetre drainage openings had a permeability of 36,000 millimetres/hour 'as laid', which decreased over time. After five years a permeability of 3600 millimetres/hour was measured. However, the infiltration rate of a pervious pavement is in practice dependent on many factors, most notably the degree of clogging which is often related to the age of the pavement. The use of geofabrics in pervious pavements can also reduce the infiltration rate to as low as 2 millimetres/hour

A further issue is that permeable pavements do not generally incorporate overlying surface storage areas and therefore once this infiltration rate is exceeded quite often the permeable pavement is bypassed.

Scale and Application

As discussed above, bitumen, concrete and other hard surface areas (such as paving surrounding buildings) are typically impermeable and result in high runoff rates during a storm event. Runoff can be reduced by interspacing permeable material, such as lawn or pebbles, between widely spaced impermeable pavers, or by installing porous paving. The intent is to create a paved surface where water can infiltrate into the underlying soils.

Pervious paving may also be used as a general measure to reduce the impervious fraction of a site where it is not considered itself as a treatment measure.

Pervious paving can be utilised in:

- Streets with low traffic volumes and light traffic weight (such as cul-de-sacs);
- Car parks and for paving within residential and commercial development (e.g. pedestrian paths or footpaths); and
- Public squares.

Pervious pavements have been found to be most practical and cost effective when serving catchment areas between 0.1 and 0.4 ha (Upper Parramatta River Catchment Trust 2004). As a guide, the contributing catchment area to pervious area should not exceed 4 to 1. Where sediment and organic loads are high the ratio should be reduced to 2 to 1 (Allen et al. 2005).

Acceptable performance can be achieved provided the correct design and construction procedures are followed, including any manufacturer's recommendations.

Performance Efficiency

Pervious pavements can improve the water quality of runoff through several processes, including:

- Filtration of runoff through the pavement media and underlying material;
- Potential biological activity within the base and submedia; and
- An overall reduction of pollutants entering urban streams through reduced runoff volumes.

Pervious pavements are most effective in removing coarse to medium sediments and attached pollutants (such as nutrients, free oils/grease and metals).

An indication of the water quality improvement efficiencies that a correctly designed and maintained pervious paving system is capable of achieving is demonstrated in **Table 7.1**. A wide range is presented due to the high variability in the performance of pervious paving systems.

Table 7.1 Pervious Pavements Performance Efficiencies

Gross Pollutants	Coarse Sediment (0.5–5mm)	Medium Sediment (0.06–0.5mm)	Fine Sediment (< 0.06mm)	Free Oil and Grease	Total Nitrogen	Total Phosphorous	Metals
-	50-80%	30-50%	30-50%	10-50%	40-80%	50-80%	10-50%

Note: Indicative efficiencies are based on average annual load reduction

Sources: Upper Parramatta River Catchment Trust (2004), Melbourne Water (2005) and Urban Water Resource Centre (2002)

7.2 Legislative Requirements and Approvals

Before undertaking a concept design of a pervious pavement system it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to pervious pavements in your area. Refer to the suggested design process in **Section 7.4**.

The legislation which is most applicable to the design and installation of pervious pavements in the Greater Adelaide Region includes:

- *Development Act 1993* and *Development Regulations 2008*; and
- *Environment Protection Act 1993.*

Development Act 1993

Installing pervious pavements will generally be part of a larger development (for new developments), however whenever pervious pavements are planned (such as retrofitting), it is advised that the local council be contacted to:

- Determine whether development approval is required under the *Development Act 1993*; and
- Determine what restrictions (if any) there may be on the installation of pervious pavements on site.

Environment Protection Act 1993

Any development, including the installation of pervious pavements, has the potential for environmental impact, which can result from vegetation removal, stormwater management and construction processes. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on the whole site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when considering installation of pervious pavements are discussed below.

Water Quality

Water quality in South Australia is protected under the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development. In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, building sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise the potential for environmental impact during construction. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 7.8**).

Air Quality

Air quality may be affected during the installation of pervious pavements. Dust generated by machinery and vehicular movement during site works, and any open stockpiling of soil or building materials at the site must be managed to ensure that dust generation does not become a nuisance off site.

Waste

Any wastes arising from excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*. For example, during construction all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites*.

7.3 Design Considerations

As with other infiltration systems (see **Chapter 6**), designing pervious pavement systems requires consideration of the site conditions and potential contamination of the receiving groundwater environment. There are also some specific considerations for the design of pervious pavements. Some pervious pavement systems have a high failure rate that is attributed to poor design, clogging by fine sediment and excess traffic use (Department of Environment WA 2004).

The factors that will maximise the likely success of a pervious pavement include:

- Low traffic volumes and light vehicle weights;
- Low sediment loads;
- Moderate soil infiltration rates; and
- Regular and appropriate maintenance of the pavement's surface.

Pervious paving must therefore be carefully designed in areas with (Hobart City Council 2006):

- High water table levels;
- Wind blown or loose sands;
- Clay soils that collapse in contact with water; and
- Soils with a hydraulic conductivity of less than 0.36 millimetres/hour.

Design considerations for pervious pavements include:

- Subgrade stability;
- Low permeability liner;
- Pre-treatment of runoff;
- Vegetation;
- Flow management;
- Slope;
- Structural integrity;
- Safety;
- Clogging.

The following sections provide an overview of the key design issues that should be considered when conceptualising and designing pervious pavements.

Subgrade Stability

Many clay soils become weak when subjected to saturated conditions for long periods, combined with heavy, continuous traffic conditions. Pervious pavements may not be suitable where there is a heavy loading due to such traffic as commercial vehicles, particularly where there are clay soils (ACT Planning and Land Authority 2007).

Low Permeability Liner

In some locations, infiltration to clay is undesirable. For example, designers must carefully consider infiltration systems next to footings where the shrinking and swelling of some clays can cause structural damage. A minimum clearance of 5 metres from footings or impermeable lining should be used in these areas (ACT Planning and Land Authority 2007). Allen et al (2005) directly addresses the matter of infiltration in a number of different soil types and the appropriate 'setback' of infiltration systems.

Pre-treatment of Runoff

Pre-treatment of runoff entering a pervious paving system is primarily required to minimise the potential for clogging of the paving media and to protect groundwater quality where infiltration is proposed. Runoff should therefore be treated to remove coarse and medium sized sediments and litter.

Depending on the nature of runoff to the paving system, suitable pre-treatment to pervious paving systems includes:

- Provision of leaf and roof litter guards along the roof gutter;
- Application of buffer strips;
- Swales; or a
- Small sediment forebay.

Vegetation

In modular or grid paving systems, vegetation may be grown in the voids. Vegetated systems have demonstrated good long-term performance in the Greater Adelaide Region.

However, the following factors may result in this being unsuccessful:

- Lack of sufficient soil depth and nutrients for vegetation to grow;
- Heat retained in the pavers; and
- Wear from vehicle movement.

Vegetation should only be considered where these factors will not affect plant growth. The design should demonstrate mitigation of these factors if vegetated systems are proposed.

Non-vegetated systems also have a tendency to develop unplanned vegetation, as organic matter is a high proportion of the clogging material in the pavement voids. Although it may be aesthetically unpleasant, this basic aspect of vegetation in the void spaces may be argued to benefit the infiltration of runoff through the pavement as the roots of the vegetation maintain pathways for the infiltration of runoff. Furthermore, the long Adelaide dry season can lead to the death of some plants species.

Flow Management

Where possible, flows that are 'above design' flows should be directed to bypass the pervious paving system. This can be achieved in a number of ways. For example, an overflow pipe or pit, which is connected to the downstream drainage system, can be used.

'Above design' flows or overflows from the pervious paving should be diverted towards another WSUD measure or the stormwater (or drainage) system. Design of overflows should demonstrate that overflow will not be directed towards or cause damage to buildings, structures or services.

Slope

The surface of the pervious paving area must be relatively flat or as close to this as possible to ensure a uniform and distributed flow coverage, but also to prevent hydraulic overloading on a small portion of the surface. Some grade is important to ensure that overflows are conveyed past the pervious pavement, however where the grade is too steep it will encourage flow short circuit paths, reducing the performance.

Pervious paving should not be constructed on slopes of greater than 4% unless an engineering design is completed to assess the impact of the paving system on downstream environments, in particular the stability of surrounding areas (Upper Parramatta River Catchment Trust 2004; Gold Coast City Council 2007).

Structural Integrity

Consideration should be given to structural integrity where pervious pavements are to be used in locations where vehicles may be stopping or turning. Consideration should also be given to the likely loads due to traffic.

Lateral forces on pavers can occur due to forces exerted by turning wheels. Interlocking pavers provide greater resistance to lateral forces and are better suited to vehicle turning locations.

Where vehicles are stopping or turning, slippage can occur between the paver bedding material and basecourse. In such instances it is advisable not to place a geotextile membrane between the two layers.

Safety

Designers must also consider the likelihood of pedestrian traffic across the pavement surface and ensure that the pervious pavement does not present a public safety risk. Key considerations in the design of pervious paving systems in pedestrian traffic areas will include minimising trip hazards and slips and falls associated with a slippery pavement surface. Careful construction tolerances and subsequent maintenance regimes are therefore required.

A particular hazard in this case is where permeable paving with large gaps is applied. It is important that pedestrian traffic be restricted until all voids are filled with an appropriate filling media (such as fine gravel media screenings between 2-5 millimetres). Please also note that this must be gravel screenings, as gravel/sand mixtures will be detrimental to the design infiltration rate for the system.

Clogging

Partial or total clogging of pervious pavements with sediment and oil is a major potential cause of failure and must be avoided. Clogging can occur during or immediately after construction or through long-term use. The design procedure must take account of surface clogging as outlined in the design process section (**Section 7.4**) of this document.

The likelihood of clogging can be avoided by the following measures:

- Avoiding the use of pervious pavement for access ways with high traffic volumes or with regular heavy vehicle traffic;
- Avoiding the installation of pervious pavement in locations that are likely to receive large quantities of sediment and debris washed down by stormwater, or windblown sand or other material;
- Applying, where possible, pre-treatment measures such as sediment traps, vegetated buffer strips or specially designed gutter systems to remove sediments prior to reaching the pervious pavement;
- Protecting pervious pavements from sediment inputs during construction;
- Undertaking regular vacuum sweeping or high pressure hosing to remove sediment material that prevents infiltration.

7.4 Design Process

Overview

The design process for pervious pavements consists of a number of key steps:

- Assess site suitability;
- Identify objectives and targets;
- Consult with council and other relevant authorities;
- Select the pervious pavement type:
- Structural design of a pervious pavement;
- Determine the design flows;
- Size the pervious pavement system;
- Specify pervious pavement layers;
- Check the design objectives;
- Prepare a construction plan; and
- Prepare a maintenance plan.

Further details regarding the detailed design process are contained in **Appendix A** and a design calculation checklist is provided in **Appendix B**.

The design assessment checklist presents the key design features that should be reviewed when assessing the design of a pervious paving system. These considerations include configuration, safety, maintenance and operational issues that need to be addressed during the design phase.

A proposed design should have all necessary approvals for its installation.

Depending on the scale of the development, it should be noted that not all of the suggested steps in the design process will be required. The design process is also discussed in general in **Chapter 3** of the Technical Documents.

Site Suitability

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of site conditions is therefore a fundamental part of designing a development that effectively incorporates WSUD.

Selection of where to place the pervious pavements is important and is not only a matter of appearances. An assessment of site conditions is necessary to identify what measures, if any, are required to ensure that the pervious pavements will perform for their entire lifetime.

Pervious pavements show a decline in permeability with exposure to sediment and organic matter through their lifetime. To ensure adequate performance of these pavements it is necessary to design the pavements to utilise only a portion of the 'as new' capacity reported by product manufacturers.

Pervious paving can, in some cases, result in a risk of contamination of shallow aquifers by toxic substances derived from asphalt, vehicular traffic and road use. Assessment of the groundwater should be undertaken to define existing water quality, potential uses (current and future) and suitability for recharge. This will be an important consideration in areas where aquifer storage, transfer and reuse (ASTR) schemes are operating, such as certain catchments in the City of Salisbury. Designers are urged to contact the local council to determine any special prohibitions that may affect the use of infiltration systems (including pervious pavements).

Pervious paving systems should be located in areas so that they avoid:

- High water tables;
- Saline soils;
- Acid sulphate soils;
- Wind blown areas;
- Runoff from areas expected to have a high sediment load;
- High traffic volumes; and
- Services (existing or proposed).

The design should demonstrate avoidance of these kinds of areas or conditions.

Objectives and Targets

The design objectives and targets will vary from one location to another and will depend on site characteristics, development form (including structural integrity requirements) and the requirements of the receiving ecosystems. It is essential that these objectives are established as part of the conceptual design process and discussed with the relevant council prior to commencing the engineering design.

The design approach for pervious pavements is generally based on achieving the following broad objectives:

- For infiltration (or retention) systems, providing sufficient surface area and capacity of the reservoir (sub-base) storage to contain the treatment volume and allow infiltration to the subsoil between storm events; or

- For detention systems, providing sufficient capacity of the reservoir (sub-base) storage to provide adequate detention during high runoff events to reduce peak outlet design discharges to specified pre-development conditions.

Pervious paving systems can be designed to achieve a range of specific objectives including:

- Minimising the volume of runoff from a development;
- Preserving pre-development hydrology;
- Capturing and detaining, or infiltrating, flows up to a particular design flow;
- Utilising WSUD techniques without compromising the hard standing surface requirements such as parking or trafficability;
- Enhancing groundwater recharge or preserving pre-development groundwater recharge; and
- Removing some sediments and attached pollutants by passing runoff through an underlying media layer.

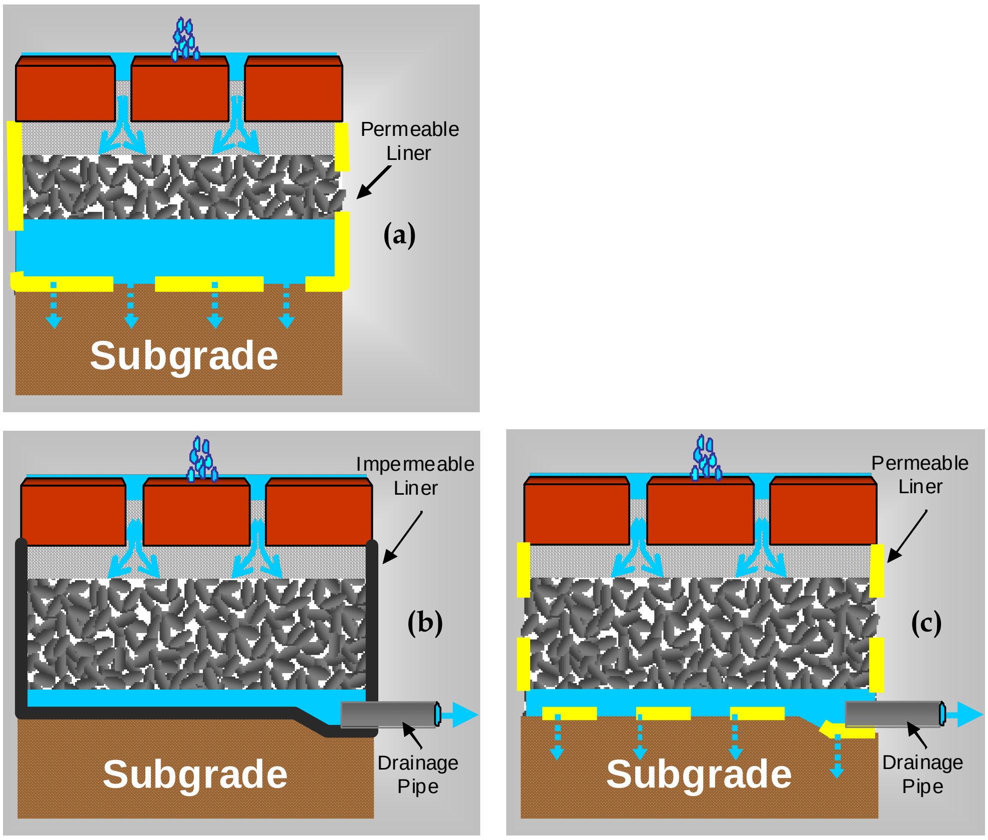


Figure 7.2 (a) Infiltration, (b) Detention and (c) Combined Infiltration and Detention Pervious Pavement Systems

Further information on setting objectives and targets can be found in **Chapter 3** of the Technical Manual.

Consultation with Council and Other Relevant Authorities

The designer (or applicant) should liaise with civil designers and council officers prior to proceeding any further to ensure:

- Pervious paving will not result in water damage to existing services or structures;
- Access for maintenance to existing services in maintained;
- No conflicts arise between the location of services and WSUD devices; and
- The objectives and targets are consistent with council directions stated in documents such as strategic plans and stormwater management plans.

The council will also be able to assist with determining whether:

- Development approval is required and, if so, what information should be provided with the development application;
- Any other approving authorities should be consulted; and
- Any specific council requirements need to be taken into consideration.

Land and asset ownership issues are key considerations prior to construction of a WSUD measure, including pervious pavements. A proposed design should clearly identify the asset owner and who is responsible for maintenance and this aspect should also be discussed during a meeting with the local council.

Select Type of Pervious Pavement

A number of pervious paving products are commercially available including:

- Concrete, ceramic or plastic modular pavers – pavers may be made of porous material or if not permeable, designed and installed to leave gaps between the pavers to allow runoff to penetrate into the subsurface;
- Grid or lattice systems – these are made of concrete or plastic grids filled with soil or aggregate that water can percolate through. These systems may also be vegetated (usually with grass); and
- Porous asphalt or concrete (monolithic structures) – open graded asphalt or concrete with reduced or no fines and a special binder that allows water to pass through the pavement by flowing through voids between the aggregate.

Selection of the paving type for a particular application must occur as part of the conceptual design process by assessing the site conditions and desired amenity or built environment/local character requirements against the functional types of paving systems.

Table 7.2 shows a range of suitable applications for different pervious paving types in the Greater Adelaide Region.

Table 7.2 Potential Applications for Pervious Pavements

Condition/Use	Porous Asphalt / Concrete	Porous Pavers / Grid Systems	Interlocking Concrete Paving Systems
Commercial parking lots	Yes	Yes	Yes
Perimeter/overflow parking	Yes	Yes	Yes
Perimeter/light commercial driveways	Yes	Yes	-
Patios/other paved areas	Yes	Yes	-
Sporting courts	Yes	-	-
Industrial storage yards/loading zones	Yes	Yes	-
Parking pads (e.g. caravan parks)	-	Yes	Yes

Source: Gold Coast City Council (2007)

The various types of pervious pavements are discussed in more detail below.

Porous Paving

There are different types of porous pavements, including:

- Porous asphalt pavement;
- Porous concrete pavement; and
- Modular interlocking concrete bricks with internal or external drainage cells.

Porous pavers make up the surface of the porous paving system; however there are a number of layers to the overall system.

The porous pavement is typically laid on top of a high void aggregate or gravel base layer, with a geotextile in between. The runoff passes through the pore spaces of the pavement, through the geotextile and into the aggregate/gravel layer, which provides temporary storage as the water gradually infiltrates into the subsoil. Where the subsoil has low permeability, the water can be removed by providing a slow drainage outlet to the receiving stormwater system.

Where base soils have low porosity, water is removed by ‘slow drainage’ to another WSUD measure, nearby drainage path or receiving water.

The aggregate also serves as the road or parking area’s support base and must be sufficiently thick to support expected traffic loads. A final filter layer may be provided at the base of the paving system below the aggregate layer. This can be fine sand mixed with base course material that contains the underdrainage system and is the final layer prior to infiltration to surrounding soils or discharge to a piped drainage system.

Geotextile fabric is generally used to separate the surrounding fine soils from the base course material. It can also be used to provide separation between the bedding layer and the base course layer.

In the Greater Adelaide Region, soils are predominately clay and hence porous paving usually requires a drainage sublayer of material to discharge excess water laterally to the drainage system. Special consideration is required where changes in soil moisture result in significant swelling, particularly where there is infrastructure vulnerable to differential movement.

These pavements can be sensitive to clogging from fine sediments and excessive organic matter. Any decision to install these pavements should consider nearby sources of sediment (exposed soil and beaches) and organic material (trees and shrubbery). After the pavement has been installed it should be protected from short-term sources of sediments (a load of landscaping material for a garden for instance or development work such as new house construction). Porous pavement should be scheduled as a final step in any development process.

Permeable Pavements

Permeable pavements comprise a layer of paving blocks, typically impervious but specially shaped to allow the ingress of water by way of vertical 'slots' or gravel-filled 'tubes'. The blocks are placed on fine (2 to 5 millimetre) aggregate bedding screenings and may be underlain by a layer of non-woven geotextile fabric.

This surface sits on a substructure reservoir of gravel, typically gap-graded and thick, 200-400 millimetres in carpark applications where vehicle and truck wheel loads require such measures. Substructures of half this depth are satisfactory where permeable paving is used in footpaths or pedestrian only concourse areas (Allen et al. 2005).

In all other respects, permeable pavements operate and behave in much the same manner as porous pavements. Pollutant removal by absorption, filtering and biological decomposition is similarly successful (Allen et al. 2005).

Structural Design of a Pervious Pavement

The structural design methodology for a pervious pavement system is not currently covered by this Technical Manual. However, the key consideration in the design of pervious paving is the structural integrity of the system. The key consideration is not dissimilar to a standard pavement, except that the base course must be able to infiltrate runoff. Design software (the Lockpave-PermPave software package) is available to address the structural design of a pervious pavement (see **Section 7.5**).

Determining the Design Flows

The hydraulic design for pervious paving should be based on the following design flows:

- A minor storm event for sizing the surface area, detention or retention volume and overflow pit of the paving system; and
- A major storm event for overflow or bypass of the system. These flows will flow over or bypass the system and enter the stormwater drainage system (either piped system or overland flow).

A range of hydrologic methods can be applied to estimate design flows. If typical catchment areas are relatively small, the Rational Method design procedure is considered suitable. For further information see **Section 7.5**.

Sizing Pervious Pavements

The rate at which water can flow through the surface is a key design measure of pervious pavements. This information is available from the pavement manufacturers and is essential in ensuring that the paved area is appropriately sized to cater for design flows.

For design, it is recommended that the design infiltration rate be based on 'effective' design life infiltration rate. The 'effective' life can be chosen on the basis of minimum infiltration rate or structural deterioration. Evidence suggests that the infiltration rate of pervious pavements reduce to about 20% of their initial rate after 10 years and this is a suitable ratio to adopt in the design process. For example, where a manufacturer specifies an infiltration rate of 1200 millimetres/hour for their product, practitioners are advised to apply an infiltration rate of 240 millimetres/hour.

The size of a pervious paving system requires consideration of:

- The volume and frequency of runoff discharged to the paved area;
- The available detention or retention volume; and
- The infiltration rate (product of 'infiltration area' and hydraulic conductivity of the paving system).

The required 'detention volume' is defined by relating the volume of inflow and outflow for a particular design storm, and then deriving the 'infiltration area' to ensure the system empties prior to the commencement of the next storm event.

Where the design objective for a particular pervious paving system is peak discharge attenuation or the capture and infiltration of a particular design storm event, then the design storm approach may be adopted for sizing the pervious paving system and a check for emptying time is performed to ensure the system can manage successive storm events.

The emptying time check is necessary as the limitation with the design approach is the inability to account for antecedent conditions that might affect the hydraulic performance. In particular, the greatest uncertainty is the available storage at the onset of the design storm event. This uncertainty is overcome by undertaking continuous simulation modelling using historical rainfall data at small time steps (i.e. 6 minutes). The outcome of continuous simulation is the ability to determine the hydrological effectiveness of the drainage system and hence its performance for managing runoff whether it is for flood, treatment or harvesting.

An alternative means for sizing pervious pavement can be using PermPave software, which has been developed by the Concrete Masonry Association of Australia (see **Chapter 15** and **Section 7.5**).

If treatment or harvesting performance is required, hydrological effectiveness curves can be used which have been developed for the Greater Adelaide Region (see **Appendix C**). The alternate design approaches are described in more detail in the Appendices.

Specify Pervious Paving Layers

The following design and specification requirements should be documented as part of the design process for pervious pavement systems:

Pervious Paving Surface

The pervious paving layer will depend on the type of paving selected through the design process. The pervious paving surface type should be specified along with any proprietary requirements and specifications.

Retention / Aggregate Layer

Where the 'detention volume' is created through the use of a gravel-filled trench then the gravel should be clean (free of fines) stone/gravel with a uniform size of between 25-100 millimetres in diameter. The material utilised should be documented.

Geotextile Fabric

Geotextile fabric should be installed along the side walls and through the base of the detention volume to prevent the migration of in-situ soils and material from the bedding and filter layers into the system. Geotextile fabric with a minimum perforation or mesh of 0.25 millimetres should be used. The type of geotextile fabric utilised should be documented. As previously noted, geotextiles may have an influence on the structural integrity of a system where vehicular traffic is stopping and starting aggressively and regularly. The geotextile layer may form a slip plane in the pavement construction.

Alternative means to preventing the migration of surface layers to the base course will be careful application of soil filter criteria as described below.

Filter Media Mixing

The simplest way to prevent two layers of basecourse material from mixing is through the use of a permeable geotextile product. However, there is some concern over the use of geotextiles at the surface of a pavement construction due to the potential formation of a 'slip plane' (Prof Brian Shackel, pers. Comm.). This concern is founded on the potential for the geotextile to prevent an adequate interlock between the 2-5 millimetre aggregate laying course and the larger layer of base course immediately beneath.

In cases where this 'slip plane' effect is expected to eventuate the use of a geotextile is inappropriate. Other methods must be used to ensure that the laying course does not simply mix with the base course. Designers can refer to and adapt geotechnical engineering literature where similar problems have been encountered for the construction of filters and dam walls.

Retention Criterion

The retention criterion is established to prevent one layer mixing with another to produce a more heterogeneous mixture of materials. Designers must ensure that layers of soil or aggregate materials remain as discrete layers. This has been progressively addressed, but for larger particle materials such as those applied in permeable pavements, Reddi (2003) indicates that:

'It is generally established that if the pore spaces in filters are small enough to hold the 85% size (D_{85}) of adjacent soils in place, the finer soil particles will also be held in place.'

$$\frac{D_{15}}{d_{85}} < 4$$

Where:

D_{15}	=	**Laying course particle size according to 15% finer**
d_{85}	=	Particle size of base course material corresponding to 85% finer

Permeability Criterion

Particle size variation between discrete layers must also be selected to ensure there is not a build up of excess pore pressure that will inhibit flow. This is not particularly important in aggregate layers as the pore spaces are generally sufficiently large to ensure that pore pressure does not build up excessively. Designers should ensure that they satisfy the general criteria outlined by Reddi (2003):

$$\frac{D_{15}}{d_{15}} < 4$$

Where:

D_{15}	=	**Laying course particle size according to 15% finer**
d_{15}	=	Particle size of base course material corresponding to 15% finer

Check the Design Objectives

This step involves confirming the design objectives, defined as part of the conceptual design, to ensure the correct pervious paving system design method is selected. The treatment performance of the system should be confirmed (including revisiting and checking of any modelling used to assess treatment performance).

Construction Process

Numerous challenges exist that must be appropriately considered to ensure successful construction and establishment of pervious paving, including:

- Sediment loads during construction phase which can clog the paving surface; and
- Construction traffic and other works which can damage paving surface and layers.

Where large scale pervious paving systems are proposed, a detailed construction and establishment plan, including temporary protective measures, should be prepared.

To prevent premature clogging, pervious pavement should generally not be placed until all of the surface drainage areas contributing to the pavement have been stabilised. In addition, it is critical to ensure that any pre-treatment system for pervious paving is fully operational before flows are introduced.

During construction, heavy equipment should not be used on the pervious pavement area to prevent compaction of soils and subsequent reduction of infiltration rates.

Figure 7.3 Construction of the Linden Gardens Car Park

Source: Courtesy of the City of Burnside

If at the commencement of operations there is some clogging of the pavement surface, then the surface should be tilled, vacuum swept or high pressure hosed to clean or unblock the surface.

An example Construction Checklist in **Appendix B** presents the key items to be reviewed when inspecting the pervious paving during and at the completion of construction.

Maintenance Requirements

For efficient operation of pervious pavements it is essential that the gaps between the paver and the underlying bedding layer do not become clogged by fine sediment. To prevent this from occurring, pervious pavements require the following maintenance activities:

- High pressure hosing, sweeping or vacuuming (depending on the manufacturer's specifications) to remove sediments and restore/maintain porosity;
- Repair of potholes and cracks;
- Replacement of clogged/water logged areas;
- Rectification of any differences in pavement levels;
- Maintenance of the surface vegetation (if present) including weeding or mowing where appropriate; and
- Periodic replacement of aggregate layer (about every 20 years) and replacement of geotextile fabric.

Following construction, pervious pavements should be inspected every month (or after each major rainfall event) for the initial six months of operation to determine whether or not the infiltration zone requires immediate maintenance. After the initial six months, inspections may be extended to the frequencies shown in the example Maintenance and Inspection Checklist for Pervious Pavements in **Appendix B**.

Inspections can include checking for:

- Areas of sediment build-up and clogging and blockage of the underlying aggregate or filter layers;
- Potholes and cracking;
- Areas of significant pavement deflection;
- Areas of scour, litter build up, sediment accumulation or blockages of inlet points;
- Blockage of the outlet pipe (if applicable);
- Surface ponding (which would indicate clogging or blockage of the underlying aggregate);

- Stabilisation of the contributing catchment area to ensure that it is not a significant source of sediment;
- Effective operation of any pre-treatment systems; and
- Dewatering of the system following storm events.

Concrete grid, ceramic and modular plastic block pavers require less maintenance than asphaltic porous paving as they are less easily clogged. They are also easier to repair.

The performance and life of these pavements can be increased by regular vacuum sweeping or high pressure hosing (once every three months) to remove sediments.

As with traditional pavements, asphalt porous paving requires occasional resurfacing. Concrete grid, ceramic and plastic modular blocks require a maintenance schedule similar to that for conventional road surfaces. This involves retaining the pavers and removing trapped sediment.

All maintenance activities should be specified in an approved maintenance plan (and associated maintenance inspection forms) to be documented and submitted to council as part of the development approval process. Maintenance personnel and asset managers will use this plan to ensure the pervious paving continues to function as designed.

In addition to checking and maintaining the function of pre-treatment elements, the maintenance checklist can be used during routine maintenance inspections of the pervious paving and kept as a record of the asset condition. More detailed site specific maintenance schedules should be developed for major pervious paving systems and include a brief overview of the operation of the system and key aspects to be checked during each inspection.

7.5 Design Tools

Various design tools are available for the concept and detailed design of pervious pavements as detailed in **Chapter 15** and discussed briefly below.

PermPave

One of the modelling tools which can assist the design process of pervious pavements is PermPave. PermPave has been developed to undertake a basic assessment of the hydrological performance of concrete segmental permeable pavement design inputs for:

- Flood mitigation: using design rainfall approach according to the Institution of Engineer's *Australian Rainfall and Runoff*. Outputs include inflow and outflow hydrographs, pavement required storage capacity and depth;
- Water quality improvement: a simple water quality improvement analysis is based on hydrological effectiveness, derived from continuous time series modelling using 6 minute historical rainfall data; and
- Water harvesting: yields-storage relationship and suggested storage, based on unit storage volume benefit and dis-benefit approach.

The program incorporates methods outlined in the Institution of Engineer's *Australian Rainfall and Runoff*, as well as Australian Runoff Quality (IE Aust. 2006) documents.

Sizing the pavement for flood management is undertaken using the design storm method, while the hydrological effectiveness approach is adopted for water quality and harvesting design. The software is relatively simple to use and has several inbuilt features that allows the user to consider primary objects, traffic conditions, effective service life, geotechnical properties, etc.

The Lockpave-PermPave Software Package is able to assist with the structural design of interlocking concrete segmental pavements and permeable pavements (available to order from **http://www.cmaa.com.au/html/TechInfo/TechInfoSale.html**).

Hydrological Effectiveness Curves

The performance of storage systems with a discharge (infiltration or pipe) can be described (quantified) in terms of hydrological effectiveness, which takes account of A_{EIA} (equivalent impervious catchment area), historical rainfall series, storage, infiltration (outflow), bypass and overflow.

It should be noted that 'hydrological effectiveness' is identical to the term 'retention efficiency' used in Allen et al. (2005).

A set of hydrological effectiveness curves has been generated for the Greater Adelaide Region which is presented in **Appendix C**. The curves allow the user to assess the approximate performance of pervious pavements for a range of rainfall regions.

The derivation of the curves is based on a continuous water balance simulation using more than 20 years of historical rainfall series at 6 minute intervals. The following assumptions were made in the development of the curves:

- Equivalent impervious catchment area, A_{EIA} is determined, incorporating an appropriate volumetric runoff coefficient;
- All runoff is directed to storage and the facility excludes a bypass passage;
- Overflow occurs when the storage component fills;
- Infiltration rate (or supply to harvesting systems) is considered to be constant throughout the period of storage.

An example of the use of the hydrological effectiveness curves is contained in **Appendix D**.

7.6 Approximate Costs

The construction cost for pervious pavements depends largely on the type of pervious pavement selected (i.e. no fines asphalt/concrete or block) and the depth of the underlying gravel reservoir layer. The construction cost of pervious paving is similar to that of traditional pavement and is less than the cost of traditional paving when savings in stormwater infrastructure is considered. Research shows that pervious paving can be up to three times less expensive than traditional road and stormwater management approaches (Hobart City Council 2006).

However, the supply cost for pervious pavement is typically greater than conventional pavements (Upper Parramatta River Catchment Trust 2004).

The estimated unit rate construction costs for a typical pervious pavement area (using block pavers with a 400 mm thick base course layer) is summarised in **Table** 7.3.

Table 7.3 Estimated Construction Cost of Permeable Block Pavement

Works Description	Quantity	Unit	Rate	Cost ($/m²)
Excavate and profiling subgrade surface	1	m²	2	2
Supply permeable pavement blocks	1	m²	40	40
Install pavement blocks	1	m²	25	25
Supply and install geofabric liners	2	m²	5	10
Supply and place gravel reservoir layer (350 mm thick)	0.35	m³/m²	55	19.2
Supply and place bedding layer (50 mm thick)	0.35	m³/m²	45	2.2
TOTAL				98.4

Source: Upper Parramatta River Catchment Trust (2004)

These cost estimates are provided as an indication only and current, locally specific cost estimates should always be obtained.

7.7 Case Studies

Parking Bay, Kirkcaldy Avenue, City of Charles Sturt

Two permeable pavement parking bays were constructed along Kirkcaldy Avenue, Grange, in 1999. The bays were designed to collect, treat and infiltrate runoff generated on the roadway and the parking bays themselves. The scheme reduces both storm runoff (peak flow and volume) and pollution conveyance to downstream waterways.

Figure 7.4 Kirkcaldy Avenue Pervious Pavements

Source: Courtesy of University of South Australia

The catchment consists of the two parking bays and approximately 90 metres of Kirkcaldy Avenue carriageway (limited to half the road pavement); a total of 650 square metres.

The pavement comprises:

- Permeable pavement blocks (80 millimetres in deep);
- No fine sand jointing between pavers;
- 2 to 5 millimetres screenings (50 millimetres depth);
- 20 millimetres screenings, surrounded by geotextile fabric (150 millimetres minimum depth);
- Runoff drains to the roadway kerb and gutter which are directed to the permeable pavement surface. It then infiltrates this surface and fills the storage voids in the pavement base material before slowly infiltrating to the underlying soil;
- The pavement is designed to retain all runoff generated from the catchment area during storm events up to and including the 5 year ARI event. This translates to the capture of more than 95% of all stormwater runoff;
- In periods between storms, water stored in the pavement infiltrates to the underlying soil making this storage available for the next event;

- In large storms (>5 year ARI), short-term ponding occurs on the pavement (up to 40 millimetres depth). Excess runoff continues past the parking bays and enters the existing stormwater network via side entry pits at the northern end of Kirkcaldy Avenue;
- Allowance is made in the design for a 90% reduction in infiltration capacity over the 20 year design life. To avoid exceeding this level of blockage, it was recommended that the permeable surface be cleaned twice a year with a mechanical suction brush;
- Pollutants borne within the runoff are contained on site, the majority being trapped within the pavement layers, improving water quality in the nearby creek system; and
- The system provides increased levels of soil moisture, available to trees and grass in the vicinity of the parking bays.

Car Park, Linden Gardens, City of Burnside

City of Burnside has a water conservation goal of reducing total water consumption in the City by 25% by 2020.

The Linden Gardens Project demonstrates ways to collect and manage stormwater on site. The project involved the use of permeable paving (Hydrapave) to improve stormwater quality and provide stormwater detention.

The project also involved the inclusion of a mini wetland, a 70 metre soakage trench and a rainwater tank providing on-site stormwater retention. The rainwater tank is utilised for garden irrigation. Local indigenous plant species are used in a domestic or commercial scale setting.


Figure 7.5 Construction of the Pervious Pavements, Linden Gardens

Source: Courtesy of City of Burnside

The car park area is 670 square metres. Construction commenced in mid November 2002 and the site was completed with plantings in place by mid February 2003. Maintenance of the carpark consists of a regular visit by the City of Burnside street sweeper truck at about one month intervals.

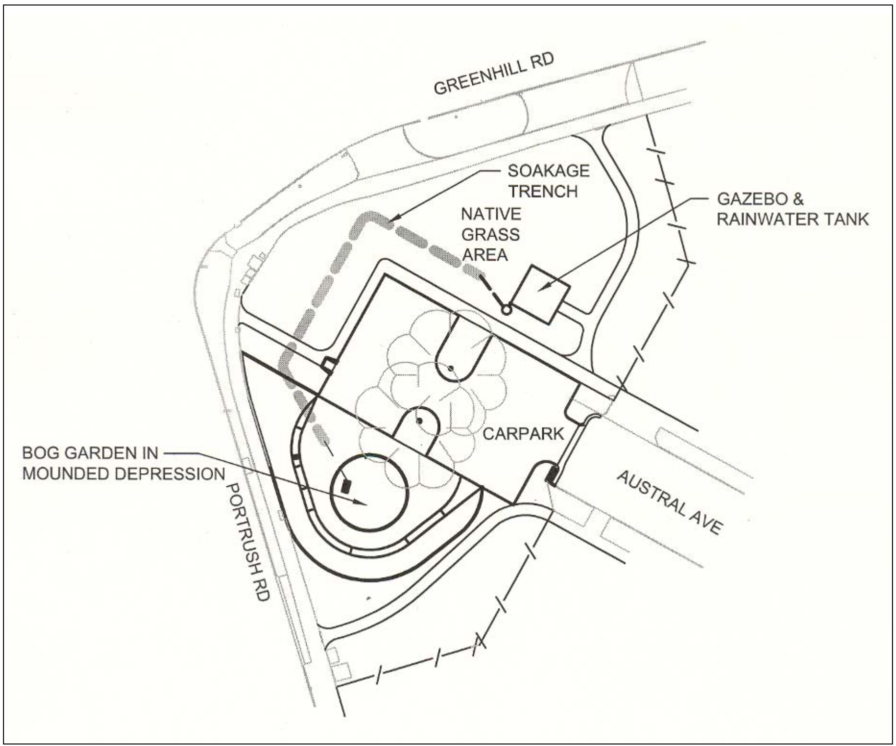


Figure 7.6 Location Plan of the Pervious Pavements, Linden Gardens

Source: Courtesy of the City of Burnside

The costs for the development were approximately:

- Total Cost: About $130,000
- Carpark: About $33,000 ($100/m^2)

$14,000 of the total cost was paid for by grant money.

7.8 Useful Resources and Further Information

Fact Sheets

www.wsud.org/downloads/Planning%20Guide%20&%20PN's/06-Paving.pdf

Practice Note 6 Paving – WSUD in the Sydney Region

www.moreland.vic.gov.au/pdfs/Environment%20Porous_Paving.pdf

Porous Paving fact sheet – Melbourne Water

Legislation

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA Information – Environmental Noise

www.environment.sa.gov.au/epa/pdfs/building.pdf

EPA Handbook for Pollution Avoidance on Building Sites

www.epa.sa.gov.au/pdfs/epp_noise_ind.pdf

Environment Protection (Industrial Noise) Policy 1994

www.epa.sa.gov.au/pdfs/info_construction.pdf

EPA information – Construction Noise

General Information

www.cmaa.com.au

Concrete Masonry Association – PermPave Software

www.wsud.melbournewater.com.au/content/treatment_measures/porous_paving.asp

Melbourne Water

www.urbanwater.info/engineering/BuiltEnvironment/PorousPavements.cfm

Urban Water Information

Design Information

http://portal.water.wa.gov.au/portal/page/portal/WaterManagement/Stormwater/StormwaterMgtManual/chapter9/Content/Chapter%2009%20BMP%203.3%20-%20Infiltration%20Systems%20-%20Pervious%20Pav.pdf

*Pervious Pavements – Stormwater Management Manua*l, Western Australia www.wsud.org/tech.htm

Water Sensitive Urban Design Technical Guidelines for Western Sydney

Suppliers

www.atlantiscorp.com.au

Atlantis

www.rocla.com.au

Rocla Products

www.cmbrick.com.au/

Ecopave

www.boral.com.au/hydrapave/default.asp?AUD=buildingDesignProfessional_MasonryProducts

Boral (HydraPave)

http://tepc.com.au/catalog.php?id=9

Total Erosion and Pollution Control

7.9 References

ACT Planning and Land Authority (2007). *Water Sensitive Urban Design General Code.* Canberra, ACT. July. http://www.actpla.act.gov.au/__data/assets/pdf_file/0013/5440/Waterways.pdf.

Argue, J. R. (Ed, 2009) *WSUD: basic procedures for 'source control' of stormwater - a Handbook for Australian practice.* Editor: Argue, J.R., Authors: Argue, J.R., Allen, M.D., Geiger, W.F., Johnston, L.D., Pezzaniti, D., Scott, P., Centre for Water Management and Reuse, University of South Australia, 5th Printing, February 2009, ISBN 1-920927-18-2, Adelaide.

Borgwardt, S. (1994). Institute for Planning Green Spaces and for Landscape Architecture. University of Hanover.

Department of Environment WA (2004). *Stormwater Management Manual for Western Australia.* Perth, Western Australia. http://portal.environment.wa.gov.au/portal/page?_pageid=55,1508622&_dad=portal&_schema=PORTAL.

Gold Coast City Council (2007). *Water Sensitive Urban Design Guidelines.* June. http://www.goldcoast.qld.gov.au/t_standard2.aspx?PID=6866.

Hobart City Council (2006). *Water Sensitive Urban Design Site Development Guidelines and Practice Notes*. Hobart. http://www.hobartcity.com.au/HCC/STANDARD/PC_1124.html.

IE Aust. (2006). *Australian Runoff Quality: A Guide to Water Sensitive Urban Design*. New South Wales.

Melbourne Water (2005). WSUD *Engineering Procedures: Stormwater*. CSIRO Publishing.

Reddi, L. N. (2003). *Seepage in Soils: Principles and Applications*. Hoboken, John Wiley and Sons.

Upper Parramatta River Catchment Trust (2004). *Water Sensitive Urban Design, Technical Guidelines for Western Sydney*. Prepared by URS Australia Pty Ltd. http://www.wsud.org/tech.htm.

Urban Water Resource Centre (2002). Permeable Pavement – Port Adelaide Enfield Council Carpark. University of South Australia.

Appendix A

Design of Pervious Pavements Using the Design Storm Approach

Pervious Pavements Design Process Details

[Note: Equally important in the design of pervious paving systems for hydraulic performance is the structural performance of a pervious pavement system. The scope of this document does not currently cover the structural design of a pervious pavement. However, the reader is directed to the following design tool for the structural design of a permeable pavement:

The Lockpave-PermPave Software Package - Structural Design of Interlocking Concrete Segmental Pavements and Permeable Pavements (available to order from http://www.cmaa.com.au/html/TechInfo/TechInfoSale.html)]

Design Storm Selection (Q_{des})

The first step is the selection of the design storm to capture for detention, retention or infiltration. This must occur in consultation with the council and will generally relate to the 3 month ARI and 1 year ARI design storms.

Retention Volume

The required 'retention volume' of a pervious paving system is defined by the difference in inflow and outflow volumes for the duration of a storm. The inflow volume (V_i) will depend on the source runoff being routed through the pervious paving system. Inflow may include:

- Rainfall onto the pervious paving system only; or
- A combination of rainfall onto the pervious paving system and runoff from other impervious areas.

The inflow volume for the design storm on the pervious paving system (treatment surface) only is (Gold Coast City Council 2007):

$$V_i = \frac{A_s \times i}{10^3} \times D$$

Where:

V_i = inflow volume

A_s = estimated surface area of the paving (m^2)

i = average rainfall intensity for design storm (mm/hr)

D = duration of storm (hrs)

The inflow for a combination of rainfall onto the pervious paving system and runoff from other impervious areas is determined, as the product of the design storm flow and the storm duration (Gold Coast City Council 2007):

$$V_i = Q_{des} \times D$$

Where:

V_i = inflow volume (for storm duration D) (m^3)

Q_{des} = design storm flow for sizing (Rational Method, Q= CIA/360 (m^3/s))

D = storm duration (hrs x 3600 s/hr)

Outflow from the pervious paving system is via the base (and in some cases the sides) of the infiltration media and is dependent on the area and depth of the structure. It is calculated using the filtration rate through the filter layer media and the storm duration.

The maximum filtration rate represents the maximum rate of flow through the paving system and is calculated by applying Darcy's equation as follows (Gold Coast City Council 2007):

$$Q_{\max} = K_{sat} \times A \times \frac{h_{\max} + d}{d}$$

Where:

Q_{max} = maximum filtration rate (m^3/s)

K_{sat} = filter layer saturated hydraulic conductivity (m/s)

A = area of the pervious paving (m^2)

h_{max} = depth of pondage above the soil filter (m)

d = depth of filter media (m)

Given there is no detention depth or ponding above the surface of the pervious paving, and conditions are likely to be fully drained, then (Gold Coast City Council 2007):

$$\frac{h_{\max} + d}{d} = 1$$

Outflow volume is calculated as (Gold Coast City Council 2007):

$$V_o = Q_{\max} \times D$$

Where:

V_o = outflow volume (m^3)

Q_{max} = maximum filtration rate (m^3/s)

D = duration of storm event

Thus, the required detention volume (V_d) of a pervious paving system can be calculated as follows (Gold Coast City Council 2007):

$$V_d = \frac{V_i - V_o}{p}$$

Where:

V_d = required detention volume (m^3)

V_i = inflow volume (m^3)

V_o = outflow volume (m^3)

p = porosity of the retention trench (gravel = 0.35)

Note: Volume calculations may need to be revised if further steps in the design process result in changes to the expected surface area of the pervious paving system.

In cases where zero surface flow is required, all design storm events should be assessed to determine the maximum storage requirement.

Depth

The depth of the pervious paving system will be determined from site constraints and the structural requirements of the paving system.

Surface Area Check

To this point in the design process an assumed surface area may have been used. A check and final surface area of the pervious paving should be determined using two steps:

Calculate surface area based on the volume and required depth; and

Check surface area has capacity to infiltrate peak flows for design storm.

The surface area of the pervious paving system should be checked using the following equation (Gold Coast City Council 2007):

$$A_s = \frac{Q_{peak}}{(1 - B) \times K_{sat}}$$

Where:

Q_{peak} = peak inflow to pervious paving surface (m^3/s)

B = blockage factor (this should be estimated based on non-pervious structural elements (e.g. plastic/concrete grids)

K_{sat} = saturated hydraulic conductivity of paving surface (e.g. concrete/asphalt)/or pervious material between pavers.

Underdrainage Design and Check

To ensure slotted pipes are of adequate size, several checks are required to ensure:

- The perforations are adequate to pass the maximum filtration rate;
- The pipe itself has sufficient capacity; and
- That the material in the filter layer will not be washed into the perforated pipes (consider a transition layer).

The capacity of the perforated under-drains need to be greater than the maximum filtration rate to ensure the filter media drains freely and does not become the hydraulic 'control' in the pervious paving system (i.e. to ensure the filter layer sets the travel time for flows from the aggregate layer rather than the perforated under-drainage system).

To ensure the perforated under-drainage system has sufficient capacity to collect and convey the maximum filtration rate, it is necessary to determine the capacity for flows to enter the under-drainage system via the perforations in the pipes. To do this, orifice flow can be assumed and the sharp edged orifice equation used. Firstly, the number and size of perforations needs to be determined (typically from manufacturer's specifications) and used to estimate the flow rate into the pipes, with the maximum driving head being the depth of the pervious paving system. It is conservative but reasonable to use a blockage factor to account for partial blockage of the perforations by the drainage layer media. A 50% blockage of the perforations should be used (Gold Coast City Council 2007).

The flow capacity of the perforations is thus (Gold Coast City Council 2007):

$$Q_{perf} = B \times C_d \times A\sqrt{2 \times g \times h}$$

Where:

Q_{perf} = flow through perforations (m^3/s)

C_d = orifice discharge coefficient (0.6)

A = total area of the orifice (m^2)

g = gravity (9.81 m/s^2)

h = maximum depth of water above the pipe (m)

B = blockage factor (0.5)

If the capacity of the drainage system is unable to collect the maximum filtration rate additional under-drains will be required.

After confirming the capacity of the under-drainage system to collect the maximum filtration rate, it is necessary to confirm the conveyance capacity of the underdrainage system is sufficient to convey the collected runoff. To do this, Manning's equation can be used (which assumes pipe full flow but not under pressure). The Manning's roughness used will be dependant on the type of pipe used.

Under-drains should be extended vertically to the surface of the pervious paving system to allow inspection and maintenance when required. The vertical section of the under-drain should be unperforated and capped to avoid short-circuiting of flows directly to the drain.

Check Emptying Time

Emptying time is defined as the time taken to fully empty a detention volume following the cessation of rainfall. This is an important design consideration as the computation procedure associated with the outflow volume assumes the storage is empty prior to the commencement of the design storm event.

Australian Runoff Quality (IE Aust. 2006) suggests an emptying time of the detention storage of pervious paving systems to vary from 12 hours to 84 hours. Designers should aim to have a drainage time of 24 to 48 hours. Emptying time is calculated simply as the ratio of the volume of water in temporary storage (dimension of storage x porosity) to the filtration rate through the filter layer (hydraulic conductivity x infiltration area) (Gold Coast City Council 2007):

$$t_e = \frac{1000 \times V_d \times \rho}{A_{\inf} \times K_{sat}}$$

Where:

t_e = emptying time (hours)

V_d = detention volume (m^3)

ρ = voids ratio of storage

A_{inf} = infiltration area (m^2)

K_{sat} = filter layer saturated hydraulic conductivity (mm/hr).

Check Requirement for Impermeable Lining

The saturated hydraulic conductivity of the natural soil profile surrounding the paving system should be tested together with depth to groundwater, chemical composition and proximity to structures and other infrastructure. This is to establish if an impermeable liner is required at the base (only for systems designed to preclude ex-filtration to in-situ soils) and/or sides of the pavement sublayers. If the saturated hydraulic conductivity of the paving system is more than one order of magnitude (10 times) greater than that of the surrounding in-situ soil profile, no impermeable lining is required (Gold Coast City Council 2007).

Appendix B
Checklists

Pervious Pavement

Design Calculation Checklist

Calculation Task	Outcome	Units
Catchment Characteristics:		
1. Catchment area contributing to paving system		Ha (or m^2)
2. Catchment land use (ie residential, commercial etc)		
3. Storm event entering pervious paving system (minor or major)		Year ARI
4. Estimated surface area of paving system		Ha (or m^2)
Confirm Design Objectives and Pavement Type:		
5. Confirm design objective as defined by conceptual design		
6. Confirm treatment performance		
7. Confirm paving type		
8. Detention system only		
Pre-treatment Design:		
9. Appropriate treatment to avoid clogging		
Determine Design Flows:		
10. Minor storm		Year ARI
11. Major storm		Year ARI
12. Time of concentration		minutes
13. Design runoff coefficient:		
Minor storm		
Major storm		
14. Peak design flows:		
Minor storm		m^3/s
Major storm		m^3/s
Size Pervious Paving System:		
15. Design storm flow		m^3/s
16. Inflow volume		m^3

Calculation Task	Outcome	Units
17. Outflow volume		m^3
18. Detention volume		m^3
19. Depth		m
20. Surface area check ok		m^2
Under-drain Design and Check:		
21. Flow capacity of filter media		m^3/s
22. Perforations inflow check		
23. Pipe diameter		mm
24. Number of pipes		
25. Capacity of perforations		m^3/s
26. Check perforation capacity > filter media capacity		
Emptying Time Check:		
27. Calculated emptying time		hrs
28. Emptying time okay (12 – 48 hrs)		
Impermeable Lining Check:		
29. Impermeable lining required		
Pervious Paving Layers Specified:		
30. Pervious paving surface type and depth		m
31. Bedding layer material and depth		m
32. Underdrainage layer material and depth		m
Inflow / Overflow Structures		
33. Overflow pipe:		
34. Pipe capacity		m^3/s
35. Pipe size		mm diam
36. Overflow pit:		
37. Pit capacity		m^3/s
38. Pit size		mm x mm

Source: Adapted from Gold Coast City Council (2007)

Pervious Pavements

Design Assessment Checklist

Asset ID:				
Pervious Paving Location:				
Hydraulics:	Minor Storm (m^3/s):		Major Storm (m^3/s):	
Area:	Catchment Area (ha):		Infiltration Area (m^2):	
	Detention Volume (m^3):			

Pavement Type	**Yes**	**No**
1. Pavement type appropriate to site based on traffic load, amenity and built environment character		
2. Pervious paving is detention system only (no infiltration)		
3. Pervious paving on slope less than 4%		
Pre-treatment	**Yes**	**No**
4. Appropriate pre-treatment provided		
5. Contributing catchment adequately stabilised and not a source of sediment		
Pervious Paving System	**Yes**	**No**
6. Design objective established		
7. Has the appropriate design storm been selected		
8. Pervious paving system designed appropriately and checks for detention volume and surface area undertaken		
9. Under-drainage provided flowing away from other conventional paved surfaces to stormwater network		
10. Emptying time checked		
11. Impermeable lining included		
12. Pervious paving layers specified appropriately		

Flow Management	Yes	No
13. Overall flow conveyance system sufficient for design flood event		
14. Bypass/overflow sufficient for conveyance of design flood event		
Comments		

Pervious Pavements

Construction Inspection Form (During Construction)

Asset ID:		Inspected By:	
Site:		Date:	
Constructed By:		Time:	
Contact During Visit:		Weather Conditions:	

Items Inspected	Checked		Satisfactory	
	Yes	No	Yes	No
A. Functional Installation				
Preliminary Works				
1. Erosion and sediment control				
2. Traffic control measures				
3. Location same as plans				
4. Site protection from existing flows (diverted around site)				
5. Excavation as designed				
6. Side slopes are stable				
Pre-treatment				
7. Contributing catchment stabilised / not a sediment source				
Structural components				
8. Location and levels of pervious paving system and overflow points as designed				
9. Pipe joints and connections as designed				
10. Concrete and reinforcement as designed				

Items Inspected	Checked		Satisfactory	
	Yes	No	Yes	No
11. Inlets appropriately installed				
12. Correct fill media/modular system used				
13. Provision of geofabric around aggregate layer				
B. Sediment And Erosion Control				
14. Stabilisation immediately following earthworks				
15. Silt fences and traffic control in place				
16. Temporary protection layers in place (if appropriate)				
C. Operational Establishment				
17. Temporary protection layers removed				
18. Surface of paving installed/ cleaned				
Comments On Inspection				
Actions Required				
1.				
2.				
3.				
Inspection Officer Signature:				

Source: Gold Coast City Council (2007)

Pervious Pavements

Construction Inspection Form (After Construction)

Asset ID:		**Inspected By:**	
Site:		**Date:**	
Constructed By:		**Time:**	
Contact During Visit:		**Weather Conditions:**	

Items Inspected	**Checked**		**Satisfactory**	
	Yes	**No**	**Yes**	**No**
1. Confirm level of inlets and outlets				
2. Traffic control in place				
3. Confirm structural element sizes				
4. Layers of paving system as specified				
5. Confirm pre-treatment is working				
6. Check for uneven settling of surface				
7. No surface clogging				
8. Maintenance access provided				
9. Construction generated sediment and debris removed				
Comments On Inspection				
Actions Required				
1.				
2.				
3.				
4.				
Inspection Officer Signature:				

Source: Gold Coast City Council (2007)

Pervious Pavements

Maintenance Inspection Form

Asset ID:		**Date of Visit:**	
Location:		**Time of Visit:**	
Description:			
Inspected By:			
Weather:			

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
	Y	N	Y	N	
Debris Cleanout					3 months
1. Pavement surface clear of debris					
Pavement Surface					3 months
2. Sediment build up					
3. Potholes					
4. Cracking of pavement					
5. Significant pavement deflection					
6. Damage/vandalism					
Dewatering					3 months
7. Pavement surface dewatering between storms					
8. Replacement required of clogged pavement					
Outlet / Overflow					Annual
9. Outlet condition					
10. Evidence of erosion downstream					

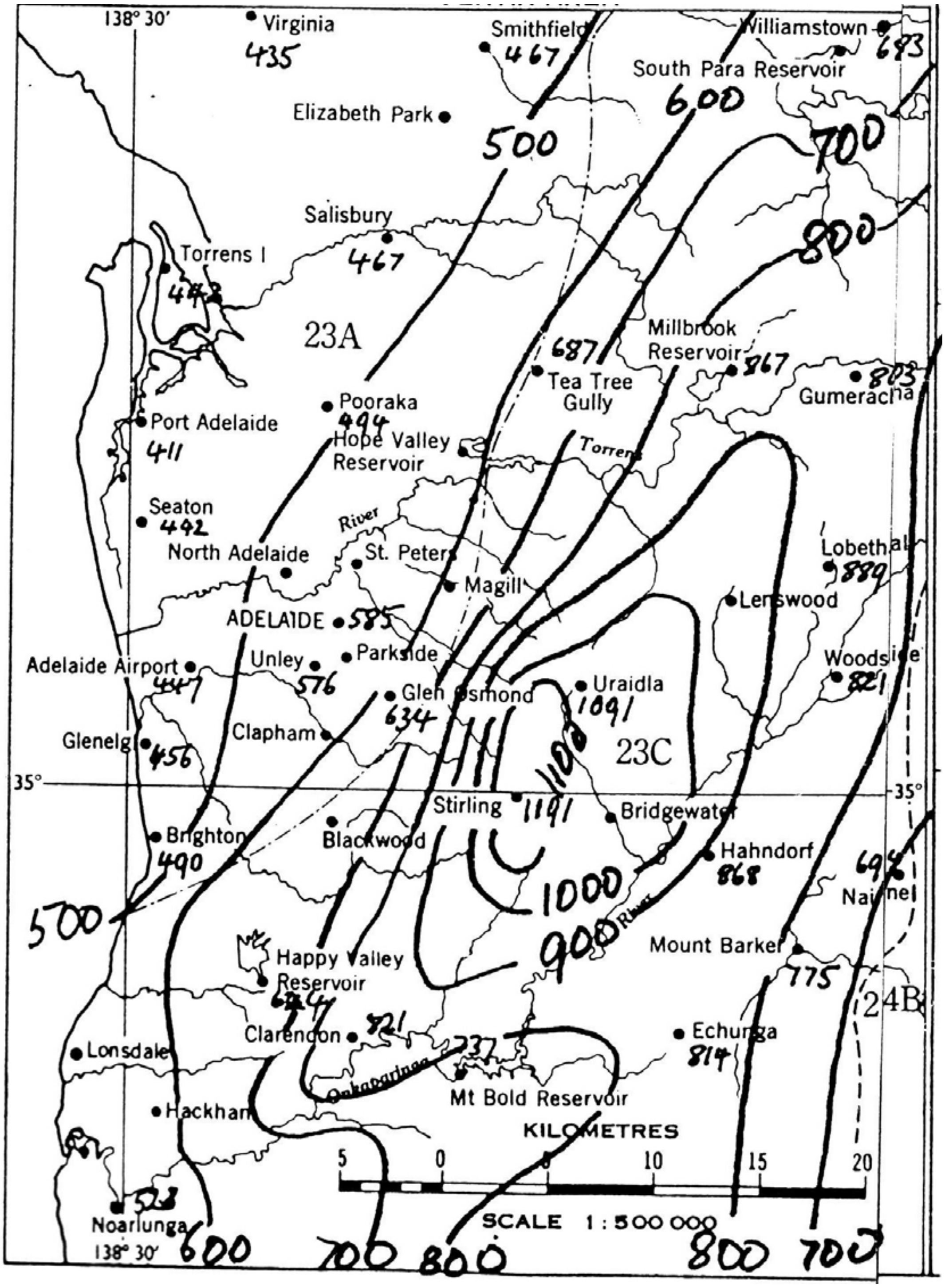
Comments On Inspection
Actions Required
1.
2.
3.
4.
5.

Source: Upper Parramatta River Catchment Trust (2004), Gold Coast City Council (2007)

Appendix C

Design Using Hydrological Effectiveness Type Curves

Annual Rainfall for Greater Adelaide Region



Equivalent impervious area (EIA) for pervious pavements involves use of runoff coefficients that are significantly less than those used to determine this parameter in flood control design. The reason for this is the high proportion of small runoff events – incorporating greater (relative) losses – that provide the database of these systems. A_{EIA} should therefore be calculated for use in the hydrological effectiveness graphs applying a factor of 0.83 to the conventional C_{10} values in flood control practice. Thus, for example, for paved areas, A::

$A_{EIA} = C_{10} \times 0.83 \times A = 0.75A$

Where: $C_{10} = 0.90$

It is possible, using sets of hydrological effectiveness curves, to determine the storage requirement or discharge rate necessary to achieve a target efficiency for particular circumstances. Storage requirement is expressed in terms of mean annual runoff volume (% MARV); discharge refers to the flow rate leaving the device whether it be through, for example, infiltration or slow drainage to an aquifer or a combination of both.

Each set of hydrological effectiveness curves takes account of all independent variables, as explained above. Therefore, a unit discharge rate, q, is introduced as a function of flow rate leaving the device and effective impervious area (EIA).

The set of hydrological curves for the Greater Adelaide Region is presented below in the following format:

Horizontal axis – storage expressed as a % of mean annual runoff volume %(MARV), β

$$\beta = \frac{\forall}{A_{EIA} \times X} \text{ x100}$$

Where:

$\forall$ = storage volume (m³)

A_{EIA} = equivalent impervious area (m^2)

(incorporating an appropriate volumetric runoff coefficient)

X = average annual rainfall (m)

Vertical axis – discharge unit rate, q, stated in L/s per m^2 of equivalent impervious area

Where infiltration is the only form of discharge:

$$Q_d = k_h \times U \times A_{avail}$$

Hence:

$$q = \frac{k_h \times U \times A_{avail}}{A_{EIA}}$$

Where:

k_h = host soil hydraulic conductivity (m/s)

U = moderation factor (see below)

A_{avail} = base area of infiltration device (m^2)

A_{EIA} = catchment EIA (m^2)

For 'slow' release to a drainage system or to meet a harvesting demand:

$$q = \frac{Q_d}{A_{EIA}}$$

Q_d= constant discharge rate (L/s)

Combinations of the two forms of discharge (infiltration and pipe) are possible: 'composite' values (simple addition) of q are needed in such cases.

Soil moderation factor, U

According to Allen et al (2005), five soil permeability categories are provided :

Sandy soil :	$k_h > 5\times10^{-5}$ m/s
Sandy clay :	k_h between 1×10^{-5} and 5×10^{-5} m/s
Medium clay and some rock :	k_h between 1×10^{-6} and 1×10^{-5} m/s
Heavy clay :	k_h between 1×10^{-8} and 1×10^{-6} m/s
Constructed clay :	$k_h < 1\times10^{-8}$ m/s,

Where k_h is the value of hydraulic conductivity determined by Jonasson's (1984) 'falling head' auger hole method.

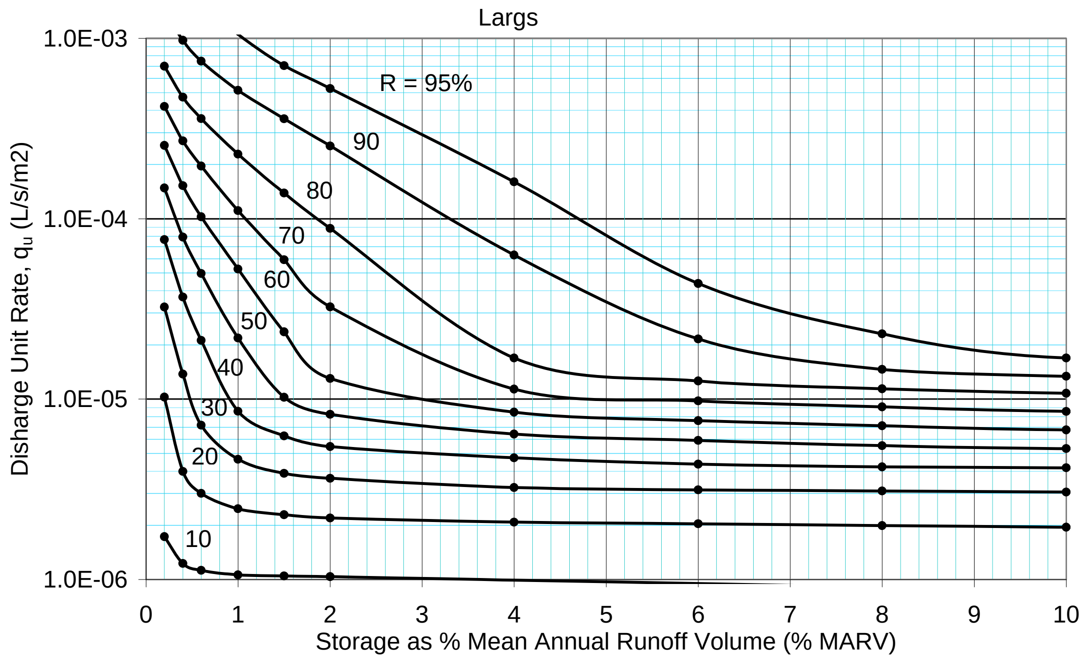
When the hydraulic conductivity results from a small volume infiltration test are compared with field data from infiltration systems, it is found that field hydraulic conductivity is different. This observation has led to the introduction of a correction factor, moderation factor, U, which should be applied to hydraulic conductivity, kh, in the formulae which follow (Argue 2004):

Clay soils - U = 2.0

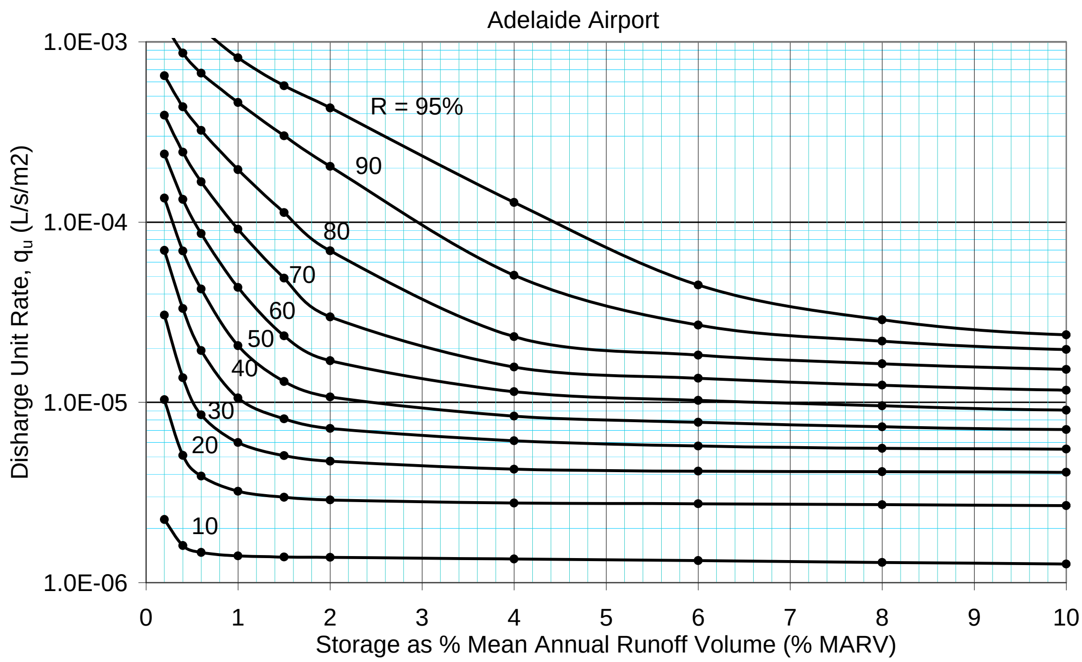
Sandy clay soils - U = 1.0

Sandy soils - U = 0.5

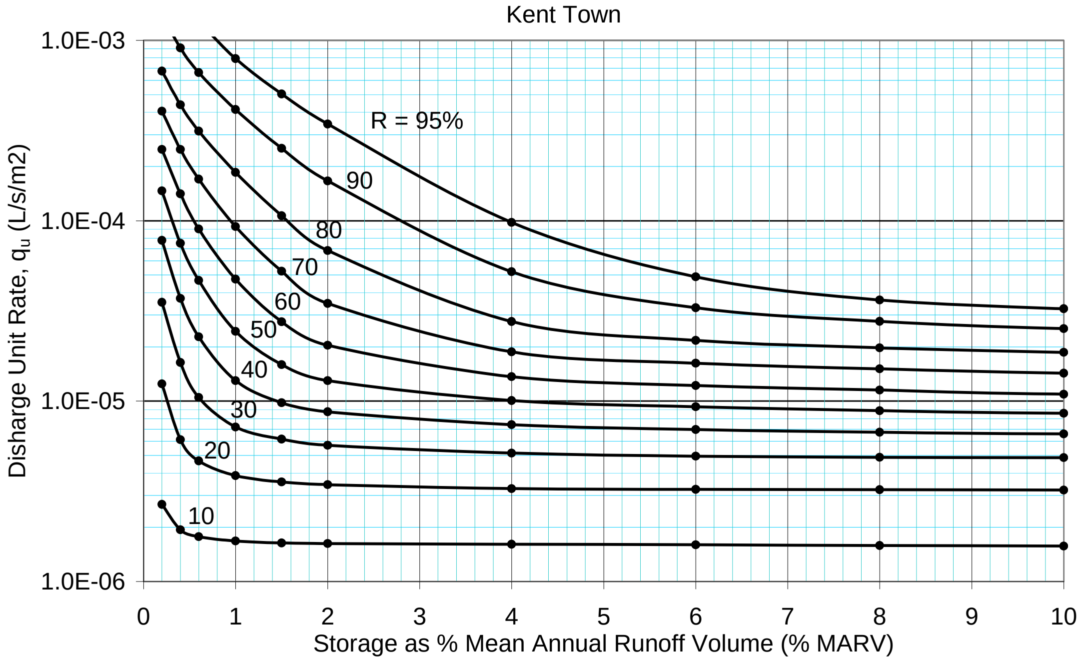
Rainfall = 300-400 millimetres per annum



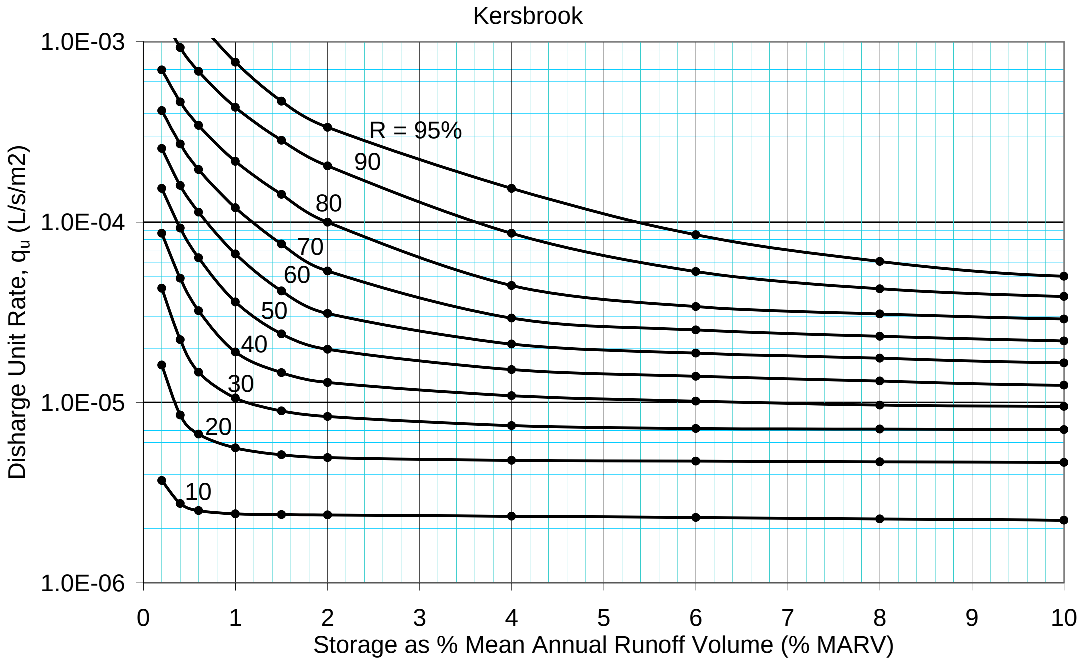
Rainfall = 400-500 millimetres per annum



Rainfall = 500-600 millimetres per annum



Rainfall = 600-800 millimetres per annum



Appendix D

Hydrological Effectiveness Type Curves Illustrative Example

Hydrological Effectiveness Type Curves Illustrative Example

Location: Adelaide (Kent Town)

Average annual rainfall: X = 545 mm/yr

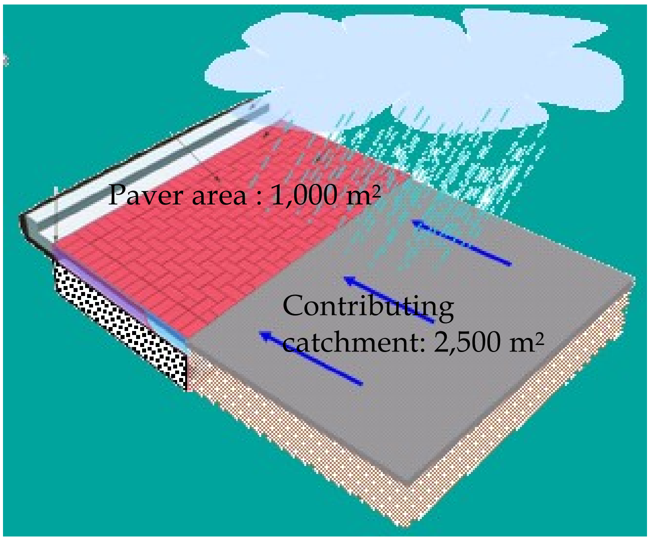
Soil: Medium clay, $k_h = 1 \times 10^{-6}$ m/s

Moderation factor, U = 2.0

Contributing catchment: = 2500 m^2 (EIA)

Space available: A_{avail} = 1000 m^2

Combined Equivalent Impervious Area (EIA) = 3500 m^2



Storage device: gravel-filled basecourse S = 0.2

Hydrological effectiveness, R = 95%

Objective: Determine depth of permeable paving basecourse (if required depth exceeds maximum allowable, determine slow drainage, necessary to limit depth to maximum allowable)

Step 1: Determine volume of soak away

According to Allen et al (2005), five soil permeability categories are provided:

Sandy soil:	$k_h > 5\times10^{-5}$ m/s
Sandy clay:	k_h between 1×10^{-5} and 5×10^{-5} m/s
Medium clay and some rock:	k_h between 1×10^{-6} and 1×10^{-5} m/s

Heavy clay: k_h between 1×10^{-8} and 1×10^{-6} m/s

Constructed clay: $k_h < 1\times10^{-8}$ m/s,

Where k_h is the value of hydraulic conductivity determined by Jonasson's (1984) 'falling head' auger hole method.

When the hydraulic conductivity results from a small volume infiltration test are compared with field data from infiltration systems, it is found that field hydraulic conductivity is different. This observation has led to the introduction of a correction factor, moderation factor, U, which should be applied to hydraulic conductivity, k_h, in the formulae which follow (Allen et al. 2005):

Clay soils - U = 2.0

Sandy clay soils - U = 1.0

Sandy soils - U = 0.5;

Hence:

Moderated hydraulic conductivity:

$$k_h = (1 \times 10^{-6}) \times U$$

$$= 1 \times 10^{-6} \times 2.0 = 2 \times 10^{-6} \text{ m/s}$$

For sandy soils the moderation factor U = 2. For further information about the moderation factor refer to **Chapter 10** of the Technical Manual.

Infiltration discharge unit rate, q, L/s/m² of EIA

$$q = \frac{k_h \times U \times A_{avail}}{A_{EIA}}$$

$$q = 2 \times 10^{-6} \times 1000/3500$$

$$= 5.7 \times 10^{-4} \text{ L/s/ m}^2$$

Locate q on figure;

It can be seen that the required storage ratio β (%MARV) is 1.3%.

Hence volume of soak away required:

$$\beta = \frac{\forall}{A_{EIA} \times X} \text{ x } 100\text{...........}$$

$$\forall = (\beta / 100) \text{ x EIA x X}$$

$$\forall = 0.013 \text{ x } 3500 \text{ x } 0.545$$

$$\forall = 24.8 \text{ m}^3$$

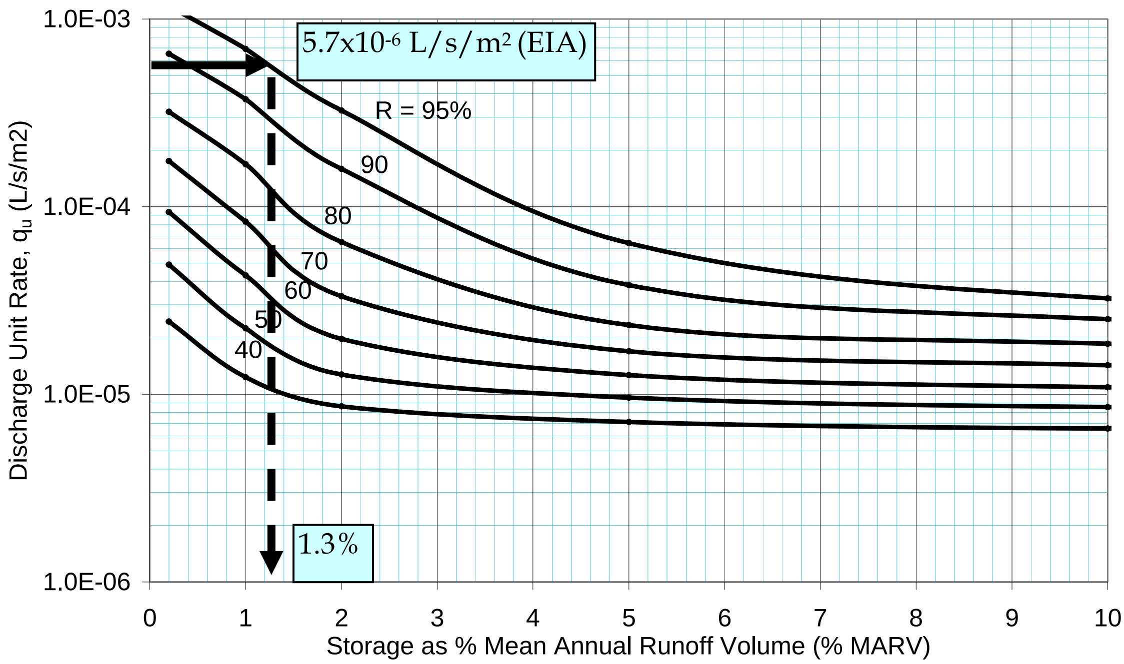
Step 2: Determine depth, H, of soak away

$\forall = H \times A_{avail} \times eS..$

Hence, depth required: $H = \frac{\forall}{A_{avail} \times e_s}$

H = 24.8/(1000 x 0.2)

= 124 mm (say 130 mm)

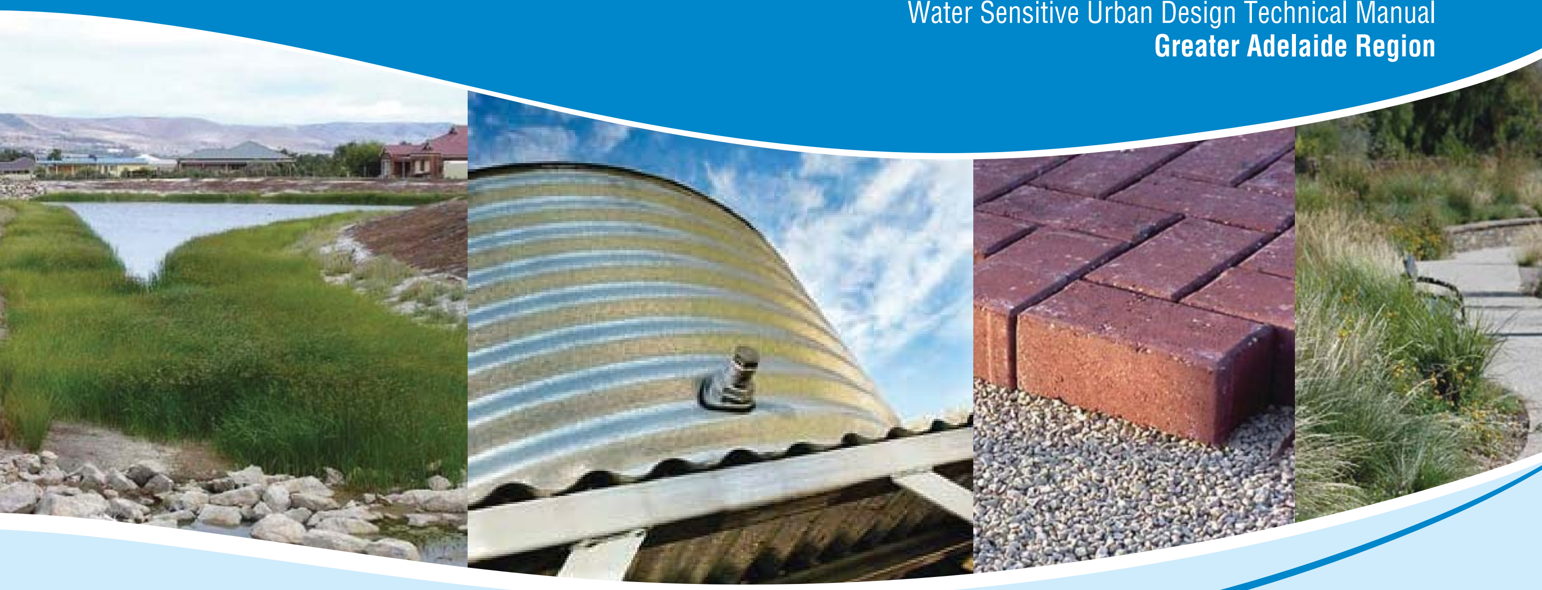


July 2009

Chapter 8

Urban Water Harvesting and Reuse

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Chapter 8
Urban Water Harvesting and Reuse

8.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Urban water harvesting and reuse is one of those measures.

Sustainable approaches to urban water management involve the use of locally generated runoff and wastewater to supplement traditional urban water sources.

The incorporation of these water sources in the urban water resource planning framework reflects the increased scarcity of water sources to meet demands; technological advancements; increased public acceptance; and improved understanding and management of risks including those concerning public health.

There is a myriad of methods to utilise runoff and wastewater as a resource.

Applications

Urban water harvesting and reuse schemes can be developed for existing urban areas or new developments and are mainly suitable for non-drinking purposes such as:

- Residential uses (including toilet flushing);
- Irrigation of public open spaces (including sporting grounds);
- Industrial uses; and
- Water features.

Harvesting of urban water is possible over a number of scales, from individual domestic allotment level to community scale or industrial precinct development.

Key factors in determining the type and scale of harvesting possible is dependent on:

- The proposed water source and quality (i.e. runoff, treated wastewater etc);
- The proposed water use (i.e. irrigation);

- The demand pattern and volume (i.e. summer for irrigation);
- The seasonality and volume of water available for harvest (depends on type and source of water);
- The storage options and site constraints (if required);
- Treatment options (if required);
- Objectives for harvesting system (i.e. reduced mains water supply or reduced runoff from site);
- Capital and operational costs including monitoring and maintenance costs.

Capture and use of water on site is an environmentally preferable source of alternative water as this method generally does away with the need for piping or pumping. Fewer resources are needed and greenhouse gas emissions are reduced.

As urban water harvesting and reuse can be applied at a range of scales and can utilise a range of water sources and storage options, this chapter only provides an overview of the range of options and the factors to be considered. The reader is referred to more detailed information as summarised in **Section 8.7**.

It should be noted that this chapter does not address potable (i.e. drinking) reuse of stormwater or wastewater. The use of rainwater for potable supply is addressed in **Chapter 5** – Rainwater Tanks.

These documents also do not cover potential uses for water reuse in growing crops (such as reclaimed water use in McLaren Vale and Virginia), or in aquaculture.

Other chapters of the WSUD Technical Manual for the Greater Adelaide Region which may be relevant include:

- Swales and Buffer Strips (**Chapter 11**);
- Sedimentation Basins (**Chapter 12**);
- Constructed Wetlands (**Chapter 13**); and
- Wastewater Management (**Chapter 14**).

Water Sources

The Greater Adelaide Region has highly seasonal rainfall. This seasonal variation in rainfall affects the availability of stormwater and rainwater (or roof runoff). To maintain security of supply when demands are present for these water sources, storage is required.

Wastewater has less variation in supply as it is generally dependent on mains water use.

Climate in the region also impacts on the demand patterns for water, particularly outdoor uses. This is primarily evident for irrigation with high demand in summer and low demand in winter. Climatic conditions provide challenges which need to be addressed during the concept design phase.

Each available source of water available for urban water harvesting and reuse schemes is discussed briefly below.

Wastewater

Treated wastewater reuse can provide a relatively constant supply in the Greater Adelaide Region because its source is mains water. The production of wastewater is dependent on seasonal and diurnal fluctuations in water use habits. The primary technical disadvantage of wastewater reuse is the level of treatment and associated cost required to achieve the level of water quality necessary for reuse. The principal risk to human health is the inappropriate consumption of wastewater treated for non-potable uses. In addition, the public perception of treated wastewater reuse and possible health risks needs to be considered.

Further information on large scale reuse of wastewater can be found in **Chapter 14** – Wastewater Management.

Stormwater

South Australia is a leader in recycling stormwater. Existing stormwater harvesting schemes in Adelaide generate 6 GL/annum, with currently committed schemes expected to harvest an additional 12 GL/annum (Water For Good).

Stormwater can require a similar level of treatment to wastewater and can be a variable source of water that is dependent on rainfall patterns. Stormwater supply may not be available during long dry periods. A back up supply from another water source can be used to maintain continuity of supply.

Investigations into the public perception of water reuse show that the past use of water has an effect on how it is viewed (Po et al. 2003). From a health perspective, a study in Perth has shown that public perceptions of stormwater reuse are more positive than wastewater reuse (Mitchell et al. 2006).

Rainwater

Rainwater captured in rainwater tanks often requires little or no treatment and can be more easily used for a variety of end uses than stormwater and wastewater because of its higher raw water quality.

During long dry periods a rainwater supply may not be available but the provision of a mains water top up or bypass system can ensure continuity of supply. Further information on the use of roofwater can be found in **Chapter 5** - Rainwater Tanks.

It should be noted that it is possible to blend multiple water sources for recycling. The Mawson Lakes development in the City of Salisbury is an example of the utilisation of a combination of treated stormwater and wastewater.

Figure 8.1 Warning Sign of Recycled Water Use at Mawson Lakes Residential Development

Source: www.mawsonlakes.com.au

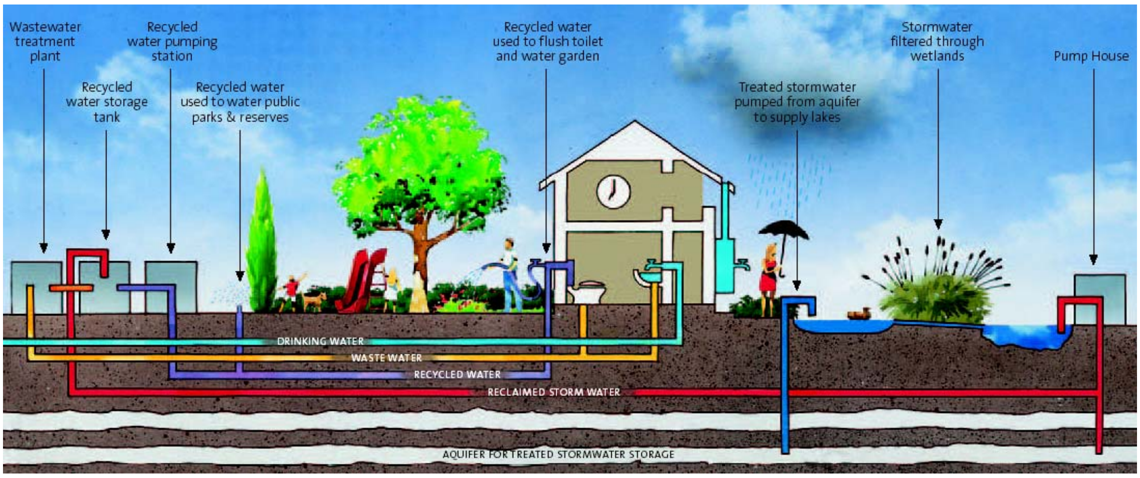


Figure 8.2 Schematic of Recycled Water Use at Mawson Lakes Residential Development

Source: www.mawsonlakes.com.au

Water Storage Options

The capacity of any harvesting and reuse scheme is significantly influenced by the size and possible type of storage system.

There are various types of storage systems including:

- Rainwater tanks;
- Underground storage tanks;
- Above ground storage tanks;
- Surface storages (e.g. dams or wetlands); and
- Groundwater (e.g. aquifer).

A summary of the advantages and disadvantages of these storage systems is contained in **Table 8.1**.

Storages used in urban water reuse schemes can provide a varying level of treatment in addition to other processes included in the treatment train. For example, storage in an aquifer can reduce the number of microorganisms present. Other water storages such as dams or tanks can reduce suspended solids and particulates through settling.

Table 8.1 Potential Advantages and Disadvantages of Various Storage Types

Storage Option	Advantages	Disadvantages
Open storages	■ Low capital and maintenance cost ■ Potential water quality improvement	■ Public safety ■ High evaporation ■ Contamination ■ Mosquito breeding potential ■ Higher potential for eutrophication ■ Aesthetic issues with fluctuating water levels
Above ground tanks	■ Potential water quality improvement ■ No evaporation ■ Limited public safety issues	■ Aesthetic issues ■ Space requirements
Underground tanks	■ Moderate capital and maintenance cost ■ No evaporation ■ No public safety issues	■ Higher capital cost ■ Higher maintenance costs
Aquifer	■ Little space required (unless wetland required for water quality treatment) ■ Cost effective ■ No evaporation ■ Prevents saltwater intrusion to aquifer	■ Required suitable geology ■ High treatment costs ■ Potential to pollute groundwater unless pre-treated ■ Recovery efficiency

Source: Adapted from Department of Environment and Conservation NSW (2006)

Public Perception

Public perception is a key issue for the design and implementation of water harvesting and reuse projects. In general, as the end use becomes more personal, support for water recycling falls (Po et al. 2003).

Investigations have also shown that there is a correlation between the scale of a water harvesting and reuse project and its degree of public acceptance. Water from a person's own home is generally more acceptable than a communal or neighbourhood scale water harvesting system. However, acceptance is high again with respect to a large scale system such as that serving a city (Mitchell et al. 2006).

8.2 Legislative Requirements and Approvals

A thorough investigation of required approvals and permits should be undertaken as part of the conceptual design of an urban water harvesting and reuse scheme. This would include consultation with:

- Local council;
- Environment Protection Authority;
- Department of Health;
- SA Water;
- Department of Water, Land and Biodiversity Conservation; and
- Natural Resources Management Boards.

A proposed urban water harvesting and reuse scheme needs to meet the requirements of a range of legislation including:

- *Development Act 1993*;
- *Environment Protection Act 1993*;
- *Natural Resources Management Act 2004*;
- *Local Government Act 1999*; and
- *Public and Environmental Health Act 1987.*

A brief description of the requirements of each is contained below.

Development Act 1993

An urban water harvesting and reuse scheme will generally be part of a larger development. However, whenever an urban water harvesting and reuse scheme is planned, it is advised that the local council be contacted to determine whether Development Approval is required under the *Development Act 1993*.

The likely issues that a council may want covered in a development application involving an urban water harvesting and reuse scheme include:

- Compatibility of the proposed scheme with council's objectives, plans or strategies, including any relevant strategic water management plan or strategy;
- Compatibility of the proposed plan with surrounding land uses (compliance with zoning requirements);
- Anticipated benefits and impacts associated with scheme construction and operation (including social, environmental and economic aspects);

- Consideration of environmental impacts during construction and operation phases;
- How public health and safety risks are addressed;
- Management arrangements (including monitoring and maintenance) for the scheme;
- What (if any) risks and/or financial obligations would be transferred to council if it operates the scheme (e.g. operations, maintenance, monitoring and reporting costs); and
- A management plan for the scheme (including monitoring and maintenance).

Environment Protection Act 1993

Any development, including the construction of an urban water harvesting and reuse scheme, has the potential for environmental impact which can result from vegetation removal, stormwater management and construction.

There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on a site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when an urban water harvesting and reuse scheme is being considered are discussed below.

Water Quality

Water quality in South Australia is protected under the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development. In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, building sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise potential for environmental impact during construction.

In addition, the discharge of water into any water body must meet the requirements of the Environment Protection (Water Quality) Policy 2003.

Noise

The issue of noise has the potential to cause nuisance during any construction works or ongoing operation (i.e. if pumps are required) of an urban water harvesting and reuse scheme. The noise level at the nearest sensitive receiver should be at least 5 dB(A) below the Environment Protection (Industrial Noise) Policy 1994 allowable noise level when measured and adjusted in accordance with that policy.

Reference should be made to the EPA Information Sheets on Construction Noise and Environmental Noise respectively to assist in complying with this policy (see **Section 8.7**).

Air Quality

Air quality may be affected during the construction phase of an urban water harvesting and reuse scheme. Dust generated by machinery and vehicular movement during site works, and any open stockpiling of soil or building materials at a site, must be managed to ensure that dust generation does not become a nuisance off site.

Waste

Any wastes arising from excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*.

For example, during construction all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal.

Guidance can be found in the EPA Handbook for Pollution Avoidance on Building Sites (see **Section 8.7**).

Licence

Certain activities – whether development or not – require a licence granted under the *Environment Protection Act 1993*.

The discharge of stormwater from stormwater infrastructure (from areas greater than 1 ha) to underground aquifers in the metropolitan Adelaide region is presently an activity specifically requiring a licence (Schedule 1, 4(2) of the *Environment Protection Act 1993*).

It should be noted that there is no provision in the licence for extraction of the water.

The Code of Practice for Aquifer Storage and Recovery (Environment Protection Authority South Australia 2004) outlines the requirements of the Environment Protection Authority for the storage of waters in aquifers.

It should be noted that the Code of Practice for Aquifer Storage and Recovery is currently under review by the EPA and a revised draft, which will cover managed aquifer recharge (MAR), is expected in late 2008.

Guidelines

The South Australian Reclaimed Water Guidelines (Treated Effluent) (Environment Protection Authority South Australia 1999) was developed by the Environment Protection Authority and the Department of Health.

The guidelines describe methods by which reclaimed water can be used in a sustainable manner without imposing undue risks to public health or the environment. It considers the use of reclaimed water for agricultural, municipal, residential (non-potable), environmental and industrial purposes. It provides information on the quality of reclaimed water required for each use, treatment processes, system design, operation and reliability, site suitability, and monitoring and reporting.

These guidelines should be consulted when considering an urban water harvesting and reuse scheme, in addition to the Australian Guidelines for Water Recycling (see below).

Natural Resources Management Act 2004

The *Natural Resources Management Act 2004* provides the statutory framework for water extraction from rivers, lakes and groundwater.

If groundwater is to be extracted from the aquifer, the proponent must obtain a licence from the Department of Water, Land and Biodiversity Conservation (DWLBC) to extract water as required by the *Natural Resources Management Act 2004*.

The proponent must also obtain a well construction permit from the DWLBC for any proposed wells (i.e. groundwater bores) that will intersect the water table.

DWLBC currently licenses the discharge of stormwater to underground aquifers wherever an EPA licence is not required under the *Environment Protection Act 1993*.

Public and Environmental Health Act 1987

The Department of Health (Environmental Health Branch) is responsible for the implementation of the *Public and Environmental Health Act 1987* in South Australia. This agency provides the required information and assistance in establishing an urban water harvesting and reuse scheme with regards to health issues.

National Guidelines

The Environment Protection and Heritage Council and the Natural Resource Management Ministerial Council have developed Australian Guidelines for Water Recycling (Environment Protection and Heritage Council 2006). The guidelines comprise a risk management framework and specific guidance on managing the health risks and the environmental risks associated with the use of recycled water.

Phase one of the guidelines focuses on large scale treated wastewater to be used for:

- Residential garden watering, car washing, toilet flushing and clothes washing;
- Irrigation for urban recreational and open space, and agriculture and horticulture;
- Fire protection and fire fighting systems;
- Industrial uses, including cooling water; and
- Greywater treated on site (including in high rise apartments and office blocks) for use for garden watering, car washing, toilet flushing and clothes washing.

The Australian Guidelines for Water Recycling (Environment Protection and Heritage Council 2006) call for a four step process to prepare the required risk management plan for a recycled water scheme. The guidelines state that a risk management plan should be prepared for every recycled water system.

Phase two of guideline development is currently in draft and focuses on three modules:

- Stormwater harvesting and reuse;
- Managed aquifer recharge; and
- Augmentation of drinking water supplies.

The Australian Guidelines are expected to replace the existing South Australian Reclaimed Water Guidelines (Treated Effluent) (Environment Protection Authority South Australia 1999) and will be the basis for assessment of urban water harvesting and reuse schemes.

8.3 Design Tools

A range of design tools is available for the concept and detailed design of urban water harvesting and reuse schemes as detailed in **Chapter 15**. The modelling tools which are able to assist include (but are not limited to):

- MUSIC;
- WaterCress; and
- E2.

Further information on these tools is contained in **Chapter 15**.

The local council will be able to advise as to whether modelling is required as part of the development application process.

8.4 Design Process

Overview

There is a range of scales and types of urban water harvesting and reuse schemes that can be designed and installed. The type of scheme can vary from a greywater diversion hose in a household yard for garden irrigation to a community scale dual reticulation system using tertiary treated wastewater. The scope and degree of complexity is dependent on the individual system.

Key drivers for complexity in the systems are:

- The number of users;
- The quality of the water to be recycled; and
- The end use.

The greater the treatment requirements, the more complex the treatment component and the more involved the monitoring and management systems will need to be.

Water harvesting and reuse schemes can be implemented either in existing urban areas or as part of a new urban development. The project's context will therefore influence the nature of the planning and design process.

The key steps in the design process for an urban water harvesting and reuse scheme include:

- Assess the site, catchment and appropriate regulatory requirements;
- Identify the objectives and targets;
- Identify potential options;
- Consult with key stakeholders and relevant authorities;
- Evaluate of options;
- Prepare a detailed design of selected option;
- Undertake the approvals process; and
- Develop an operations, maintenance and monitoring plan.

The design process is likely to be iterative, requiring several rounds of review in earlier stages as new information arises and negotiations progress with stakeholders (including end users) that may alter the objectives and/or available options.

Assess the Site, Catchment and Appropriate Regulatory Requirements

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of the site conditions is a fundamental part of designing a development that effectively incorporates WSUD.

This step identifies and assesses the potential constraints and opportunities of the proposed project site. Potential constraints may include:

- Topography;
- Land use (including surrounding catchment land use);
- Adjacent land uses (including potential land use conflicts);
- Watercourse characteristics;
- Vegetation and other sensitive ecosystems (potential biodiversity impacts);
- Soil characteristics, such as salinity or acid sulphate;
- Existing water management infrastructure;
- Depth to groundwater, groundwater quality and existing uses of the groundwater in the vicinity; and
- Statutory or regulatory constraints.

This step should identify opportunities for reusing treated stormwater or wastewater, as well as suitable locations for storages. Other aspects of the end users' operations may also be important, such as future development plans or land use changes that may affect longer term water use patterns.

The level of the site and catchment investigation required should match the size and scale of the development and its potential impacts (i.e. larger developments having a greater impact would require greater site investigation).

A staged approach to site investigations can be adopted to minimise costs. This involves an initial screening level assessment using readily available information to identify major constraints and opportunities, and then focusing efforts on any identified constraints.

An evaluation of the pollutants that may be present within runoff needs to be carried out on a catchment basis, as the quality of runoff for a reuse project is affected by the characteristics of the scheme's catchment. Pollutants will vary according to whether the catchment drains residential, industrial, rural or a combination of any of these land use types. For example, the risk of chemical pollution in a catchment increases with the extent and nature of industrial uses and paved roads, particularly those with high traffic volumes.

The impact of such diffuse pollution sources can be gauged by investigating water quality during wet and dry weather, or by referring to existing water quality data. Similarly, the scheme should investigate the impacts on water quality from any point sources of pollution. The hazard assessment for the scheme may need to consider both diffuse and point sources of pollution.

Concentrations of pollutants typically have seasonal or within event patterns, and heavy pollutant loadings can be avoided by being selective in the timing of diversions (e.g. not diverting flow during large floods when treatment systems are often bypassed). Knowledge of the potential pollutant profile helps to define water quality sampling and analysis costs when determining the viability of a project (for example, if there are any specific industrial activities upstream that contribute particular pollutants such as hydrocarbons).

Identify Objectives and Targets

The design objectives and targets will vary from one location to another and will depend on site characteristics, development form and the requirements of the receiving ecosystems. It is essential that these objectives are established as part of the conceptual design process and approved by the relevant council prior to commencing the engineering design.

Specifying the objectives for an urban water harvesting and reuse scheme is an important step for ensuring that it operates as intended.

In developing reuse schemes for a site, broader catchment or regional objectives are important. These could involve specified reductions in:

- Mains (potable) water use;
- Runoff flow rates and/or volumes;
- Runoff pollution loads;
- The effective (connected) impervious area of the catchment; and
- Wastewater disposal volumes.

Organisational objectives, government policies and environmental planning instruments may also provide a strategic context for the project.

The most common project objectives will relate to:

- Managing public health and safety risks;
- Managing environmental risks;
- Meeting the requirements of the end user, primarily relating to water quality, quantity and reliability of supply; and
- Protecting or enhancing visual amenity or aesthetics.

Further information on setting objectives can be found in **Chapter 3** of the Technical Manual.

Identify Potential Options

This step identifies various possible layouts for a scheme to meet the project's objectives.

Various combinations of WSUD measures can be used in a water harvesting and reuse scheme, depending on the nature of the site and the end uses. The design process needs to consider the following components:

- Collection (i.e. swales);
- Storage (i.e. rainwater tanks, wetlands, underground tanks);
- Treatment (i.e. wetlands, wastewater treatment plant); and
- Distribution.

This step is likely to involve modelling the outcomes from various options and identifying the degree to which each option meets the adopted project objectives. This could be iterative, modelling the influence of a number of key aspects of the project (such as different storage volumes against predicted outcomes), and may include modelling of:

- Water balance;
- Water pollution and environmental flows; and
- Water peak flows and flood levels.

A risk assessment approach should be utilised during this stage of the process.

Identify and Consult with Key Stakeholders

The designer (or applicant) should liaise with civil designers and council officers prior to proceeding any further to ensure:

- Urban water harvesting and reuse scheme will not result in water damage to existing services or structures;
- Access for maintenance to existing services is maintained;
- No conflicts arise between the location of services and WSUD devices; and
- The objectives are consistent with the council's directions for the area.

The council will also be able to advise whether:

- Development approval is required, and if so, what information should be provided with the development application;

- Any other approving authorities should be consulted; and
- Any specific council requirements need to be taken into consideration.

Key stakeholders should also be consulted throughout the planning process (depending on the scale of the scheme), particularly during the setting of project objectives. Their engagement in the scheme from the planning stage will:

- Allow for any concerns or misconceptions to be identified and addressed early in the scheme; and
- Provide opportunities for educating the community and the proponents and build user confidence in the scheme, resulting in greater use of treated water as an alternative to mains water.

The key stakeholders will depend on the nature of the scheme.

Evaluate Options

The various options identified should be evaluated, taking into account social, economic and environmental considerations.

The evaluation of options should primarily assess how well each option meets the project's objectives. It is likely that during this process trade offs between objectives may need to be assessed as, for example, it may not be cost effective to meet all objectives.

There is no widely used evaluation technique for urban water harvesting and reuse schemes. This may be partially due to the difficulty in quantifying many of the costs and benefits of such schemes, and where some of the costs and benefits can be attributed to parties not directly involved in the proposed scheme.

Possible evaluation techniques include:

- Cost-benefit analysis;
- Triple bottom line analysis; and
- Multiple criteria decision analysis.

Detailed Design of Selected Option

During the detailed design of the selected scheme, a risk management strategy should be developed. This should identify public health and environmental hazards and an appropriate mix of controls to be implemented during the design and operational phases.

Undertake Approvals Process

As discussed in **Section 8.2**, there are several approvals that would generally be required for an urban water harvesting and reuse scheme. Therefore, ensuring that there is adequate time to obtain the approvals is an important part of the process.

Maintenance and Monitoring

Appropriate maintenance of urban water harvesting and reuse schemes is important to ensure that the scheme continues to meet its design objectives in the long-term and does not present public health or environmental risks. The actual maintenance requirements will depend on the nature of the scheme. Maintenance may include measures relating to each element of a scheme.

Protection of treatment, retention and detention systems from contamination is a necessary part of designing an urban water harvesting and reuse system. This includes constructing treatment systems away from flood prone land, taking care with or avoiding the use of herbicides and pesticides within the surrounding catchment, planting non-deciduous vegetation, and preventing mosquitoes and other pests breeding in storage ponds.

Contingency plans should be developed to cater for the possibility of contaminated water being inadvertently utilised. These plans should focus on:

- Determining the duration of recovery pumping required (to extract contaminated water);
- Sampling intervals required; and
- Managing recovered water.

Regular inspections of a scheme are needed to identify any defects or additional maintenance required. The inspections may need to include:

- Storages for the presence of cyanobacteria (i.e. algae), particularly during warmer months;
- Spillways and creeks downstream of any on line storage after a major storm for any erosion;
- Water treatment systems;
- Distributions systems for faults (e.g. broken pipes); and
- Irrigation areas for signs of erosion, under watering, waterlogging or surface runoff.

8.5 Approximate Costings

Due to the variability in the scale and type of urban water harvesting and reuse schemes, it is difficult to provide an indication of the approximate costs of construction and operation of such schemes.

However, Kellogg Brown & Root Pty Ltd (2004) undertook a review of various scale stormwater harvesting schemes and was able to develop a relationship between unit production cost against average annual production which is presented in **Figure 8.3**. For example, it is estimated that a 10 ML/a stormwater harvesting scheme would have a water supply cost of $2/ kilolitre.

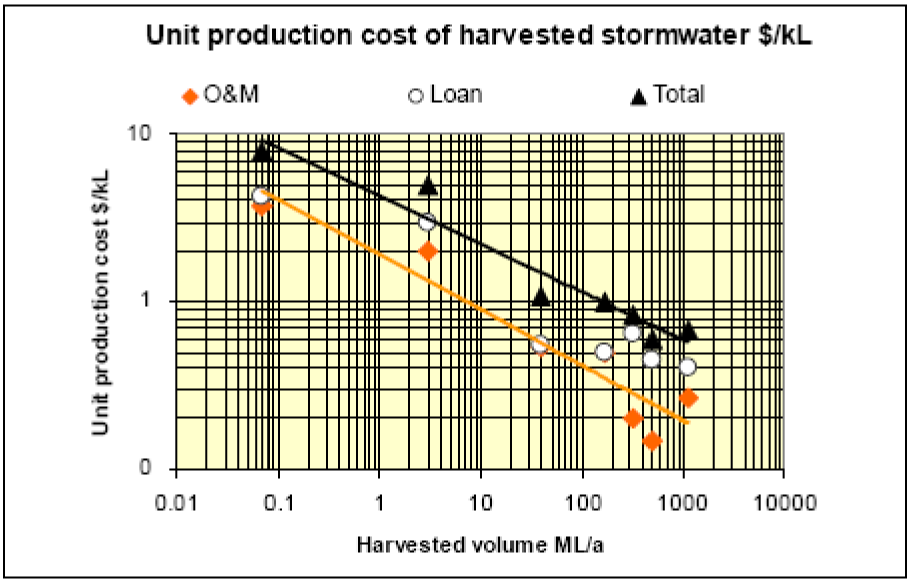


Figure 8.3 Unit Production Costs of Harvested Stormwater

Source: Kellogg Brown & Root Pty Ltd (2004)

8.6 Case Studies

Grange Golf Club Stormwater Harvesting and Reuse Scheme

Text and photos courtesy of the Adelaide and Mt Lofty Ranges Natural Resources Management Board

The Grange Golf Club Wetland and Aquifer Storage and Recover (ASR) Scheme is a major urban stormwater management project for irrigation. The club is located at the downstream end of the 4.2 km^2 Trimmer Parade stormwater catchment in the suburb of Seaton in the City of Charles Sturt.

The scheme is designed to harvest approximately 320 megalitres of urban stormwater by diverting water from the Trimmer Parade and adjacent West Lakes Boulevard systems into a wetland constructed on the golf course.

Using wetland processes, the water is treated to a standard suitable for injection into the locally used and stressed aquifer. The water will then be extracted from the aquifer in summer for sustainable irrigation use.

Figure 8.4 Grange Golf Club Stormwater Harvesting and Reuse Scheme - During Construction (June 2006)

The scheme was identified as a priority in the City of Charles Sturt's Trimmer Parade Catchment Initial Urban Stormwater Master Plan (USMP). The USMP identified wetlands at the Grange Golf Club as providing the major opportunity for water quality improvement for stormwater discharges into West Lakes and the Port River. The USMP also indicates that the Grange Golf Club is the only location within the catchment capable of implementing a viable wetland and ASR scheme for major water reuse. The feasibility study indicated that the scheme would intercept and reuse approximately 12% of the total urban stormwater inflow to the West Lakes system.

Irrigation of the Grange Golf Club's two 18-hole golf courses used approximately 300 ML of groundwater withdrawn from the upper Port Willunga Formation. The Grange Golf Club was the single largest groundwater user in the region and the implementation of this scheme is intended to effectively make them self sufficient on stormwater resources.

In 2003 the Torrens Catchment Water Management Board (now the Adelaide and Mt Lofty Ranges Natural Resources Management Board) and the Grange Golf Club jointly committed $70,000 to a comprehensive feasibility study that determined the technical feasibility and the preferred option for scheme layout. Groundwater modelling and wetland functional design work was also undertaken towards detailed design.

The net present value (NPV) of the scheme (capital and ongoing operational costs) is approximately $3.1 million which was funded jointly by the Adelaide and Mt Lofty Ranges Natural Resources Management Board, the Grange Golf Club and the Catchment Management Subsidy Scheme.

Environmental benefits of the scheme are significant and include:

- A reduction in polluted inflows of runoff to West Lakes, the Port River and ultimately the Gulf St Vincent;
- A major reduction in use of the locally stressed aquifer;
- An immediate pressure improvement and long-term salinity reduction in the local aquifer; and
- An increase in biodiversity and an opportunity to recreate native aquatic habitats.

Figure 8.5 Grange Golf Club Stormwater Harvesting and Reuse Scheme - Trimmer Parade Diversion and Frederick Road Pit (August 2006)

Social benefits include:

- Reinforcement of community awareness of water conservation issues;
- An opportunity to increase community awareness of biodiversity issues;
- Improved amenity and visual aspect to Frederick Road, a major arterial road to the West Lakes commercial and sporting precinct; and
- The opportunity to demonstrate best practice in environmental protection and water conservation to the local, state, national and international community (via the Club's high profile events calendar).

Figure 8.6 Grange Golf Club Stormwater Harvesting and Reuse Scheme – First Fill (September 2006)

Economically, the benefits of the scheme are:

- A sustainable water supply and secured long-term future for one of Adelaide's premier sporting venues;
- An aesthetic asset that increases the amenity of the Grange Golf Club adding to its value as a venue for national and international golfing events; and
- Avoidance of the need to use reticulated supply (River Murray) if the aquifer eventually reaches salinity limits for turf application.

Figure 8.7 Grange Golf Club Stormwater Harvesting and Reuse Scheme – Completed Wetland (January 2007)

Parafield Partnerships Urban Stormwater Initiative

The Parafield Partnerships Urban Stormwater Initiative (PPUSI) was a landmark project commissioned in early 2003 to manage stormwater in Salisbury's last remaining catchment to receive, filter and clean stormwater.

It is a partnership between the City of Salisbury and G.H. Michell & Sons (Australia's largest wool processing company) with significant funding contributions provided by the State and Commonwealth Governments. The funding ($1.8 million) came from the Commonwealth's Urban Stormwater Initiative and Clean Seas Program.

Michell's woolscour is one of the largest in the world. To produce its premium products it requires large volumes of good quality input water (about 1 billion litres per year). Prior to this scheme being implemented, Michell's was the biggest individual water user in Adelaide.

On the output side, the woolscour's annual waste stream provides a challenge as it contains up to 20,000 tonnes of sludge and over 4000 tonnes of salt. This wastewater was the largest single input to the Bolivar Wastewater Treatment Plant on Gulf St Vincent. After treatment, the water was either discharged into the Gulf or piped for reuse to the horticultural district of Virginia.

The City of Salisbury, Michell and Parafield Airport worked together, with the support of Environment Australia and the Northern and Barossa Catchment Water Management Board (now the Adelaide and Mt Lofty Ranges Natural Resources Management Board), to create a scheme to capture stormwater from over 2000 hectares of urban catchment that is treated in reed beds and stored in the underground aquifer for continuing industrial wool scouring use.

The scheme involves diversion of stormwater via a weir in the main Parafield drain to a 50 ML capacity 'in stream' capture basin (designed to meet 10 year ARI storm event). The water is then pumped to a similar capacity holding basin, from where it gravitates to a two hectare cleansing reed bed and then flows continuously through the densely planted reed bed to biologically cleanse the water. The reed bed ponds are located on Parafield Airport land and are appropriately bird-proofed. Surplus water is stored in an aquifer for use during summer.

Nutrient and pollutant loads are reduced by up to 90% with the treated water having salinity less then 220 mg/L (compared to average Adelaide mains supply salinity > 400 mg/L).

The residency period of the water in the treatment ponds prior to being pumped direct to users, or stored in the aquifer (approximately 650 ML is injected annually), is between seven and 10 days, depending on inflow water quality.

The scheme achieves approximately 70% capture of catchment yield.

Water quality monitoring is conducted using real time online monitoring of pH, TDS and turbidity in addition to grab sampling and composite sampling. The volume of water captured, supplied, injected and extracted is also monitored.

This scheme saves in the order of 1100 megalitres of water per year, which otherwise would have been pumped from the River Murray to meet Michell's demands. On the output side, 2 megalitres/day of rinse water is available for irrigation in urban developments, parks and gardens following polishing in another constructed wetland.

In addition, sludge generated from Michell's is being combined with green waste collected from residential properties to produce a high quality fertiliser for the horticultural and wine industries.

8.7 Useful Resources and Further Information

Fact Sheets

www.dwlbc.sa.gov.au/assets/files/fs5_asr_in_sa.pdf

ASR in South Australia (DWLBC)

www.waterforgood.sa.gov.au/

Water For Good fact sheets – Stormwater Use and Wastewater Recycling

www.cwmb.sa.gov.au/kwc/programs/why_wetlands/Morphettville%20Racecourse%20Wetland%20Fact%20Sheet.pdf

Morphettville Wetland and ASR Scheme fact sheet

www.decs.sa.gov.au/docs/documents/1/WaterSmartAquiferStorage.pdf

Water Smart: Aquifer Storage And Recovery for Irrigation of School Playing Fields

www.southeastwater.com.au/SiteCollectionDocuments/Recycled%20water/Use%20and%20recycle.pdf

The facts about recycled water (South East Water)

www.wsud.org/downloads/Planning%20Guide%20&%20PN%27s/10-Groundwater.pdf

Practice Note No. 10 Groundwater WSUD in the Sydney Region

www.brisbane.qld.gov.au/bccwr/lib184/wsud%20practice%20note%2010%20aquifer%20storage%20&%20recovery.pdf

Practice Note 10 Aquifer Storage and Recovery, Brisbane City Council

www.brisbane.qld.gov.au/bccwr/lib184/treatment_train_72dpi_rgb_nobleed.pdf

Stormwater Treatment Train, Brisbane City Council

Legislation

www.epa.sa.gov.au/pdfs/cop_aquifer.pdf

Code of Practice for Aquifer Storage and Recovery, EPA

www.epa.sa.gov.au/pdfs/bccop1.pdf

Stormwater Pollution Prevention Code of Practice for the Building and Construction Industry, EPA

www.epa.sa.gov.au/pdfs/guide_waterwell.pdf

Pollutant Management for Water Well Drilling Guideline, EPA www.epa.sa.gov.au/pdfs/guide_wws.pdf

Water and Wastewater Sampling Guideline, EPA

www.epa.sa.gov.au/pdfs/reclaimed.pdf

South Australian Reclaimed Water Guidelines

www.epa.sa.gov.au/pdfs/guide_lagoon.pdf

Wastewater and Evaporation Lagoon Construction Guideline

www.epa.sa.gov.au/pdfs/info_construction.pdf

Construction Noise information sheet, EPA

www.epa.sa.gov.au/pdfs/info_noise.pdf

Environmental Noise information sheet, EPA

http://dataserver.planning.sa.gov.au/publications/654p.pdf

Guide for Applicants, Planning SA

General Information

www.asrforum.com/

Aquifer storage recovery (ASR)

www.iah.org/recharge/

International Association of Hydrogeologists – Managing Aquifer Recharge (IAH–MAR)

www.ephc.gov.au/ephc/water_recycling.html

Australian guidelines for water recycling

www.plumbingindustry.com.au/stormwaterinterception.htm

Stormwater interception

www.envirotank.com.au/index.htm

Underground water tank suppliers

www.enviro-friendly.com/tankmasta-underground-water-tanks.shtml

Underground water tank suppliers

www.healthywaterways.org/FileLibrary/9_aquifer_storage.pdf

Aquifer Storage and Recovery – WSUD Technical Guidelines for South East Queensland

www.brisbane.qld.gov.au/bccwr/lib78/wsud_chapt10_aquifer_storage_and_recovery.pdf

Aquifer Storage and Recovery – Brisbane City Council Draft WSUD Technical Guidelines

8.8 References

Department of Environment and Conservation NSW (2006). *Managing Urban Stormwater: Harvesting and Reuse*. Sydney, New South Wales. April. http://www.epa.nsw.gov.au/resources/managestormwatera06137.pdf.

Environment Protection and Heritage Council (2006). *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1).* November. http://www.ephc.gov.au/pdf/water/WaterRecyclingGuidelines-02_Nov06_.pdf.

Environment Protection Authority South Australia (1999). *South Australian Reclaimed Water Guidelines*. Adelaide, South Australia. http://www.dh.sa.gov.au/pehs/branches/wastewater/reclaimed-water.pdf.

Environment Protection Authority South Australia (2004). *Code of Practice for Aquifer Storage and Recovery.* Adelaide. www.epa.sa.gov.au/pdfs/cop_aquifer.pdf.

Kellogg Brown & Root Pty Ltd (2004). *Metropolitan Adelaide Stormwater Management Study, Part B - Stormwater Harvesting and Use.* Local Government Association, South Australia. Adelaide, South Australia. http://www.dwlbc.sa.gov.au/assets/files/metro_adelaide_stormwater_mgmnt_study_PartB.pdf.

Mitchell, V. G., Hatt, B. E., Deletic, A., Fletcher, T. D., McCarthy, D., Magyar, M. (2006). *Integrated Stormwater Treatment and Harvesting.* Institute for Sustainable Water Resources, Faculty of Engineering, Monash University. Melbourne.

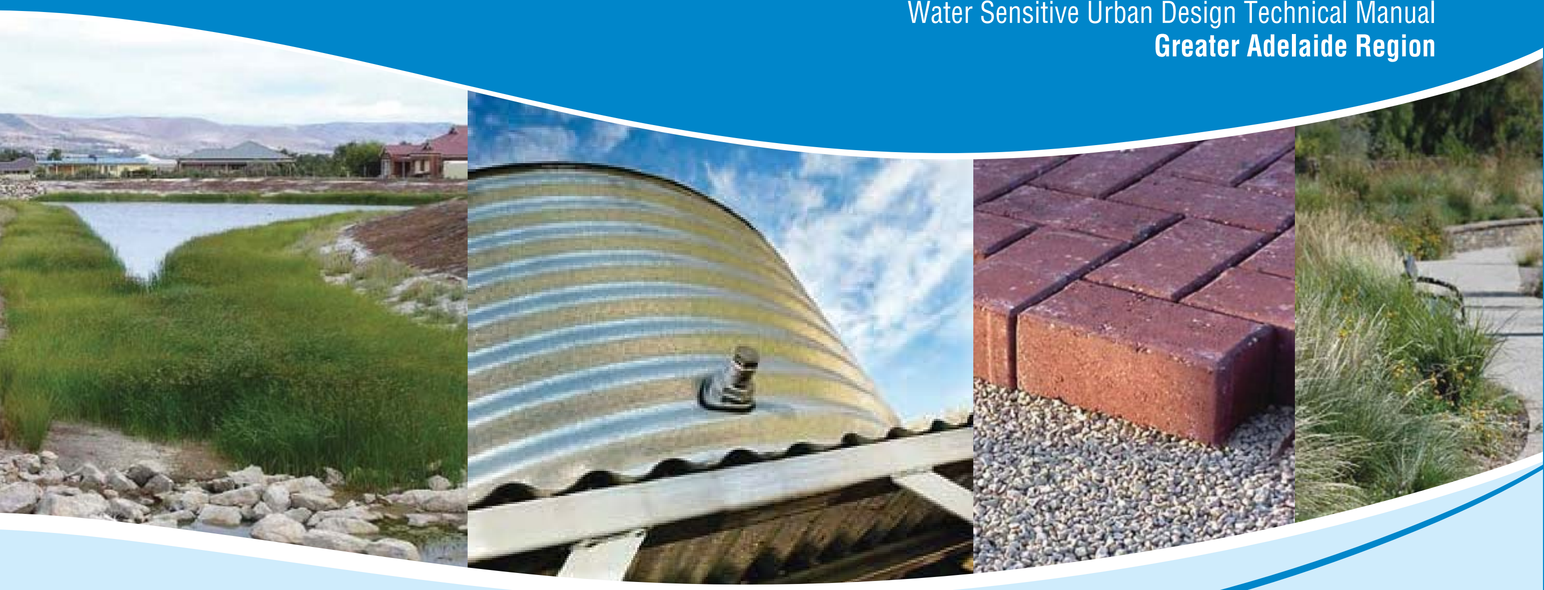
Po, M., Kaercher, J. D., Nancarrow, B. (2003). *Literature Review of Factors Influencing Public Perceptions of Water Reuse.* CSIRO Land and Water. December. http://www.clw.csiro.au/publications/technical2003/tr54-03.pdf.

July 2009

Chapter 9

Gross Pollutant Traps

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 9
Gross Pollutant Traps

9.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Gross Pollutant Traps (GPTs) are one of those measures.

There are numerous techniques available for removing gross pollutants from water. The most effective strategies involve a combination of non-structural measures (e.g. education and waste management programs, and source controls) and structural treatments.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing an overview of Gross Pollutant Traps (GPTs) (i.e. structural controls) and how they can be utilised to assist in achieving the objectives and targets of WSUD.

Description

Gross Pollutant Traps (GPTs) are devices for the removal of solids conveyed by runoff that are typically greater than 5 millimetres. There is a variety of GPTs currently suitable for use in urban catchments including gully baskets, in-ground GPTs, trash racks and pipe nets.

Purpose

The main function of GPTs is water quality control.

All forms of development and land use generate gross pollutants (litter and debris greater than 5 millimetres) of one kind or another. Gross pollutants are a threat to wildlife and aquatic habitats, look unpleasant, smell and attract vermin.

The primary purpose of GPTs is to remove gross pollutants and coarse sediments washed into the stormwater system before the stormwater enters the receiving waters. While most GPTs capture both categories of pollutants, there are some that target litter and debris exclusively and others that are designed for sediment removal only.

Generally GPTs are used to provide primary treatment within a WSUD treatment train. GPTs do not contribute to flood control. Indeed, unmaintained inline GPTs can contribute to increased flooding by generating additional backwater effects.

Scale and Application

The typical application scale for GPTs is the precinct (neighbourhood) or regional (catchment wide) scale. A precinct system would involve smaller traps in side inlet pits and pit systems that filter runoff from a small number of blocks. Precinct systems are those that include racks and booms across rivers and major stormwater flow corridors.

GPTs serve as a component of traditional conveyance drainage networks. GPTs can operate in isolation to protect immediate downstream receiving waters, or as part of a more comprehensive treatment system. When acting in isolation they are used primarily for aesthetic reasons, to protect downstream waters from litter or to address specific items.

In integrated treatment systems (or treatment trains) they are the most upstream measure and play an important role in protecting the integrity of the downstream treatments (such as wetlands) by removing the coarsest fraction of contaminants and preventing downstream treatments from becoming overloaded.

GPTs represent a significant public investment in the capital cost of the device as well as ongoing cleaning and maintenance costs.

Performance Efficiency

There are limited field studies which quantify removal efficiency of GPTs. However, Fletcher et al. (2004) report on the performance of litter and sediment management systems along with the rationale for these estimates and considerations for their application. Based on the outcomes of this report, performance estimates of GPTs for a range of pollutants are shown in **Table 9.1**.

Table 9.1 Estimate of Performance Efficiencies for GPTs

Pollutant	Expected Removal	Comment
Litter	10-30%	Depends on effective maintenance, specific design (hydraulic characteristics, etc). 10% where trap width is equal to channel width, 30% where width is three or more times channel width
Total suspended solids	0-10%	Depends on hydraulic characteristics; will be higher during low flow
Total nitrogen	0 % (negligible)	Transformation processes make prediction difficult
Total phosphorus	0 % (negligible)	Total phosphorus trapped during storm flows may be re-released during inter-event periods, due to anoxic conditions
Coarse sediment	10-25 %	Depends on hydraulic characteristics; will be higher during low flow
Heavy metals	0 %	

Source: Fletcher et al. (2004)

Gross pollutant trapping devices should be considered at the scoping stage of any WSUD project. As the pollutants trapped by GPTs may interfere significantly with the performance of other WSUD measures, they are an important consideration for any stormwater treatment train (in most cases, depending on scale).

9.2 Legislative Requirements and Approvals

Before undertaking a concept design of a GPT (or purchase of a GPT) it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to GPTs in your area.

The legislation which is most applicable to the design and installation of GPTs in the Greater Adelaide Region includes:

- *Development Act 1993* and Development Regulations 2008; and
- *Environment Protection Act 1993.*

Development Act 1993

Installing a GPT will generally be part of a larger development (for new developments), however whenever GPTs are planned (such as retrofitting), it is advised that the local council be contacted to:

- Determine whether development approval is required under the *Development Act 1993*; and
- Determine what restrictions (if any) there may be on the installation of GPTs on a particular site.

Environment Protection Act 1993

Any development, including the installation of a GPT, has the potential for environmental impact, which can result from vegetation removal, stormwater management and construction. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on the whole site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when installing GPTs are discussed below.

Water Quality

Water quality in South Australia is protected using the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development. In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, construction sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise potential for environmental impact during construction. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 9.8**).

The installation of a GPT will assist in improving the water quality that is discharged to receiving waters. However, the GPT needs to be designed so that it prevents resuspension of captured contaminants.

Air Quality

Air quality may be affected during the installation of a GPT. Dust generated by machinery and vehicular movement during site works, and any open stockpiling of soil or building materials at the site, must be managed to ensure that dust generation does not become a nuisance off site.

Waste

Any wastes arising from any excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*. For example, during construction, all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 9.8**).

Odour

The maintenance of GPT systems must be able to demonstrate that captured contaminants can be stored so as not to cause significant adverse environmental impact or nuisance (e.g. odours and putrefaction).

9.3 Design Tools

A range of design tools is available for the concept and detailed design of GPTs as detailed in **Chapter 15** and discussed briefly below.

The Cooperative Research Centre for Catchment Hydrology (now eWater) has recently developed stormwater management evaluation software called MUSIC (Model for Urban Stormwater Improvement Conceptualisation). The software serves as a planning and decision support system, and packages the most current knowledge of the performance of a range of stormwater treatment measures into an easily used tool. MUSIC is designed to operate at a range of temporal and spatial scales, suitable for modelling stormwater quality treatment systems for individual lots up to regional scales.

MUSIC is designed to simulate urban stormwater systems operating at a range of temporal and spatial scales and provides a user-friendly interface to allow complex stormwater management scenarios to be quickly and efficiently created, with results viewed using a range of graphical and tabular formats. MUSIC provides the ability to simulate both quantity and quality of runoff from catchments and the effect of treatment facilities on these components.

MUSIC is an aid to decision making. It enables users to evaluate conceptual designs of stormwater management systems to ensure they are appropriate for their catchments. By simulating the performance of stormwater quality improvement measures, MUSIC determines if proposed systems can meet specified water quality objectives.

GPTs can be modelled in MUSIC as part of a treatment train.

MUSIC requires the user to describe the performance of the GPT (using a graphical function editor) for each pollutant type, and does not provide default performance figures. The reason for this is that there are many GPTs available, including several proprietary products, which may perform very differently.

9.4 Design Considerations

The following design considerations should be used when the installation of a GPT is proposed, or as a basis for the information required when selecting an appropriate proprietary product.

Flood Capacity

Litter booms are usually designed to float and therefore adjust with increasing flow. Trash racks should be designed to act as weirs if their design flow rate is exceeded. Inground GPTs often operate with a bypass system that is designed to divert the treatment flows into a separation chamber. Flows higher than this are diverted over or around a diversion weir. Alternative bypass techniques include a release mechanism for a net system, triggered by increasing upstream flow levels.

Every GPT should be designed with provision for a high flow bypass system. The bypass should:

- Protect the operational integrity of the trap during floods;
- Ensure no flooding is caused by the trap in surrounding areas; and
- Prevent excessive scour of collected pollutants in a trap.

It is important that a hydraulic analysis of the drainage system incorporating a GPT is performed. This analysis needs to include headloss of the GPT and diversion weir under flood conditions (IE Aust. 2006). The design of a bypass system should also be checked to assess impacts on the local drainage system.

Figure 9.1 Gross Pollutants at the Torrens Weir – December 2007

Source: Courtesy of Australian Water Environments

Trapped Pollutant Storage

Holding trapped pollutants until removed is achieved by containing pollutants in a wet sump (in baskets or chambers) or by storing pollutants in baskets, nets or behind screens that are free draining.

The GPT needs to be designed so that it prevents resuspension of captured contaminants during flows in excess of the design ARI.

The continuous wet conditions in a pollutant containment sump and possibly limited turn over, mixing or aeration can lead to organic material decomposition, with depleted oxygen levels creating severe reducing conditions. Under these conditions, collected pollutants can be transformed from a relatively innocuous state to highly bio-available forms that are then released to downstream waters with any through flow.

Therefore, when installing as a stand alone GPT (i.e. without downstream treatment measures) the impact on downstream waterways from the release of potentially bio-available pollutants from wet sumps should be considered. In some cases, it may be the only option for a GPT. If so, a low flow treatment system downstream should be considered.

Maintenance

The main environmental issues with GPTs are associated with:

- Long-term storage of pollutants that may be remobilised or cause odour; and
- Limitations on the disposal of the trapped material.

A poorly maintained treatment measure may not only perform badly, it may become a flood hazard or a source of pollution itself. Maintenance is the most commonly overlooked aspect of GPT selection, yet it is one of the most important for gross pollutant reduction (IE Aust. 2006).

GPT operation and maintenance requirements vary widely. When considering a treatment measure's maintainability and operability, the following issues should be considered:

- Access to the treatment site (i.e. by vehicle);
- Ease and frequency of maintenance; and
- Disposal of waste.

The ease of maintenance relates to the systems and equipment required to clean a GPT. Cleaning systems range from:

- Manual handling of collected pollutants;
- Vacuuming collected pollutants;
- Using a crane to retrieve collected pollutants from a basket or net; or
- Using large excavators to remove pollutants.

The design of any removable sump or basket collection system must ensure that floatable contaminates do not overspill the basket during lifting or clean out operations.

Some GPT devices will allow the removal of pollutants to be undertaken during periods of dry weather. It is considered appropriate practice to disregard the need to include a flow isolation option in the design and installation of these GPTs.

Due to the seasonal nature of rainfall in the Greater Adelaide Region, cleaning and other maintenance procedures will be easier to undertake in the summer months. It may be appropriate to consider basing monitoring and maintenance on the occurrence of summer storms during this period. However, a regular inspection and maintenance schedule should be put in place for the wet winter period.

It is important that an assessment of the catchment pollutant load be undertaken in winter months to determine the likely pollutant 'wash off' and collection load. This load can be used to determine the holding capacity (or pollutant storage volume) required of the GPT for the catchment. This knowledge can also be applied in combination with winter climatic conditions to determine the frequency of clean out procedures required to ensure the trap is working efficiently.

Further information on maintenance is contained in **Section 9.5**.

Siting a GPT

A GPT should only be located at sites where access for inspection and maintenance can be carried out using standard maintenance vehicles. Adequate access and hardstand areas for maintenance plant (vacuum loader, crane, tippers etc) from the street to the device should be provided.

The siting of GPTs in inaccessible locations, such as at the bottom of embankments, should not be undertaken. Where practicable, GPTs should not be located near electrical equipment.

Consideration should be given to whether:

- Any road closures are required (during installation and subsequent maintenance) and how much disturbance this will cause;
- There are any services required for maintenance (e.g. wash down water);
- There are any potential odour concerns at the location;
- There will be an impact on the aesthetics of the area;
- There is an area nearby to dry the waste material.

GPT devices are to be located such that a downstream overland flow path through a public road or open space is available to carry any surcharge flows which may occur due to blockage of the GPT device or other causes. However, a downstream overland flow path through private land or easement is not appropriate.

Waste Disposal

Disposal costs depend on whether the collected material is retained in wet or free-draining conditions. Handling of wet material is more expensive and requires sealed handling vehicles.

Issues to consider regarding waste disposal include:

- Will the material be in wet or dry condition and what cost implications are there?
- Are there particular hazardous materials that may be collected and will they require special disposal requirements (e.g. contaminated waste)? What are the cost implications?
- What is the expected load of material and what are the likely disposal costs?
- Where is the material going to be disposed?

9.5 Design Process

Overview

The design process for GPTs consists of a number of steps including:

- Assess site suitability and catchment analysis;
- Determine design objectives and targets;
- Consult with council and other relevant authorities;
- Select type of GPT;
- Determine the design flows;
- Size the GPT system;
- Determine land and asset ownership;
- Check the design objectives;
- Obtain approvals;
- Develop a construction plan; and
- Develop a maintenance plan.

Figure 9.2 Inside a GPT

Source: Courtesy of University of South Australia

The design process is also discussed in general in **Chapter 3**.

A Design Calculation Checklist is provided in **Appendix A**.

A number of the steps in the design process are discussed below.

Site Suitability and Catchment Analysis

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of the site conditions is therefore a fundamental part of designing a development that effectively incorporates WSUD.

Careful selection of where to place a GPT is important. An assessment of site conditions is necessary to identify what measures, if any, are required to ensure that the GPT will perform for its entire lifetime.

It is also important to understand the pollutant profile of the catchment when undertaking the site suitability assessment, which will assist in the selection and sizing of the GPT.

The pollutant profile of a catchment area is determined largely by the area's land use and stormwater management measures.

For GPTs, the primary target pollutants are:

- Gross pollutants: litter and vegetation larger than 5 millimetres; and
- Sediment: particles larger than 0.125 millimetres.

To isolate pollutants in any catchment, the designer needs to examine receiving water degradation in light of the area's land use and current management practices. The sections below provide information to assist the site suitability analysis.

Source and Type of Gross Pollutants

All forms of development and land use generate gross pollutants of one kind or another.

In assessing the source and type of pollutant to be collected, consideration needs to be given to the potential change in pollutant source and type of pollutant which may occur as a catchment develops or is redeveloped.

In residential areas, the bulk of the volume of pollutant is organic matter such as leaves from street trees, grass clippings, etc with only small volumes of materials such as plastic, bottles and cans. Residential areas also contribute pollutants such as paint, pet droppings, detergents and oils as a result of household activities.

Studies and logic indicate that a significant proportion of gross pollutants discharged to waterways are generated by residential catchments (including the surrounding street network), as this type of development constitutes a significant proportion of the land use in most catchments.

Figure 9.3 Image of Various Types of Gross Pollutants

In tourist areas and general commercial and office areas, the type of pollutant is more likely to be floatable (i.e. cans, cigarette butts, paper and food wrappers) and motor vehicle generated pollutants (e.g. oils, brake linings, etc). These items, when discharged to waterways, are highly visible to the public. The volume of pollutant may be small in comparison with pollutants generated elsewhere in the system, but degrade the appeal of the waterway.

Industrial areas are more likely to generate gross pollutants such as sediment, polystyrene, wood particles, cardboard and wrappings. Industrial sites are also more likely to generate spills of oil, chemicals and similar liquid contaminants, which are not generally trapped by physical gross pollutant control devices.

Shopping centre developments are more likely to concentrate pollutants related to food, packaging and motor vehicles (i.e. parked vehicles leak oils, cars deposit brake linings).

Rural developments are likely to generate volumes of organic matters (i.e. grass, leaves, etc) and chemical pollutants associated with farming type land use.

In general, gross pollutants are composed of approximately 20% litter (plastic, paper and metal) and 80% organic material (such as leaves and twigs). The majority of gross pollutants are carried during times of the highest flows. Less than 20% of litter is transported as floating material; the remainder is either entrained in the flow or sinks.

The general composition of urban gross pollutants and urban litter is demonstrated in **Figure 9.4**.

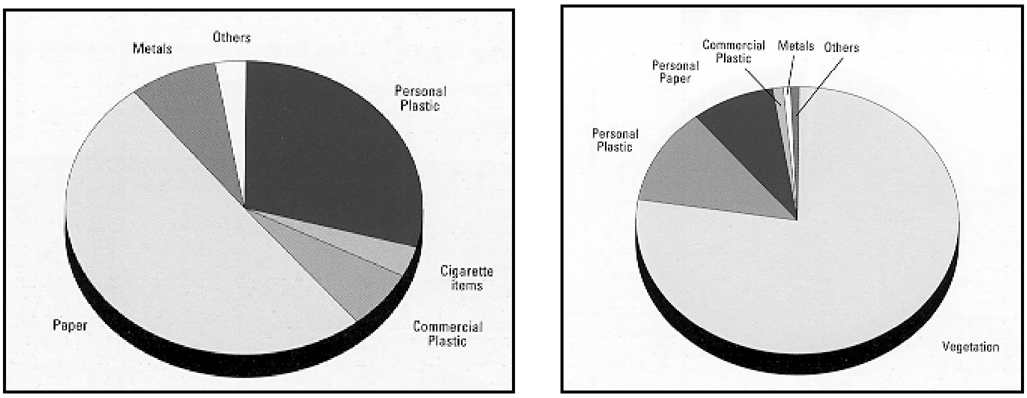


Figure 9.4 Composition of (a) Urban Gross Pollutants and (b) Urban Litter

Source: Allison et al (1997)

Locating a GPT

When determining the location for a GPT, its relevance to other stormwater treatment measures in the catchment should be considered. A location for a GPT should be complementary to other treatment measures and be consistent with the strategic catchment treatment objectives. In addition, other factors such as topography, available space and proximity to pollutant source areas determine the best location for a GPT and its catchment size.

Site Characteristics

The characteristics of a particular site can severely limit the choice of a treatment GPT suited to an area. Constraints fall broadly into categories of physical and social.

Physical factors to consider include:

- Topography – GPTs may not operate effectively on sites with steep grades, while on mild slopes head losses can cause local flooding;
- Soils and geology;
- Groundwater/tides;
- Space;
- Access; and
- Overhead restrictions.

Social factors include issues of health and safety, aesthetics and impacts on recreation facilities. Factors to consider include:

- Odour problems;
- Visual impacts;
- Safety concerns; and
- Vermin.

Design Objectives and Targets

Specifying the objectives for a GPT is an important step in ensuring that it operates as intended. The objectives should include details and consideration of the following:

- Treatment objectives;
- Design flows;
- Flood capacity;
- Trapped pollutant storage; and
- Maintenance requirements.

The design objectives and targets will vary from one location to another and will depend on site characteristics, development form and the requirements of the receiving ecosystems. It is essential that these objectives are established as part of the conceptual design process and discussed with the relevant council prior to commencing the engineering design.

An example design target is that a GPT will capture a minimum of 90% of all solid gross pollutants (including floatables) greater than 2 mm in any dimension and sediment greater than 0.125 mm in diameter.

Further information on objectives and targets can be found in **Chapter 3** of the Technical Manual.

Consult with Council and Other Relevant Authorities

The designer should liaise with civil designers and council officers to ensure:

- GPTs will not result in water damage to existing services or structures;
- Access for maintenance to existing services is maintained; and
- No conflicts arise between the location of services and WSUD devices.

The council will also be able to advise whether development approval is required and whether any other approving authorities should be consulted.

Select Type of GPT

(Note and acknowledgment: information in this section draws heavily from IE Aust. 2006)

The design of GPTs has evolved considerably since their inception in Australia in the 1980s. Most current designs are proprietary products and available 'off the shelf'.

The most pressing issue for managers of stormwater systems is specifying the requirements of a GPT and selecting an appropriate GPT for a particular location, as there is a wide range of available products.

GPTs vary in size, cost and trapping performance by orders of magnitude. GPTs are continuously being developed and modified as vendors research the operation of their traps and respond to treatment requirements.

Selection of the type of GPT device for a particular application must occur as part of the conceptual design process.

The decision of which type (and brand) of trap to select is a trade-off between the life cycle costs of the trap, the expected pollutant removal performance in regard to the values of the downstream water body and any social or political considerations. Selection of the type of GPT must take into consideration an assessment of the site conditions against the relative merits of the different available devices.

The filtration efficiency and effectiveness of the GPT must be sustainable during intervals between cleaning and the treatment flow capacity and hydraulic performance must not be reduced by accumulation of contaminants within the captured area.

Construction related issues which may sway a decision on which trap is most suitable, include:

- Does the cost include a diversion structure that will be required?
- Is specialist equipment required for installation (e.g. special formwork, cranes or excavators) and what are the cost implications of these?
- Is particular below ground access required, or will ventilation and other safety equipment be needed? If so, at what cost?
- Will the trap affect the aesthetics of the area?
- Will landscape costs be incurred after the trap installation? If so, how much?
- Will the trap be safe from interloper or misadventure access?
- Do the lids/covers have sufficient loading capability (particularly when located within roads)? What is the cost of any increase in load capacity and will it increase maintenance costs?
- Will the trap be decommissioned (e.g. after the development phase) and what will remain in the drainage system?
- Are there tidal influences on the structure and how will they potentially affect performance or construction techniques?
- Will protection from erosion be required at the outlet of the device (particularly in soft bed channels) and what are the cost implications?

A checklist for assisting in the selection of a GPT is contained in **Appendix A**.

The following sections divide the array of GPTs available into five categories:

- Drainage entrance treatments;
- Direct screening devices;
- Non-clogging screens;
- Floating traps; and
- Sediment traps.

Drainage Entrance Treatments

Entrance type treatment systems are generally used in locations where it is not practical to utilise larger 'end-of-line' systems that are capable of servicing a much larger catchment area. Entrance systems are usually the best option when the receiving water environments are close to the catchment or in situations where the catchment area is small.

Examples include:

- Grate entrance systems;
- Side entry pit traps;
- Return flow litter baskets; and
- Channel nets.

Method of Pollutant Removal

Drainage entrance treatments involve preventing entry into the stormwater drainage system, or capturing the pollutants at drainage entrance points. This can be achieved by restricting the stormwater entrance size, capturing pollutants as stormwater falls into the drainage system, or retaining the pollutants in the entrance pit. Entrance treatments are free draining as collected pollutants are suspended above the base of a drainage pit. More recent designs use fine mesh bags or nets that can contain much finer material including gravel and coarse sediments.

Benefit

Entrance treatments are usually located close to a pollutant source, allowing the most polluted areas to be targeted. Use of entrance treatments can also help reduce downstream pipe blockages, which was their original intended use. Entrance treatments can target specific high pollutant generation areas. Their size and accessibility is governed by existing drain conditions.

Disadvantages

Often in low lying areas the depth of drain entrances limits their applicability because pits can be too shallow to provide sufficient pollutant storage. Another issue for established urban areas is the presence of connections to the drainage network that do not connect via street entrances e.g. private carparks and roof areas.

Maintenance

Maintenance can involve numerous locations and the size of inlets can limit the capacity of traps, thus requiring more frequent cleaning. Maintenance involves lifting an access lid and removing collected pollutants manually or with a vacuum system. Cleaning times can be governed more from gaining access to the many pits than the actual pollutant removal task.

Direct Screening Devices

Examples of direct screening devices include:

- Litter collection baskets (see **Figure 9.5** and **Figure 9.6**);
- Release nets;
- Trash racks (see **Figure 9.8**);
- Diversion weirs (see **Figure 9.9**);
- Return flow litter baskets; and
- Channel nets (see **Figure 9.7**).

Figure 9.5 Litter Collection Baskets at Sunshine, Victoria

Source: IE Aust. (2006)

Figure 9.6 Litter Collection Basket in Collingwood, Victoria

Source: IE Aust. (2006)

Figure 9.7 Channel Nets at West Torrens, Adelaide, SA

Source: IE Aust. (2006)

Figure 9.8 Trash Rack Installed at Broadmeadows, Victoria

Source: IE Aust. (2006)

Figure 9.9 Vane Style Diversion Weir, Sebastopol, Victoria

Source: IE Aust. (2006)

Method of Pollutant Removal

Direct screening traps retain gross solids by passing flow through a grid, mesh, rack or net barrier assembly with flows perpendicular to the screening surface. As pollutants build up behind a barrier, material smaller than the pore sizes may also be retained due to the reduced effective pore size. There are various trapping methods using baskets, prongs, racks or perforated bags, and this category of GPT contains the most products.

Direct screening devices are installed in drainage lines (usually in pipes) with catchment areas typically between five and 200 hectares. Much larger catchments have been targeted, usually with lower trapping efficiencies.

While most of the direct screening devices are installed 'in line', many are located next to drainage pipes and have treatment flows diverted into them via diversion weir arrangements. Flow rates above treatment flows overtop the diversion weirs and bypass treatment. This is a way to protect collected pollutants from scour and the device from damage.

The configuration of diversion weirs can vary and includes solid walls, slotted pipes, staggered vanes and diversions forced by outflows from collection chambers. In each case the intention of the bypass system is the same.

Some direct screening traps are located completely within channels, which is mainly because of space limitation or the scale of the channels. Older designs located within channels were prone to scouring of collected pollutants and subsequent transport downstream when overtopped. Newer in-channel designs have means of retaining gross pollutants during flood events, typically with nets, and are designed to withstand the forces associated with floods. Direct screening devices can be installed above or below ground and this typically determines whether the pollutants are retained in a wet sump (underground units) or free draining.

Some above ground GPTs, such as trash racks and those with solid diversion weirs, can collect considerable quantities of coarse sediment as it settles out when flows are backed up behind an obstruction and flow velocities fall significantly. Predicting removal rates is difficult and depends on local conditions.

Benefit

An advantage of underground systems is the ability to locate them in highly developed urban areas with little or no visual impact.

There are obvious benefits of above ground systems including being able to monitor collection rates, keeping material in an aerobic state and simplified cleaning procedures.

Coarse sediments can be retained by many direct screening devices, particularly below ground installations. Underground GPTs can act as a sump and collect bed load sediment as it is transported through the drainage network.

Disadvantages

A limitation with underground traps is the potential transformation of pollutants into more bio-available forms in wet sumps and an 'out of sight, out of mind' mentality towards maintenance.

While above ground systems have a larger visual impact, this can be exploited and used to raise public awareness of stormwater pollution and urban waterway protection. Consideration should be given to health and safety issues associated with exposed systems that are easily accessible to the public.

Maintenance

Cleaning systems for direct screening GPTs involves removing material that has collected behind the screening surfaces (or in sumps) and cleaning the screen of debris. Collected pollutants can be removed with vacuum machines, small excavators, small truck-mounted cranes for nets or larger cranes to lift baskets from sumps.

Figure 9.10 Clean Out of GPT Baskets Across Third Creek, Adelaide

Cleaning debris from screens can represent a more substantial task. It involves manual scraping of the screen surface to remove entangled debris, or knocking debris from the screen, depending on the type of screen arrangement. Cleaning a screen of debris is a critical component of maintenance for direct screening GPTs so they can collect gross pollutants with maximum efficiency at the start of the next storm event.

Non-clogging Screens

Examples of non-clogging screens include circular and downwardly inclined screens.

Only a few GPTs have non-clogging screens. These direct flows along or around a screen such that the flows maintain a tangential direction to the screen face. In addition, screens are aligned such that blockages of material are minimised.

Method of Pollutant Removal

The tendency of in-line screens to block is their main limitation. To improve screen performance, numerous attempts have been made to design a non-clogging trash screen. The principle is to align flows tangentially to the screen surface, thus encouraging flows to move debris along the screen while flows move through the screen. The configuration of the screen face must also be appropriate for a device to remain free of blockages during storm events.

Two types of non-clogging screens include an underground and an above ground device. Underground systems use circular screens with rotating flows in a collection sump, whereas above ground systems use a drop in the channel bed to force flows down an inclined screen.

Non-clogging screen GPTs have pollutant holding chambers or areas, much the same way as direct screening GPTs. They are also cleaned in similar ways to direct screening traps (with vacuum systems, sump basket retrieval or small excavators).

Benefit

The main advantage of non-clogging screens is that they maintain flows through a trap for the duration of a storm event, thus treating more runoff volume for any given storm event. Direct screening GPTs tend to have reduced flow through the device with increasing load accumulation progressively leading to early system bypass (if not maintain regularly) compared with non-clogging screens.

Maintenance

They share the advantages and limitations associated with above ground and underground direct screening GPTs for maintenance and collected pollutant breakdown.

Floating Traps

Examples of floating traps include:

- Flexible floating booms; and
- Floating debris traps.

Figure 9.11 Floating Boom Operating at Netley, West Adelaide

Floating traps are usually intended to remove highly buoyant and visible pollutants. These are typically installed in lower reaches of waterways where velocities are lowest and where upstream attempts of litter control have been exhausted. One benefit of floating traps is their high visibility and that they have the potential to be used as a public education and awareness tool.

Method of Pollutant Removal

As their name suggests, floating traps target only the most buoyant material. For litter this is typically 10% of the total load.

Floating traps usually consist of a partly submerged floating barrier fitted across the waterway, which retains the pollutants or deflects them into a retention chamber. More recent developments incorporate pollutant retention chambers and advanced trap-cleaning methods.

Silting of floating traps is a key consideration. The main issues include selecting areas where flow velocities are low, where litter tends to accumulate, where they are protected from high flows and not in the way of waterway traffic.

Benefits

Floating GPTs have the advantage of portability and can be repositioned to areas that tend to collect litter (in eddies along rivers for example). Maintenance is easily monitored because of their high visibility.

Disadvantages

The main limitations with floating traps relate to their limited holding capacity, poor capture efficiency during high flows and maintenance difficulties. Recent designs incorporate submerged barriers suspended below floating traps and pollutant retention chambers in an attempt to increase holding capacity and prevent losses from wind or tidal movements.

However, when flow velocities increase, this material is often washed out from beneath a trap or entrained in the flow around the boom arms.

Maintenance

Floating traps are typically maintained from boat access, which can be time consuming and expensive. Some small booms are manually cleansed with vacuum devices and specially designed barges are now used to streamline this process. Flood flows can present difficulties for floating traps positioned in the lower reaches of waterways, subjecting them to large forces, and their inability to bypass high flows. Their structural integrity can be compromised when subjected to high velocities and this reinforces the importance of site selection in slow moving waterways.

Sediment Traps

Examples of sediment traps include:

- Sediment settling basins (see **Figure 9.12**);
- Ponds;
- Circular settling tanks; and
- Hydrodynamic separators (see **Figure 9.13**).

Figure 9.12 Sediment Settling Basin in Perth, WA

Source: IE Aust. (2006)

There is a number of sediment traps available to control sediment transport once mobilised. These range from simple earthen or concrete basins to complex structures using vortices and secondary flows for sediment retention. Each trapping system aims to create favourable flow conditions for sedimentation, but the footprint per unit of flow for each device varies depending on the processes employed.

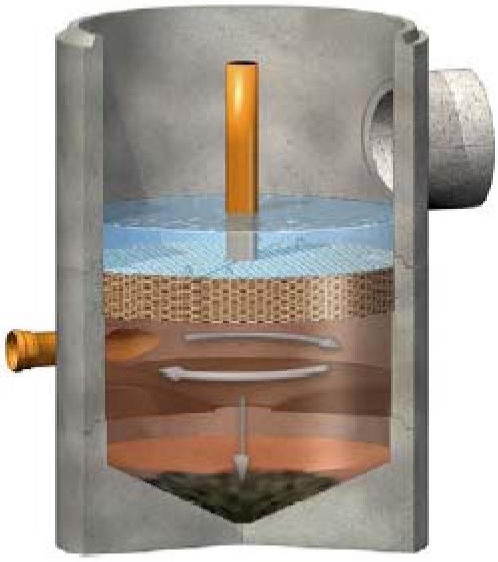


Figure 9.13 A Hydrodynamic Separation Device Cross Section

Note: inlet is on the left, encouraging rotation and enhanced settling of solid matter

Source: Courtesy of Hydrocon Australasia

Method of Pollutant Removal

The two processes of sediment removal involve: (i) fine screening or secondary flow motions and (ii) simple sedimentation processes. Devices using secondary flow patterns or screening systems, including direct screening and non-clogging screen GPTs, are typically proprietary products and design information is limited.

The basin type sediment traps can be concrete basins or more natural ponds constructed with site soil. They retain sediments by simply enlarging a channel so that velocities are reduced and sediments settle to the bottom.

There are also smaller scale sediment traps which can be fitted into stormwater drainage pipe network systems including some proprietary products.

Maintenance

Proprietary products are usually maintained with vacuum equipment. For simple basin sediment traps, maintenance is performed by excavating collected sediments following dewatering of the basin or pond. This can involve significant works and disturbance to an area. Therefore, sediment traps (or basins) are designed for maintenance frequencies of one to five years, depending on the catchment disturbance and activities.

The cleaning procedure involves dewatering the basin, removing sediments and re-establishing the area. The nature of collected pollutants can determine their suitability for disposal. Sediment traps are typically designed for coarse sediments only (typically larger than 0.125 mm) and this material is expected to have relatively low quantities of contaminants but should nevertheless be monitored during maintenance.

Design Flows

The overall treatment effectiveness of a GPT is a function of its pollutant removal rate for flows that pass through a trap and the volume of runoff treated. The maximum flow rate at which a GPT is designed to operate effectively is termed the 'design flow'.

A high flow bypass is usually adopted to protect GPTs from large flood flows that could damage the device or scour and transport previously collected pollutants downstream. This will be dependent on the design pipe or channel capacity.

Selecting a design flow rate is a trade-off between the cost and space requirements of the device (a higher design flow will usually require a larger facility with additional costs) and the volume of water that could potentially bypass the measure and avoid treatment.

GPTs will generally be designed to treat a minimum design flow of a 1 in 3 month ARI, as this will lead to hydrological effectiveness of greater than 97% (see **Figure 9.14**). Above this design flow, where possible, flows should bypass the filtration systems via an alternative bypass arrangement that can accommodate flows up to the 100 year ARI flow without creating any additional flooding issues to those that might already exist.

At specifically defined locations it may be necessary to design GPTs to treat flows from a recurrence interval greater than the one in three month event. This will depend on an assessment of the capacity of the receiving waterway downstream of the GPT to accept a pollutant load and the hydraulics of the drainage system.

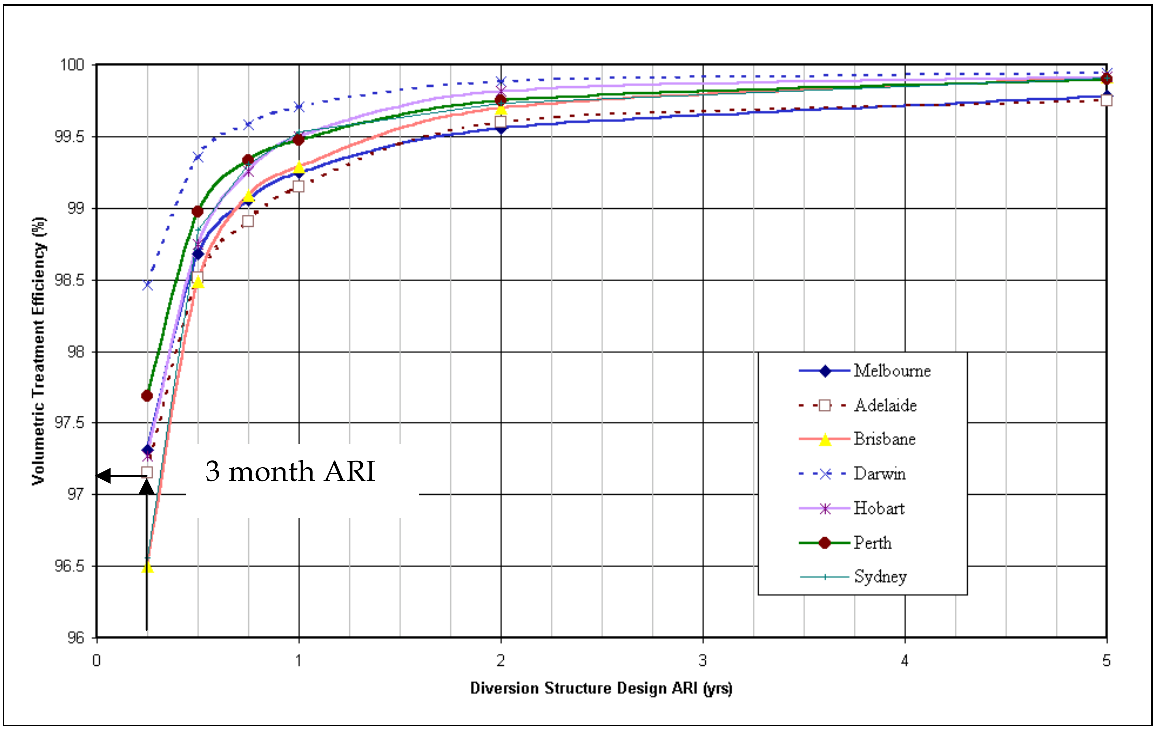


Figure 9.14 Typical Trap Efficiencies vs Design Standard of Stormwater Hydraulic Structures for Time of Concentration Equal to 1 Hour

Source: Wong et al (1999)

Sizing GPTs

To estimate the size of a required storage and containment chamber, catchment gross pollutant loads should be estimated, and a maintenance frequency selected. From this information an appropriate pollutant holding capacity can be determined.

Typically, GPTs should be sized for cleaning between four and 12 times per year (IE Aust. 2006). Alternatively, the capacity of the GPT should be sized based on intended cleaning frequency.

Loads can be estimated using a simple decision support system that requires rainfall and land use information (see Allison et al (1998)). If no other information is available, the values in **Table 9.2** could be adopted for litter and gross pollutant loading rates.

For the sizing of the adopted GPT, detailed hydraulic calculations will need to be prepared to establish the hydraulic response of the drainage system downstream and upstream of the devices.

Table 9.2 Approximate Litter and Gross Pollutant Loading Rates for Melbourne

Land Use Type	Litter Volume (L/ha/yr)	Litter Mass (kg/ha/yr)	Gross Pollutants (Litre/ha/yr)	Gross Pollutants Mass (kg/ha/yr)
Commercial	210	56	530	135
Residential	50	13	280	71
Light industrial	100	25	150	39

Source: IE Aust. (2006)

Check the Design Objectives

This step involves confirming the design objectives, defined as part of the conceptual design, to ensure the correct GPT system design method is selected. The treatment performance of the system should be confirmed (including revisiting and checking of any modelling used to assess treatment performance).

Obtain Approvals (If Required)

If a development application is required, key GPT information to be collated and provided with the application may include (if available/appropriate):

- Objectives of the GPT;
- Details of the size, hydrological and hydraulic response of the catchment;
- Details of the source and type of pollutants likely to be generated by the catchment both now and in the future;
- Sketches/plans of the proposed GPT;
- Facts detailing the performance of the GPT device;
- Details of the verification procedure to be applied by the body operating the GPT to confirm that the GPT is performing as stated by the designers;
- Copies of reports on the performance of the device from laboratory and/or field trials;
- Details of cleanout/maintenance procedures to be adopted. Cleanout/maintenance will need to utilise plant and equipment currently in use or readily available;
- Structural calculations showing the device, the roofs and access covers are designed for heavy traffic load. Access covers are to be large enough to enable vertical removal of components where required;
- Details of the inspection/maintenance access lids to the GPT;

- Details regarding method to isolate the device from upstream and downstream flows;
- Maintenance plan for the GPT.

Construction Process

There exists a number of challenges that must be appropriately considered to ensure successful construction and establishment of a GPT.

The risks to successful construction and establishment of WSUD measures, including GPTs, during the construction phase of work are generally related to the following:

- Construction activities which can generate large sediment loads in runoff; and
- Construction traffic and other works that can result in damage to the GPT structure.

To overcome the challenges associated with installing GPTs, the following steps are recommended:

- Construction of the functional elements and structures associated with the GPT should occur at the end of any landscaping works; and
- Temporary protective measures to preserve the functional infrastructure of the GPT against damage should be installed.

An example Construction Checklist in **Appendix A** presents the key items to be reviewed when inspecting the GPT during and at the completion of construction.

Maintenance Requirements

GPTs require a considerable amount of maintenance to ensure that they continue to operate at the design level of performance. A maintenance and monitoring management plan to: (i) monitor the performance of, and (ii) service the given GPT device, should therefore be developed during the design process.

The maintenance plan should include the following information:

- The location and type of device proposed;
- Who is going to perform the routine maintenance and who will incur the costs of maintenance;
- What parts of the device are to be cleaned and how;
- Type of maintenance and likely frequency;
- What, if any, machinery is required to maintain the device;
- Expected maintenance and inspection frequency;

- Expected maintenance costs or other resource requirements;
- Access issues such as locked gates, entry through private property etc including contact telephone numbers;
- Any environmental safeguards required during cleaning (i.e. hay bales required to filter stormwater drained from device);
- Occupational Health and Safety issues (i.e. is confined spaces accreditation required to clean the device?);
- Alternatives to proposed cleaning method (i.e. device may be cleaned by lifting out baskets by crane or by vacuum truck);
- Any other information that is important to the routine maintenance of the device; and
- Monitoring, measurement, recording and reporting of system capture performance.

The maintenance/cleanout procedure to be adopted for the GPT device should utilise plant and equipment readily available or currently in use by the management body.

All maintenance activities should be developed to ensure they require no manual handling of collected pollutants because of safety concerns with hazardous material.

The minimum level of maintenance and cleanout required to ensure the GPT system operates at the design level of performance to maximise pollutant capture without causing adverse environmental or hydraulic impacts should be specified. The maintenance of GPT systems must be able to demonstrate that captured contaminants can be stored so as not to cause significant adverse environmental impact or nuisance (e.g. odours and putrefaction, or flooding).

The maintenance program should allow for the costs of collection, transport and delivery of captured gross pollutants to an appropriate waste disposal facility.

Where monitoring of the GPT cleanout is required, allowance should be provided in the maintenance program to undertake the necessary on-site or laboratory processing to separate the contaminants into the specified categories.

Until written approval is received from council indicating that the device has been taken over, the developer retains responsibility to ensure routine maintenance is performed.

Maintenance personnel and asset managers will use the maintenance plan to ensure the GPT continues to function as designed. An example operation and maintenance inspection form is included in the checking tools provided in **Appendix A**. These forms should be developed on a site-specific basis as the nature and configuration of GPTs varies significantly.

9.6 Approximate Costs and Manufacturer Information

Overview

The costs of GPTs vary significantly based on size and application (i.e. total area from which the GPT is receiving stormwater). Taylor (2004) reported the following costs, which are based predominantly on cost surveys completed in NSW:

- Stream guard – catch basin insert: capital $290 and maintenance $200 per year;
- Ecosol RSF100: capital $430 to $903 and maintenance $200 per year;
- Ecosol RSF1000: capital $4,000 to $12,000 and maintenance $12 per hectare per month;
- CSR Humes Humeceptor: capital $10,000-$50,000 and maintenance $20 per hectare per month (suction cleaning);
- Rocla Downstream Defender: capital $12,000 to $36,000 and maintenance $20 per hectare per month (suction cleaning).

Life cycle costs are a combination of the installation and maintenance costs and provide an indication of the true long-term cost of the infrastructure. It is particularly important to consider life cycle costs for GPTs because maintenance costs can be significant compared with the capital cost of installation.

Version 3 of the MUSIC model provides a methodology that can be used to estimate life cycle costs for GPTs.

To determine life cycle costs, an estimated duration of the project needs to be assumed (e.g. 20 or 25 years) or if the trap is to control pollutants during the development phase only, it may be three to 10 years.

A checklist for determining the life cycle costs of GPTs is contained in **Appendix A**.

Factors which should be considered when determining installation, maintenance and disposal costs are discussed below.

Installation Costs

Installation costs include the cost of supply and installation of a GPT. Variables related to ground conditions (such as rock or groundwater conditions) or access issues may vary construction costs significantly.

To estimate the installation costs there are a number of local issues that will need to be considered. These include:

- Design flow rate;
- Size and configuration of the trap (with regard to site constraints);
- Hydraulic impedance and the requirements for operation; and
- Safety and other construction issues.

If any of the above factors cannot be adequately satisfied by a particular trap it should be deemed as potentially inappropriate for that location.

Maintenance Costs

Maintenance costs can be more difficult to estimate than the installation costs (but are sometimes the most critical variable). This is due to variances of the techniques used, the amount of material removed and the unknown nature of the pollutants exported from a catchment. In many cases maintenance costs are the most significant cost of a treatment measure. It is therefore imperative to carefully consider the maintenance requirements and estimated costs when selecting a GPT.

One important step is to check with previous installations by contacting current owners of GPTs and asking about their annual costs (vendors can usually supply contact information).

Disposal Costs

Disposal costs will vary depending on whether the collected material is retained in wet or dry conditions (i.e. either under water or left so it can drain). Handling of wet material is more expensive and will require sealed handling vehicles.

Addressing the following questions will assist in determining disposal costs:

- Is the material in a wet or dry condition and what cost implications are there?
- Are there particular hazardous materials that may be collected and will they require special disposal requirements (e.g. contaminated waste)? If so, what cost implications are there?
- What is the expected load of material and what are the likely disposal costs?

As discussed in **Section 9.5**, loads can be estimated using the decision support system developed by the CRCCH (see Allison et al (1998)) which requires rainfall and land use information. In the event that there is no other data, the values in **Table 9.2** could be adopted.

Product Information

A range of proprietary products are available. Product information is available at several websites that are intended as 'product registers' for GPTs and can be updated as new products emerge. A summary of a number of the products available is included in **Table 9.3**.

Table 9.3 Range of Proprietary Products Available

Supplier	Products	Websites
CSR Humes	Humegard (gross pollutant trap) Humes Humeceptor	www.humes.com.au
Rocla	CleansAll CDS Units X-Wave Screen Downstream Defender	www.rocla.com.au
Ecosol	Rapid Stormwater Filtration (RSF 100, 1000 and 4000) Net Tech	www.ecosol.com.au
Baramy	Deflector Trap Dual Vane Trap Vane Ttrap Basket Drop Side Drop Thru Saw Tooth	www.baramy.com.au
Diston	Little Miser Series	www.distonsewage.com.au

9.7 Case Study

Gross Pollutant Traps, City of Holdfast Bay

The City of Holdfast Bay has seven GPTs in place. These are located at the beach end of Edwards Street, Pier Street, Moseley Square, Wigley Reserve, Young Street, Augusta Street and Jetty Road, Brighton. All of these collect debris from residential, industrial, and/or commercial areas; many of which have very large catchment areas. Edwards Street for example has a catchment of 500 hectares of which two-thirds is collected from within the City of Marion boundary.

Figure 9.15 Augusta Street, Glenelg - GPT Installation

Source: Courtesy of City of Holdfast Bay

In addition to the GPTs, the former Patawalonga Catchment Water Management Board (now Adelaide and Mt Lofty Ranges Natural Resources Management Board) has also contributed to the installation of trash racks within the City of Holdfast Bay. An example of this can be seen at the top of the Patawalonga Lake and along the Sturt River.

Since the first GPT installation in 1997, the City of Holdfast Bay has worked collectively with the Adelaide and Mt Lofty Ranges Natural Resources Management Board towards implementing additional GPTs within Holdfast Bay. Site location, installation, and ongoing cleaning and maintenance costs can hinder the process.

The City of Holdfast Bay's GPTs are cleaned out by a contractor on a quarterly basis (more or less, largely dependent on the amount of rainfall received). A summary of the GPTs and the average amount of pollutants removed each year is contained in **Table 9.4**.

Figure 9.16 GPT Maintenance – Pier Street, Glenelg

Source: Courtesy of City of Holdfast Bay

As four of the City of Holdfast Bay's GPTs receive stormwater from the City of Marion, the former Patawalonga Catchment Water Management Board established a cost share agreement to assist with the cleaning and maintenance costs. For the 2007/08 financial year, $60,000 was budgeted.

Table 9.4 City of Holdfast Bay GPT Locations and Average Amount of Pollutants Removed Every Year

Location	Average Tonnes Removed per Year	Type	Dimensions	Cost	Construction Date
Augusta Street	40	Ecosol RSF 4900	Length 6.7m width 2.7 m depth 3.51m	$53,916 ($92,152.50)	Oct 2005
Edwards Street	220	CDS 4500	NA	$284,632	Jan 1997
Jetty Road, Brighton	8	Ecosol RSF 6000	NA	$36,946	Jan 2000
Young Street, Seacliff	40	Rocla – Cleansall 1350	NA	$201, 828	July 2001
Pier Street	24	CDS P2018L	NA	$159, 013	Dec 2000
Wigley Reserve	64	CDS 3000 – P3030	NA	$263, 242	Feb 1998
Moseley Square	32	CSR Humes - Humegard HG30A/L	width 3.4m length 2.5m capacity 11m^3	$76,627 (Oct 2002)	October 2002
Average Total	**428**				

Source: City of Holdfast Bay

9.8 Useful Resources and Further Information

Fact Sheets

www.epa.sa.gov.au/pdfs/water_general.pdf

Stormwater Pollution General Information fact sheet

www.greatlakes.local-e.nsw.gov.au/files/9730/File/FactSheet_GPTHLP03.pdf

Great Lakes Council NSW Fact Sheet Gross Pollutant Traps

www.yarracity.vic.gov.au/Environment/pdf/3.4%20ATT2c.pdf

Fact sheet 3 – Gross Pollutant Traps – Yarra City Council Victoria

www.melbourne.vic.gov.au/rsrc/PDFs/Water/WSUD_part3.pdf

Fact sheet 3d – Gross Pollutant Traps – City of Melbourne Victoria

Legislation

www.epa.sa.gov.au/pdfs/epp_noise_ind.pdf

Environment Protection (Industrial Noise) Policy 1994

www.epa.sa.gov.au/pdfs/info_construction.pdf

EPA information sheet on Construction Noise

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA information sheet on Environmental Noise

www.epa.sa.gov.au/pdfs/building_sites.pdf

EPA Handbook for Pollution Avoidance on Building Sites

www.epa.sa.gov.au/pdfs/bccop1.pdf

Stormwater Pollution Prevention Code of Practice for the Building and Construction Industry

General Information

www.siavictoria.info

Stormwater Industry Association – Victorian Chapter

www.epa.nsw.gov.au/stormwater/usp/

EPA (NSW)

www.stormwater.asn.au

Stormwater Industry Association

www.urbanwater.info/engineering/BuiltEnvironment/GrossPollutantTraps.cfm

Urban Water Info

www.bmpdatabase.org

International Stormwater Best Management Practice (BMP) Database

www.epa.gov/ost/stormwater

US EPA – Stormwater Best Management Practices Study

www.amlrnrm.sa.gov.au/ProjectsTaskforce/TrashRacks.aspx

Adelaide and Mt Lofty Ranges Natural Resources Management Board

www.holdfast.sa.gov.au/site/page.cfm?u=860

City of Holdfast Bay – Gross Pollutant Traps

9.9 References

Allison, R., Chiew, F. H. S., McMahon, T. (1997). *Stormwater Gross Pollutants*. Cooperative Research Centre for Catchment Hydrology. December. http://www.catchment.crc.org.au/pdfs/industry199711.pdf.

Allison, R., Chiew, F. H. S., McMahon, T. (1998). *A Decision Support System for Determining Effective Trapping Efficiencies for Gross Pollutants.* Cooperative Centre for Catchment Hydrology. http://www.catchment.crc.org.au/archive/pubs/1000089.html.

Fletcher, T. D., Duncan, H., Lloyd, S., Poelsma, P. (2004). *Stormwater Flow and Quality and the Effectiveness of Non-proprietary Stormwater Treatment Measures*. Co-operative Research Centre for Catchment Hydrology. Melbourne, Victoria. http://www.catchment.crc.org.au/pdfs/technical200408.pdf.

Gold Coast City Council (2007). *Water Sensitive Urban Design Guidelines*. June. http://www.goldcoast.qld.gov.au/t_standard2.aspx?PID=6866.

IE Aust. (2006). *Australian Runoff Quality: A Guide to Water Sensitive Urban Design*. New South Wales.

Taylor, A. C., Fletcher, T. D. (2004). *Estimating Life Cycle Costs of Structural Measures that Improve Urban Stormwater Quality*. Cities as Catchments - International Conference on Water Sensitive Urban Design, Adelaide, South Australia http://www.wsud.org/downloads/Info%20Exchange%20&%20Lit/WSUD_04_Conf_Papers/WS040007.PDF.

Wong, T., Wootton, R. M., Argue, J. D., Pezzaniti, D. (1999). *Bringing Order to the Pollution Control Industry – Issues in Assessing the Performance of Gross Pollutant Traps.* Proceedings of the International Congress on Local Government Engineering and Public Works, Sydney, NSW.

Appendix A
Checklists

Gross Pollutant Trap

Design Calculation Checklist

Asset ID:		
GPT Location:		
Hydraulics:	Design operational flow (m^3/s):	
	Above design flow (m^3/s):	
Area:	Catchment area (ha):	

Treatment	**Y**	**N**
1. Treatment performance verified		
GPT Component	**Y**	**N**
2. Appropriate hydraulic calculations and IFD used		
3. GPT capacity sufficient for maintenance period		
4. Maintenance access provided		
5. Public access to system prevented		
6. Drainage facilities/dewatering provide for cleanout		
7. Overall flow conveyance sufficient for design flood event		
8. No headloss in drainage system		
9. No surcharge upstream		
10. Bypass sufficient for conveyance of design event		
11. Tidal influence assessment undertaken (if appropriate)		
Comments		

Source: Adapted from Gold Coast City Council (2007)

Gross Pollutant Trap

Selecting a GPT Checklist

General	Yes	No
12. Space available for the device (i.e. required footprint, access routes, services)		
13. Location suit the catchment treatment objectives (e.g. position in a treatment train)		
14. Holding chamber suitable (wet or dry retention)		
15. Sufficient safety precautions (i.e. preventing entry, access for cleaning)		
16. Visual impact (and odour potential) satisfactory		
17. Treatment flow sufficient to meet treatment objectives		
18. Flooding impact been satisfactorily addressed		
19. Sufficient consultation taken place with operational staff and the local community		
20. Expected pollutant removal rate sufficient to meet treatment objectives		
Installation	**Yes**	**No**
21. Price include installation		
22. Sufficient contingencies for ground conditions (e.g. rock, shallow water table, soft soils etc)		
23. Relocation of services been included		
24. Sufficient access or traffic management systems proposed as part of construction?		
Maintenance	**Yes**	**No**
25. Method of cleaning applicable to local conditions (e.g. OH&S issues, isolation of the unit from inflows etc)		
25. Maintenance (cleaning) techniques suitable for the responsible organisation (i.e. required equipment, space requirements, access, pollutant draining facilities etc)		
26. Size of the holding chamber sufficient (for a maximum of 12 cleans per year)		
27. Disposal costs been accounted for		

Source: IE Aust. (2006)

Gross Pollutant Trap

Construction Inspection Checklist (During Construction)

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Constructed By:			
Weather:			

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
Preliminary works				
1. Erosion and sediment control plan adopted				
2. Temporary traffic/safety control measures				
3. Location same as plans				
4. Site protection from existing flows				
Earthworks				
5. Excavation as designed				
Pre-treatment				
6. Contributing catchment stabilised / not a sediment source				
Structural Components				
7. Location and levels of inlet and outlet and overflow points as designed				
8. Pipe joints and connections as designed				
9. Concrete and reinforcement as designed				
10. Inlets appropriately installed				

Items Inspected	**Checked**		**Satisfactory**	
	Y	**N**	**Y**	**N**
Sediment and Erosion Control				
11. Stabilisation immediately following earthworks				
12. Silt fences and traffic control in place				
13. Temporary protection in place (if appropriate)				
Operation Establishment				
14. Temporary protection removed				
15. GPT diversion removed				
Comments on Inspection				
Actions Required				
1.				
2.				
3.				
4.				
5.				
Inspection Office Signature:				

Source: Gold Coast City Council (2007)

Gross Pollutant Trap

Construction Inspection Checklist (After Construction)

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Constructed By:			
Weather:			

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
1. Confirm levels of inlets and outlets				
2. Traffic control in place				
3. Confirm structural element sizes				
4. Maintenance access provided				
5. Construction generated sediment and debris removed				
Comments on Inspection				
Actions Required				
1.				
2.				
3.				
Inspection Officer Signature:				

Source: Gold Coast City Council (2007)

Gross Pollutant Trap

Maintenance Inspection Checklist

Asset ID:		**Date of Visit:**	
Location:			
Description:			
Site Visit By:			
Purpose of Site Visit:	Routine Inspection:		
	Routine Clean Out of Trash Rack and Baskets:		
	Annual Inspection:		

Inspection	
1. Percentage of GPT covered by debris (%)	
2. GPT clean out required if above >50% (Y/N)	
3. Any visible damage to GPT (if yes, complete section on condition) (Y/N)	
Cleanout of GPT	
4. Volume of debris removed (m^3)	
5. Visible damage to GPT (if yes, complete section on condition) (Y/N)	

Component Condition	**Checked?**		**Condition OK?**		**Remarks**
	Y	**N**	**Y**	**N**	
6. Concrete walls					
7. Trash rack					
8. Baskets					
9. Access ladders					
10. GPT inlet					
11. GPT outlet					
12. Lids					

Comments on Inspection:
Actions Required:
1.
2.
3.
4.
5.

Source: Gold Coast City Council (2007)

Gross Pollutant Trap

Lifecycle Costs Checklist

Installation	Y / N
1. Does the trap satisfy:	
(i) the design flow rate	
(ii) the available space constraints	
(iii) hydraulic and flooding issues	
(iv) other concerns (e.g. safety and aesthetics)	
If no to any of the above, then go no further	
2. Trap cost	
3. Installation cost	
4. Other costs (rock excavation, lid loading, access road for maintenance etc.)	
Maintenance	
5. Annual maintenance costs	
6. Cost of any special maintenance equipment	
7. Expected costs of disposal	
Life Cycle Cost	
8. Estimated project duration (in years)	
9. Life cycle costs = $\frac{\text{Installation costs} + (n \times \text{maintenance costs})}{n}$ *where n = project duration (years)*	

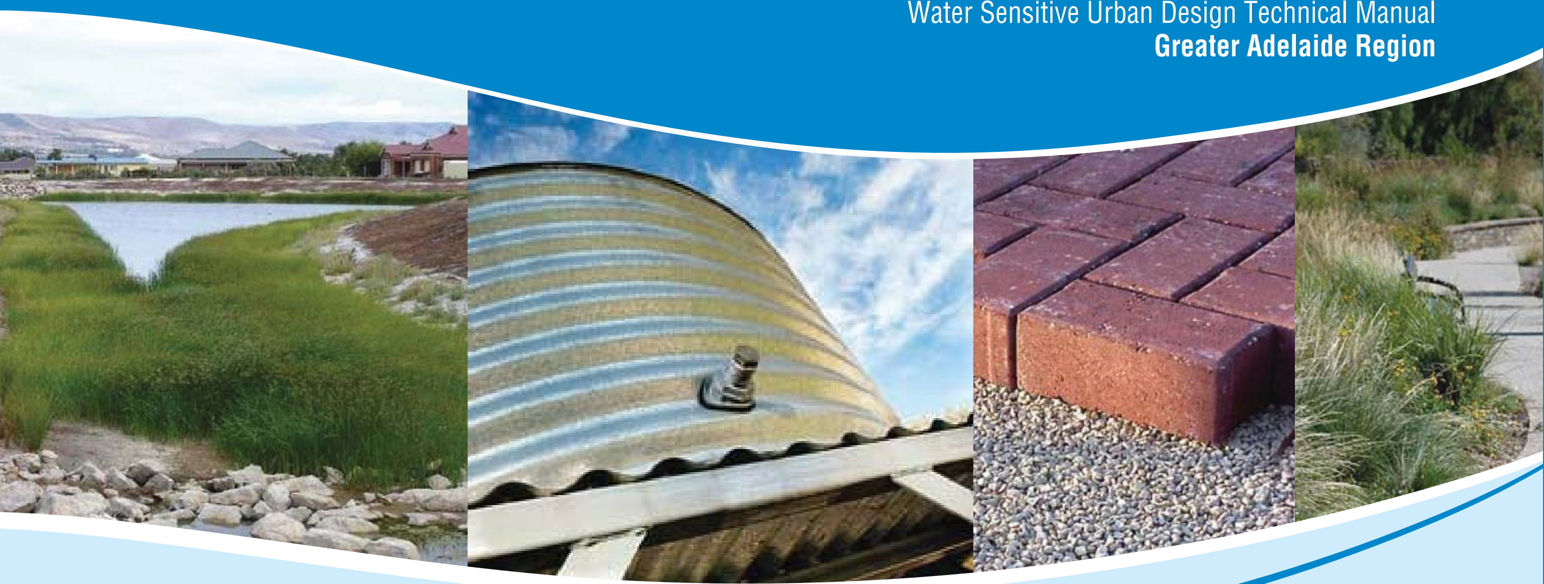
Source: IE Aust. (2006)

July 2009

Chapter 10

Bioretention Systems for Streetscapes

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 10
Bioretention Systems for Streetscapes

10.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Bioretention systems are one of those measures.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing an overview of bioretention systems and how they can be utilised to assist in achieving the objectives and targets of Water Sensitive Urban Design (WSUD).

Description

Broadly speaking, bioretention systems are WSUD measures that involve some treatment by vegetation prior to the filtration of runoff through a prescribed media. Following treatment, water may be infiltrated to the subsoil or collected in subsoil pipes for retention, further treatment or disposal. A bioretention system is most commonly implemented as a bioretention swale or bioretention basin.

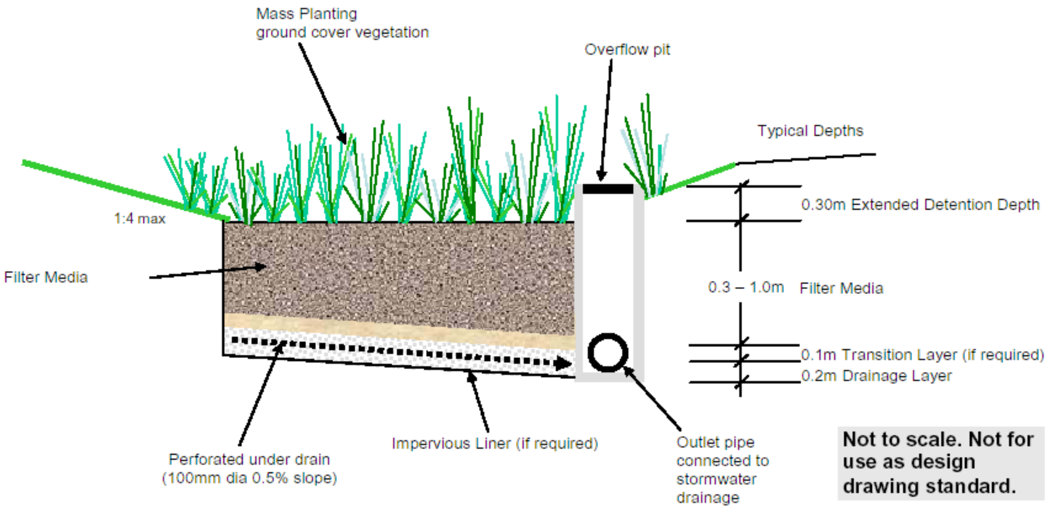


Figure 10.1 Typical Cross Section of a Bioretention System

Source: Gold Coast City Council (2007)

Bioretention Swales

Bioretention swales (or biofiltration trenches) are bioretention systems that are located within the base of a swale (see **Figure 10.2**). They may involve a continuous component of bioretention along the length of the swale, or a portion of bioretention prior to the outlet of the swale.

Bioretention Basins

Bioretention basins provide flow control and water quality treatment functions. A bioretention basin is characterised by the ability to detain runoff in a depression storage (or ponded area) above the bioretention system (see **Figure 10.3**).

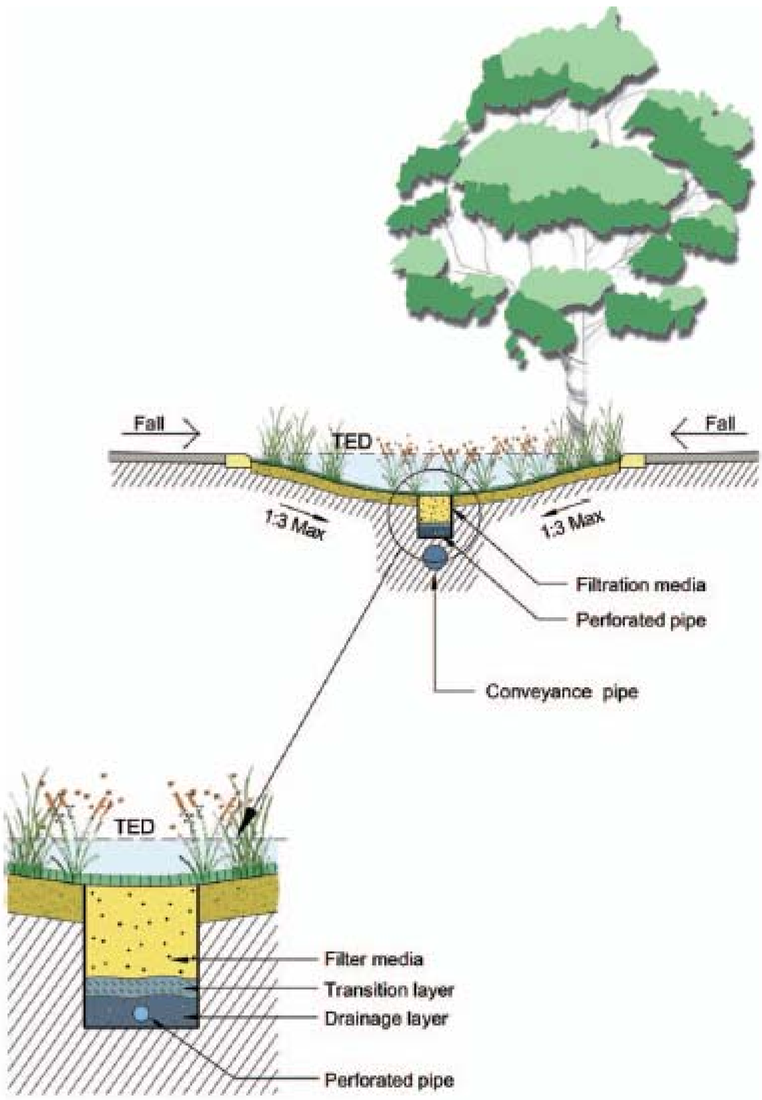


Figure 10.2 Cross Section Through a Bioretention Swale

Source: Melbourne Water (2005)

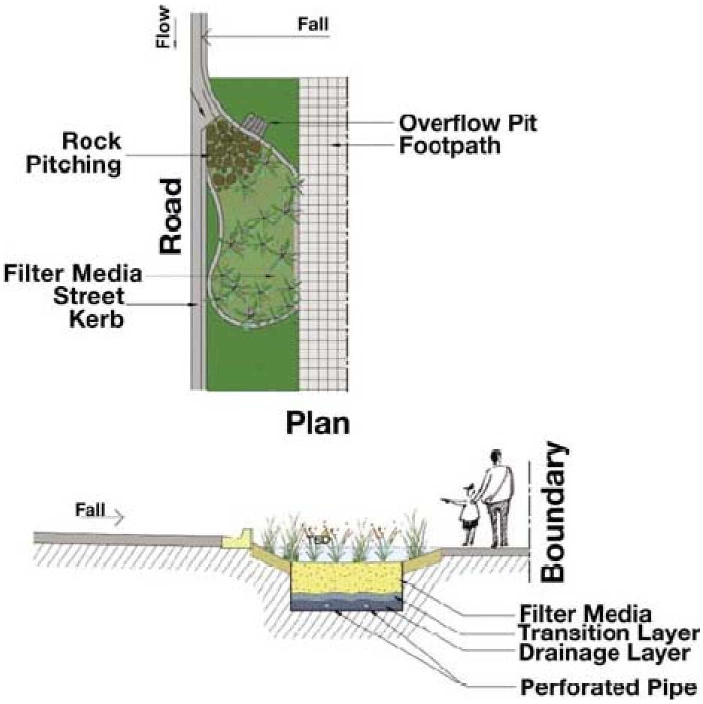


Figure 10.3 Bioretention Basin

Source: Gold Coast City Council (2007)

Purpose

The main functions of bioretention systems are water quality control, water conservation and increased amenity. They provide limited flood control, mainly because of their small volume.

Bioretention systems can provide both runoff treatment and conveyance functions including:

- The removal of coarse to medium sediments and associated pollutants (such as nutrients, free oils/grease and metals) by filtration through surface vegetation and groundcover (during conveyance, especially in a swale);
- The removal of fine particulates and associated contaminants by infiltration through the underlying filter media layers. This provides treatment by filtration, extended detention treatment and some biological uptake;
- A disconnection of impervious areas from downstream waterways and protection to natural receiving waterways from frequent storm events by delaying runoff peaks, providing retention capacity and a reduction in peak flow velocities. Swale components can be designed to convey runoff as part of a minor and/or major drainage system;
- Potential aesthetic benefits due to surface vegetation being able to be incorporated into streetscape and general landscape features; and

- The provision of quality habitat conditions for wildlife, contributing positively to biodiversity enhancement in urban areas.

Bioretention systems are generally not intended to be 'infiltration' systems – the design does not typically include runoff exfiltrating from the bioretention filter media to the in-situ soil environment. Rather, the most common application of bioretention systems is to recover the percolated runoff at the base of the filter media using perforated underdrains for subsequent discharge to receiving waterways. The water may also be directed to storage for potential reuse. Bioretention systems are therefore well suited to a wide range of soil conditions including areas affected by soil salinity and saline groundwater.

However, in some circumstances where the in-situ soils allow, and there is a design intention to recharge local groundwater, it is possible to permit the percolated runoff to infiltrate from the filter media to the underlying in-situ soils (after considering the in-situ soil properties).

The low void ratios of soils used in these systems (a typical value is 0.2) and their limited infiltration rates (typically 150 to 350 mm/h) limits their potential to provide flood control. An approximation of the available flood storage volume is a combination of 20% of the soil volume plus the above lying ponding volume, although in practice the available soil storage is unlikely to be fully utilised during a high intensity storm event.

Where both the minor and major flood flows must be conveyed over the bioretention surface, velocities should be kept preferably below 0.5 m/s to avoid scour.

Scale and Application

Bioretention systems are best suited to small (i.e. less than 5 ha) catchments in residential, commercial and industrial developments with high percentages of impervious areas. Bioretention systems can be appropriate in areas where runoff is insufficient or unreliable, evaporation rates are too high, or soils are too pervious to sustain the use of constructed wetlands.

Bioretention systems can be installed at various scales, for example, in local streets or on large highways.

They can be located within:

- Parkland areas;
- Carparks;
- Along roadway corridors within footpaths (i.e. road verges); and
- Centre medians.

Performance Efficiency

Bioretention systems can improve the water quality of runoff through several treatment mechanisms. These include, but are not restricted to:

- Coarse filtration through surface vegetation;
- Sedimentation occurring while detained water infiltrates;
- Biological uptake of organic and inorganic pollutants by vegetation;
- Biological uptake of pollutants by subsoil biota;
- Sorption of pollutants to filter media; and
- Filtration through filter media.

Correctly designed and maintained bioretention systems have been shown to retain pollutants in numerous studies. Pollutant removal efficiencies of bioretention systems that are available in the literature are summarised in **Table 10.1**.

Table 10.1 Bioretention System Performance Efficiencies

Gross Pollutants*	Coarse Sediment*	Medium Sediment	Fine Sediment	Free Oil and Grease	Nutrients**	Metals
-	80-100%	50-80%	30-50%	30-50%	30-50%	30-50%

**Assumes gross pollutant pre-treatment provided*

***Bound to sediments and some dissolved nutrients*

Source: Upper Parramatta River Catchment Trust (2004)

Figure 10.4 Bioretention Swale as a Median Strip

Source: Courtesy of University of South Australia

10.2 Legislative Requirements and Approvals

Before undertaking a concept design of a bioretention system it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to bioretention systems in your area.

The legislation which is most applicable to the design and installation of bioretention systems in the Greater Adelaide Region includes, but may not be restricted to:

- *Development Act 1993* and Development Regulations 2008; and
- *Environment Protection Act 1993*

Development Act 1993

Installing bioretention systems will generally be part of a larger development (for new developments), however whenever bioretention systems are planned (such as retrofitting), it is advised that the local council be contacted to:

- Determine whether development approval is required under the *Development Act 1993*; and
- Determine what restrictions (if any) there may be on the installation of bioretention systems on site.

Environment Protection Act 1993

Any development, including the installation of bioretention systems, has the potential for environmental impact, which can result from vegetation removal, stormwater management and construction processes. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on the whole site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when planning on installing bioretention systems are discussed below.

Water Quality

Water quality in South Australia is protected using the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development. In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, building sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise potential for environmental impact during construction. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 10.8**).

Measures also need to be taken to ensure that erosion and subsequent water quality impacts do not result after the installation of a bioretention system.

Waste

Any wastes arising from excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*. For example, during construction all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 10.8**).

Noise

The issue of noise has the potential to cause nuisance during any construction works of bioretention systems. The noise level at the nearest sensitive receiver should be at least 5 dB(A) below the Environment Protection (Industrial Noise) Policy 1994 allowable noise level when measured and adjusted in accordance with that policy.

Reference should be made to the EPA Information Sheets on Construction Noise and Environmental Noise respectively to assist in complying with this policy (see **Section 10.8**).

Air Quality

Air quality may be affected during the installation of bioretention systems. Dust generated by machinery and vehicular movement during site works, and any open stockpiling of soil or building materials at a site, must be managed to ensure that dust generation does not become a nuisance off site.

Figure 10.5 Bioretention Swale at Mawson Lakes Campus at the University of South Australia

Source: Courtesy of University of South Australia

10.3 Design Considerations

As with other WSUD measures based on soil filtration of runoff, bioretention systems require due consideration of the site conditions. In the situation where water may permeate through the base of the bioretention media, the potential for contamination of the receiving soil and groundwater environment should be considered.

Design issues that need to be considered for the bioretention component of these systems, before detailed design, are addressed in this section.

The design considerations and design process for the swale component (where relevant) should be taken into account in conjunction with the information contained in this section (see **Chapter 11**).

These design considerations include:

- Landscape design;
- Vegetation types;
- Hydraulic design;
- Use as an infiltration system;
- Prevention of infiltration;
- Bioretention filter media;
- Traffic controls;
- Services; and
- Limitations.

The following sections provide an overview of the key design issues that should be considered when conceptualising and designing bioretention systems.

Landscape Design

Bioretention systems are a combined solution that can involve treatment by extended detention and some biological uptake through the planted bioretention component. While the landscaping for either the swale (or basin) and bioretention parts is essentially similar to the treatments for the stand-alone components, consideration of the landscape interface between the vegetated swale (or basin) and bioretention is important.

As bioretention swales have the potential to perform a valuable landscape function it is important that the design is sensitive to landscape requirements. For example, landscape design of bioretention swales along the road edge can assist in defining the boundary of road or street corridors as well as providing landscape character and amenity.

Objectives

Landscape design for bioretention systems has some key objectives. These include:

- Ensuring surface treatments and planting designs address runoff quality objectives by incorporating appropriate plant species for treatment of runoff (particularly those with a biologically active root zone) while enhancing the overall natural landscape;
- Integrating planning and design of bioretention systems within their surrounding built and landscape environments;
- Incorporating Crime Prevention Through Environmental Design (CPTED) principles and road, driveway and footpath visibility safety standards;
- Creating landscape amenity opportunities that enhance community areas. This involves improvements to visual aesthetics, provision of shade and screening, view framing, and way finding; and
- Consideration of urban ecological and biodiversity value and promotion of the potential of the systems to serve as wildlife corridors.

Design

Bioretention systems can provide a relatively maintenance free finish if the planting is designed well. Key landscape considerations when designing bioretention systems are:

- Type and size of inorganic mulch;
- Density and types of plantings;
- Locations of trees and shrubs;
- Type of garden (mowing) edges to turf areas that allows unimpeded movement of runoff;
- Overall alignment of swale or basin within the streetscape;
- Timing of the planting of the vegetation;
- Provision of access for maintenance of the vegetation; and
- Water requirements, particularly considering the current drought conditions and watering restrictions.

Vegetation Types

The vegetation in a bioretention system enhances the treatment process of runoff and helps maintain the permeability of the filter media. The bioretention filter media is usually the plant growing material, which may comprise a mixture of soil, gravel, sand and/or peat.

Vegetation that grows in the filter media enhances its function by trapping and absorbing physical pollutants and preventing erosion of the filter medium. It also improves the performance of the system by continuously breaking up the soil through plant growth to prevent clogging of the system and providing biofilms on plant roots that pollutants can absorb or otherwise adhere to. While the type of vegetation varies depending on landscape requirements and climate, the filtration process generally improves with denser and higher vegetation.

Figure 10.6 Bioretention Swale Integrated into the Design of an Urban Park

Source: Courtesy of University of South Australia

The vegetation is required to:

- Cover the whole width of the system and bioretention filter media surface to encourage the trapping of suspended solids;
- Be capable of withstanding design flows; and
- Be of sufficient density to prevent the development of preferred flow paths and scour of deposited sediments.

The following points provide general information on the selection of plants for a bioretention system:

- The preferred vegetation for the bioretention component of bioretention swales is sedges and tufted grasses (with potential occasional tree plantings) that do not require mowing. Repeated mowing over a bioretention swale can result in long-term compaction of the filter media and reduce its treatment performance. The use of turf is not encouraged;
- Drought tolerant plant species with spreading growth forms are preferable to clumping growth form plant species as they provide improved water quality performance and reduce the potential for scouring;
- Perennials with deep fibrous root systems provide enhanced infiltration performance over annuals with shallow root systems;
- Avoid invasive plant species that will smother the surface and eliminate other plant types in the bioretention system;

- The more dense and tall the vegetation planted in the bioretention filter media, the better the treatment provided, especially during extended detention. Taller vegetation has better interaction with temporarily stored runoff during ponding. Dense vegetation reduces flow velocity. Both enhance sedimentation of suspended sediments and associated pollutants;
- Densely vegetated bioretention systems can become features of an urban landscape and, once established, require minimal maintenance and are hardy enough to withstand large flows.

Plant selection should also be based on pollutant removal performance relative to locality. In general, for biodiversity enhancement purposes in urban green spaces, it is important to provide a range of shade, canopy heights and variety of habitat elements. This is best achieved using a range of vegetation types rather than a single plant species.

Figure 10.7 Bioretention Basin at Palmer Street, Aldinga Beach

Source: Courtesy of City of Onkaparinga

Hydraulic Design

A key hydraulic design consideration for bioretention systems is the delivery of runoff onto the surface of a bioretention filter media. Flow must not scour the bioretention surface and needs to be uniformly distributed over the full surface area of the filter media.

It is therefore important to ensure that velocities in the bioretention systems are kept low. Flow velocities should be preferably below 0.5 m/s in a minor flood event and not more than 1.0 m/s for a major flood event (IE Aust. 2006).

Reduced flow velocities can also be achieved by creating shallow temporary ponding (i.e. extended detention) over the surface of the bioretention filter media through the use of raised field inlet pits. This may also increase the overall volume of runoff that can be treated by the bioretention filter media.

With regards to a bioretention swale, typically, when used as a continuous trench along the full length of a swale, the desirable maximum longitudinal grade of the swale is 4%. For other applications, the desirable grade of the bioretention zone is either horizontal or as close as possible to horizontal to encourage uniform distribution of runoff over the full surface area of bioretention filter media and allowing temporary storage of flows for treatment before bypass occurs.

In steeper areas, where a swale is utilised, check dams may be required along the swale to reduce flow velocities discharged onto the bioretention filter media.

A check dam is used to prevent scouring and slow down water. It is a simple structure or mechanism that can consist of anything from an area on an existing slope where water can temporarily pond before proceeding further, to a small weir device that ponds water and spreads its flow.

It should be noted that check dams may inhibit ease of maintenance i.e. they can be a hindrance to mowing.

Use as an Infiltration System

Bioretention systems can be designed to either preclude or promote exfiltration of runoff to surrounding in-situ soils. In the latter case, the bioretention system acts as an enhanced infiltration system. The incorporation of an infiltration component in the design is dependent on the runoff management objectives of the project.

Before using a bioretention system as an enhanced infiltration system in the design, the following should be considered:

- Site terrain;
- Hydraulic conductivity of the in-situ soil;
- Soil salinity;
- Groundwater; and
- Building setback.

For further guidance on infiltration systems, please refer to **Chapter 6** (Rain Gardens, Green Roofs and Infiltration Systems) of the WSUD Technical Documents for the Greater Adelaide Region.

Preventing Infiltration

In some cases it may be necessary to take measures to ensure water does not enter the soil beneath a bioretention system. The amount of water lost from bioretention systems to surrounding in-situ soils is largely dependent on the characteristics of the local soils and the saturated hydraulic conductivity of the filter media.

If the selected saturated hydraulic conductivity of the filter media is one to two orders of magnitude (i.e. 10 to 100 times) greater than that of the local soils, then the preferred flow path for runoff will be vertically through the filter media and into underdrains at the base of the filter media. However, if the selected saturated hydraulic conductivity of the bioretention filter media is less than 10 times that of the local soils, it may be necessary to provide an impermeable liner. Flexible membranes or a concrete casting are commonly used. This is particularly applicable for surrounding soils that are very sensitive to any exfiltration (e.g. sodic soils and reactive clays in close proximity to significant structures such as roads).

The greatest pathway of exfiltration is through the base of a bioretention system. The gravity and the difference in hydraulic conductivity between the filter media and the local soil would typically act to minimise exfiltration through the walls of the system. If lining is required, it is likely that only the base and the sides of the drainage layer will need to be lined.

It may be necessary to provide an impermeable liner to the sides of the filter media to prevent horizontal exfiltration and subsequent short-circuiting of the treatment provided by the bioretention system.

Bioretention Filter Media

Selection of an appropriate bioretention filter media is a key design step involving consideration of three inter-related factors:

- The saturated hydraulic conductivity required to optimise the treatment performance of the bioretention component given site constraints on available filter media area;
- The depth of extended detention provided above the filter media; and
- The suitability as a growing media to support vegetation growth (i.e. retaining sufficient soil moisture and organic content).

The maximum saturated hydraulic conductivity should not exceed 500 millimetres/hour (and should preferably be in the range 150-350 millimetres/hour) in order to sustain vegetation growth.

During the conceptual design stage, the optimal combination of filter media, saturated hydraulic conductivity and extended detention depth can be established using a continuous simulation modelling approach (e.g. MUSIC, see **Section 10.5** and **Chapter 15**). Any adjustment of these design parameters during the detailed design stage will require the continuous simulation modelling to be re-run to assess the potential impact on the overall treatment performance.

A bioretention filter media can consist of up to three layers:

- The filter media required for treatment of runoff;
- The drainage layer required to convey treated water from the base of the filter media into perforated underdrains; and
- The drainage layer, which surrounds perforated underdrains and can be either coarse sand (1 mm) or fine gravel (2-5 millimetres).

If fine gravel is used for the drainage layer, it is advisable to install a transition layer of sand or a geotextile fabric (with a mesh size equivalent to the sand size) to prevent migration of the base filter media into the drainage layer and into the perforated underdrains.

To prevent the mixing of filter media into indiscreet layers, reference must be made to soil filter criteria.

Traffic Controls

Another design consideration is keeping traffic and building material deliveries off bioretention systems, particularly during the construction phase of a development. Consequences of vehicle movement and parking on bioretention systems include:

- The compaction of the surface and damage to vegetation beyond its ability to regenerate naturally;
- Reduction in infiltration into the filter media and early bypass, and reduced treatment.;
- Ruts which can create preferential flow paths that diminish the water quality treatment performance as well as creating depressions that can retain water and potentially become mosquito breeding sites.

A staged construction and establishment method affords protection to the subsurface elements of a bioretention system from runoff with a heavy sediment load during the construction and building phases.

To prevent vehicles driving on bioretention systems and inadvertent placement of building materials on the surface of a bioretention system, it is necessary to consider appropriate traffic control solutions as part of the system design. These can include:

- Temporary fencing of the system during the construction and building phases;
- Signage erected to alert builders and contractors of the purpose and function of the system;
- Planting the interface to the road carriageway with dense vegetation that will discourage the movement of vehicles onto the system once the construction phase has been completed;

- Providing physical barriers such as kerb and channel (with breaks to allow distributed water entry to the system) or bollards and/or street tree planting.

Kerb and channel should be used at all corners, intersections, cul-de-sac heads and at traffic calming devices to ensure the correct driving path is taken. For all of these applications, the kerb and channel should extend 5 metres beyond tangent points. The transition from barrier or lay back type kerb to flush kerbs and vice versa is to be done in a way that avoids creation of low points that cause ponding onto the road pavement.

Where bollards/road edge guide posts are used, consideration should be given to intermixing mature tree plantings with the bollards to break the visual monotony created by a continuous row of bollards.

The construction stage is also discussed in **Section 10.6**.

Services

Bioretention systems located within road verges must consider the standard location for services within the verge and ensure access for maintenance of services. It is generally acceptable to have water and sewer services located beneath the batters of the system. Surface finishing from water and sewerage services should not be located within the designated water flow area of the system.

Essentially, the design must ensure:

- No services are located below the system invert;
- Enough space is provided to access services for maintenance without affecting the system invert; and
- There is no compromise to the width provided in the road verge for services.

Limitations

Site limitations that may preclude the use of bioretention systems include:

- High headloss due to vertical filtration;
- A requirement for adequate sunlight for vegetation growth;
- The potential for filter clogging if upstream pre-treatment of litter and coarse sediments does not occur; and
- The need for regular inspections and maintenance required during the vegetation establishment period.

10.4 Design Process

Overview

The design process for bioretention systems consists of a number of steps including:

- Assess site suitability;
- Determine the design objectives and targets;
- Consult with council and other relevant authorities;
- Select the type of bioretention system;
- Design of the swale components (where applicable);
- Determine the design flows;
- Size the bioretention system;
- Determine the design of kerb inlets;
- Design the bioretention system components;
- Check the design objectives;
- Specify plant species and planting densities; and
- Develop a maintenance schedule.

A number of elements of the design process are discussed briefly below. Further details regarding the detailed design process are contained in **Appendix A** and a range of checklists is provided in **Appendix B**.

A general design process for WSUD measures is contained in **Chapter 3** of the Technical Manual.

Site Suitability

Careful selection of placement of the bioretention system is important and is not only a matter of appearance. An assessment of site conditions is necessary to identify what measures, if any, are required to ensure that the bioretention system will perform for the entire design lifetime.

Careful site analysis and integrated design with engineers, landscape architects and urban designers will ensure that a bioretention system meets functional and aesthetic outcomes.

Assessment of the groundwater should be undertaken to define existing water quality, potential uses (both current and future) and suitability for recharge.

Bioretention systems show a decline in permeability with exposure to sediment and organic matter through their lifetime. To ensure adequate performance of these systems, it may be necessary to design the system to utilise only a portion of their 'as new' capacity.

Figure 10.8 Bioretention Bed, Star of Greece Car Park

Source: Courtesy of the City of Onkaparinga

Bioretention systems should be located in areas to avoid:

- High water tables;
- Saline soils;
- Acid sulphate soils;
- Wind blown areas;
- Runoff from areas expected to have a high sediment load;
- High traffic volumes; and
- Services (existing or proposed).

Design Objectives and Targets

The design objectives and targets will vary from one location to another and will depend on the characteristics of the site, form of the development and the requirements of the receiving ecosystems. It is essential that these objectives are established as part of the conceptual design process and discussed with the relevant authority (i.e. council) prior to commencing the engineering design.

The design approach for bioretention systems is generally based on achieving the following broad objectives:

- For infiltration systems, providing sufficient surface area and capacity of the reservoir (sub-base) storage to contain the treatment volume and allow infiltration to the subsoil between storm events; and
- For detention systems, providing sufficient capacity of the reservoir (sub-base) storage to provide adequate detention during high runoff events to reduce peak outlet design discharges to specified pre-development conditions.

The design approach for bioretention systems is also based on achieving the following objectives:

- Providing an adequate hydraulic residence (filtration) time through the system to enable sediments and attached pollutants to be retained; and
- Selection of suitable planting filter media to provide required hydraulic residence (filtration) time through the system.

Bioretention systems can be designed to achieve a range of specific objectives including:

- Minimising the volume of runoff from a development;
- Preserving pre-development hydrology;
- Capturing and detaining or infiltrating flows up to a particular design flow;
- Enhancing groundwater recharge or preserving pre-development groundwater recharge; and
- Removing some sediment and attached pollutants by passing runoff through an underlying media layer.

Consult with Council and Other Relevant Authorities

The designer should liaise with civil designers and council officers to ensure:

- The bioretention system will not result in water damage to existing services or structures;
- Access to existing services is not compromised for maintenance and other works; and
- No conflicts arise between the location of services and WSUD devices.

The council will also be able to advise whether development approval is required and whether any other approving authorities should be consulted.

Asset ownership and transfer, including long-term maintenance requirements, should also be discussed at this initial meeting.

Select Type of Bioretention System

Selection of the type of bioretention system for a particular application must occur as part of the conceptual design process by assessing the site conditions, runoff management requirements, desired amenity and existing built environment/local character requirements against the functional types of bioretention systems. The two types of bioretention systems, bioretention basins and bioretention swales, are discussed in **Section 10.1**.

The selection of a bioretention system will depend on the nature of the available space. A bioretention basin will be used in cases where water is to be detained and treated in a single location. Surface runoff will be directed to the basin where it will pond, before passing through the bioretention media.

A bioretention swale is used in cases where periods of 'ponding' would be unacceptable, but where long stretches of land are available – road medians and carpark areas are prime examples of the type of applications. In a bioretention swale, runoff should be conveyed away from the area of the catchment where ponding will cause a hazard to the public.

Size Bioretention Systems

Factors to consider when sizing a bioretention system are:

- The allowable width, given the proposed road reserve and/or urban layout;
- The need to allow for services;
- Delivery of flows into the system (e.g. cover requirements for pipes or kerb details);
- The vegetation height;
- The longitudinal slope;
- The maximum side slopes and base width; and
- The provision of crossings (elevated or at grade).

Depending on which of the above factors are fixed, the other variables can be adjusted to derive the optimal dimensions for the given site conditions.

Design of Kerb Inlets

Kerb inlet design on a bioretention system is an important consideration, especially in the case of a bioretention basin. It is important to allow water to enter the bioretention system in a manner that will not scour the surface of the bioretention system and not compromise the safety of road users and pedestrians.

The design of kerb inlets for bioretention swales and basins is discussed below.

Bioretention Swale

In most instances, it is necessary to have some form of kerb along the length of a bioretention swale to delineate the adjacent roadway and/or parking area from the bioretention system. This is an important consideration to control traffic as traffic can damage both vegetation and the effective infiltration rate of bioretention soil media by compaction.

Kerbs with gaps tend to be the most common way of delineating trafficable and non-trafficable areas when applying a bioretention swale. Although there is no strict guideline for the design of kerbing with gaps, it is recommended that 0.5 m gaps or 'cutaways' be used between reformed kerb sections approximately 1-2 metres in length. Some practitioners have undertaken more decorative kerbing styles, as shown in **Figure 10.9**.

Figure 10.9 Kerb Inlet Design for a Bioretention Swale

Source: Courtesy of University of South Australia

Bioretention Basin

Advice from current practitioners is a valuable resource with respect to kerb inlet design for bioretention basins. The council of the City of Kingston, Victoria, prefers the use of depressed kerb inlet pits fitted with rock and concrete 'dispersion trays'. This kerb inlet design is also prescribed by Brisbane City Council documentation.

The following images illustrate possible inlet designs. Note that the rock and concrete structure is offset from the road itself where it may present a hazard to cycle traffic at the road edge.

Figure 10.10 Kerb Inlets Design for Bioretention Basin

Source: Courtesy of University of South Australia

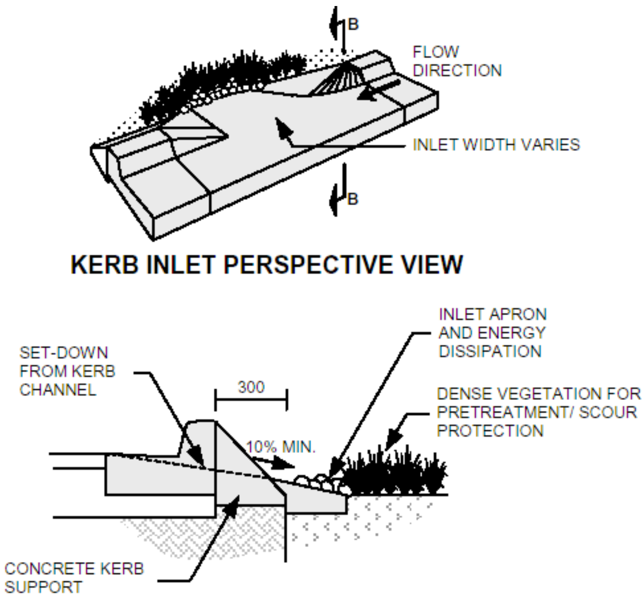


Figure 10.11 Alternative Pit Inlet Design for Depressed Bioretention Basin at Quinliven Road, Aldinga

Source: Courtesy of Martin Ely

Figure 10.12 Kerb Inlet Concept Diagram

Design of Bioretention System Components

Bioretention systems must be designed as two separate entities. The first step in any decision making process is to determine whether the primary purpose of the bioretention system will be:

- Conveyance; or
- Infiltration

Bioretention systems designed for *conveyance* should be designed with reference to the requirements for a **vegetated swale** in **Appendix A**. Note that these systems are not typically incorporating the 'retention' component as a primary aim in their design.

Bioretention systems that are designed for the *detention and subsequent filtration and collection or infiltration* of runoff should be designed in accordance with the design procedure for a **bioretention basin** in **Appendix A**.

Bioretention systems that are designed to achieve both *conveyance* and *infiltration* (for example, where a swale includes a significant area of infiltration) should be designed with reference to the design procedure for a **bioretention swale** in **Appendix A**.

Check the Design Objectives

This step involves confirming the design objectives, defined as part of the conceptual design, to ensure that the bioretention system design is appropriate. The treatment performance of the system should be confirmed (including revisiting and checking of any modelling used to assess treatment performance).

Specify Plant Species

Refer to **Sections 10.3** and **10.8** for advice on selecting suitable plant species for bioretention systems in the Greater Adelaide Region. Consultation with landscape architects is recommended when selecting vegetation to ensure that the treatment system complements the landscape design of the area. Consideration also needs to be given to how maintenance is to be performed on the bioretention system (e.g. how and where access is provided, where litter and sediment will collect etc.) and the water requirements of the species given the current water restrictions.

It should be noted that the timing of planting is critical to optimum establishment of plants. Poor timing can result in excessive erosion, poor plant establishment, plant losses and additional costs.

Maintenance Plan

A specific maintenance plan and schedule should be developed for the bioretention system.

If the bioretention system is not maintained frequently, the entire filter media may need to be replaced due to clogging of the media material with fine particles. This can result in frequent maintenance being more cost effective in the long-term.

Bioretention swales have a flood conveyance role that needs to be maintained to ensure adequate flood protection for local properties.

Vegetation plays a key role in maintaining the permeability of the soil media of the bioretention system and a strong healthy growth of vegetation is critical to its performance.

The most intensive period of maintenance is during the plant establishment period (over the first two years) when weed removal and replanting may be required. The following critical items should be monitored every one to three months during this period:

- Ponding, clogging and blockage of the filter media;
- Establishment of desired vegetation/plants and density; and
- Blockage of the outlet from the bioretention system.

It is also the time when large loads of sediments could impact on plant growth, particularly in developing catchments with an inadequate level of erosion and sediment control.

Typical maintenance of bioretention swale elements will involve:

- Routine inspection of the swale profile to identify any areas of obvious increased sediment deposition, scouring of the swale invert from storm flows, rill erosion of the swale batters from lateral inflows, damage to the swale profile from vehicles and clogging of the bioretention trench (evident by a 'boggy' swale invert);
- Routine inspection of inlet points (if the swale does not have distributed inflows), surcharge pits and field inlet pits to identify any areas of scour, litter build up and blockages;

- Removal of sediment where it is impeding the conveyance of the swale and/or smothering the swale vegetation and, if necessary, reprofiling of the swale and revegetating to original design specification;
- Repairing any damage to the swale profile resulting from scour, rill erosion or vehicle damage;
- Tilling of the bioretention trench surface if there is evidence of clogging;
- Clearing of blockages to inlets or outlets;
- Inspections of inlet and outlet points to ensure structural integrity;
- Regular watering/irrigation of vegetation until plants are established and actively growing (for the swale component), in accordance with water restrictions;
- Mowing of turf or slashing of vegetation (if required) to preserve the optimal design height for the vegetation (although heavy machinery for mowing/slashing should be avoided);
- Removal and management of invasive weeds;
- Removal of plants that have died and replacement with plants of equivalent size and species as detailed in the plant schedule;
- Pruning to remove diseased vegetation material and to stimulate new growth;
- Litter and debris removal; and
- Vegetation pest monitoring and control.

Resetting (i.e. complete reconstruction) of bioretention elements will be required if the available flow area of the overlying swale is reduced by 25% (due to accumulation of sediment) or if the bioretention trench fails to drain adequately after tilling of the surface and other maintenance/corrective actions are taken. Inspections are also recommended following large storm events to check for scour.

All maintenance activities should be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design procedure. Maintenance personnel and asset managers will use this plan to ensure the bioretention system continues to function as designed. The maintenance plan and forms should address the following:

- Inspection frequency;
- Maintenance frequency;
- Data collection/storage requirements (i.e. during inspections);
- Detailed cleanout procedures (main element of the plan) including:
  - Equipment needs
  - Maintenance techniques
  - Occupational health and safety

- Public safety;
- Environmental management considerations;
- Disposal requirements (of material removed);
- Access issues;
- Stakeholder notification requirements;
- Data collection requirements (if any); and
- Design details.

An example Operation and Maintenance Checklist is included in **Appendix B**.

10.5 Design Tools

Various design tools are available for the concept and detailed design of bioretention systems as detailed in **Chapter 15** and listed below:

Water treatment:

- Music; and
- SWMM.

Runoff conveyance for surface flow management:

- SWMM; and
- DRAINS.

10.6 Construction Process

There are numerous challenges that must be appropriately considered to ensure successful construction and establishment of bioretention systems. These include:

- Sediment loads during construction; and
- Construction traffic and other works which can damage the surface.

Where large scale bioretention systems are proposed, a detailed construction and establishment plan, including temporary protective measures, should be prepared.

Further details are contained in **Section 10.3**.

Figure 10.13 Preliminary Stages of Construction of a Bioretention Swale at Mawson Lakes Campus at the University of South Australia

Source: Courtesy of the University of South Australia

An example Construction Checklist in **Appendix B** presents the key items to be reviewed when inspecting the bioretention system during and at the completion of construction.

10.7 Approximate Costs

The construction cost for bioretention systems depend on the surface area/width, depth, type of surface vegetation and the inlet/outlet structures. The estimated unit rate construction costs for a 3 m wide x 1 m nominal deep, online bioretention trench is summarised in Error! Reference source not found. below.

The unit cost for a 3 m wide x 1 m nominal deep bioretention trench is approximately $410/metre by length, or approximately $137/metre of trench surface area. However, costs , will tend to differ as a result of the type of surface landscaping, and the sand and gravel type and source location.

Long-term maintenance costs for bioretention systems are largely unknown but are likely to be dominated by activities similar to those of swales, i.e. $1.5 to $2.5/square metre for landscaped systems (Upper Parramatta River Catchment Trust 2004).

Table 10.2 Estimated Costs for a Biofiltration Trench

Work Description	Quantity	Unit	Rate	Cost ($/m)
Excavated trench (3m x1.5m) and stockpile	4.8	m^3/m	20	96
Supply and install geofabric liner	6.2	m^2/m	5	31
Supply and place under-drainage pipe (100 diameter)	1.0	m/m	13	13
Supply and place gravel drainage layer	0.7	m^3/m	45	31.5
Supply and place filter media (sand/gravel soil)	0.5	m^3/m	55	165
Supply and place graded filter sand layer (150 nom thick)	3.0	m^3/m	45	22.5
Supply and place topsoil layer (100 nom thick)	0.5	m^3/m	7.0	21
Supply established vegetation ground cover including planting, fertiliser and watering	3.0	m^2/m	10	30
TOTAL				410

Source: Upper Parramatta River Catchment Trust (2004)

Note: Based on 2003 financial data

10.8 Useful Resources and Further Information

Fact Sheets

www.melbourne.vic.gov.au/rsrc/PDFs/Water/WSUD_part3.pdf

Bioretention Systems fact sheet – Water Sensitive Urban Design Guidelines Fact Sheets, City of Melbourne

www.brisbane.qld.gov.au/bccwr/lib184/wsud%20practice%20note%2003%20bioretention%20swales.pdf

WSUD Practice Note 3: Bioretention Swales, Brisbane City Council

www.brisbane.qld.gov.au/bccwr/lib184/wsud%20practice%20note%2005%20bioretention%20basins.pdf

WSUD Practice Note 5: Bioretention Basins, Brisbane City Council

Regulations and Legislation

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA Information – Environmental Noise

www.epa.sa.gov.au/pdfs/info_construction.pdf

EPA Information – Construction Noise

www.epa.sa.gov.au/pdfs/epp_noise_ind.pdf

EPA Industrial Noise Policy

www.epa.sa.gov.au/pdfs/building_sites.pdf

EPA Handbook for Pollution Avoidance on Building Sites

Design Information

www.wsud.org/tech.htm

Water Sensitive Urban Design Technical Information for Western Sydney

www.healthywaterways.org/FileLibrary/wsud_tech_guidelines.pdf

Water Sensitive Urban Design Technical Design Guidelines for South East Queensland

www.brisbane.qld.gov.au/BCC:STANDARD:369665131:pc=PC_1898

Water Sensitive Urban Design Engineering Guidelines: Stormwater

10.9 References

Argue, J. R. (Ed, 2009) *WSUD: basic procedures for 'source control' of stormwater - a Handbook for Australian practice.* Editor: Argue, J.R., Authors: Argue, J.R., Allen, M.D., Geiger, W.F., Johnston, L.D., Pezzaniti, D., Scott, P., Centre for Water Management and Reuse, University of South Australia, 5th Printing, February 2009, ISBN 1-920927-18-2, Adelaide.

Gold Coast City Council (2007). *Water Sensitive Urban Design Guidelines*. June. **http://www.goldcoast.qld.gov.au/t_standard2.aspx?PID=6866**.

IE Aust. (1987). *Australian Rainfall and Runoff - A Guide to Flood Estimation.* Barton, ACT. **http://www.arq.org.au/arr/index.html**.

IE Aust. (2006). *Australian Runoff Quality: A Guide to Water Sensitive Urban Design*. New South Wales.

Melbourne Water (2005). *WSUD Engineering Procedures: Stormwater.* CSIRO Publishing.

Upper Parramatta River Catchment Trust (2004). *Water Sensitive Urban Design, Technical Guidelines for Western Sydney*. Prepared by URS Australia Pty Ltd. **http://www.wsud.org/tech.htm**.

Appendix A
Bioretention System Design Process

Bioretention System Design Process Details

The design process for a bioretention system will depend on whether the system functions as a bioretention swale or bioretention basin, as these systems are described in Section 10.1. Essentially, a bioretention swale will require two separate design steps to consider the swale and the basin components. The design process for a bioretention basin system only requires consideration for the effectiveness of the basin.

Design for Vegetated Swales

The following design procedure for a swale has been adapted from IE Aust (2006).

Step 1: Determine the Dimensions

Dimensions of a swale can be determined using Manning's equation, below. This allows the flow rate and flood levels within the swale to be determined for variations in the dimensions of the swale.

$$Q = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

$$R = \frac{A}{P}$$

Where:	Q	=	Flow in the swale (m^3/s)
	A	=	Cross sectional area of the swale (m^2)
	P	=	Hydraulic perimeter (m)
	R	=	Hydraulic radius (m)
	S	=	Channel slope (m/m)
	n	=	Roughness coefficient (or Manning's n) ($m^{-1}/^{3}s$)

Flow in the swale should be determined according to the:

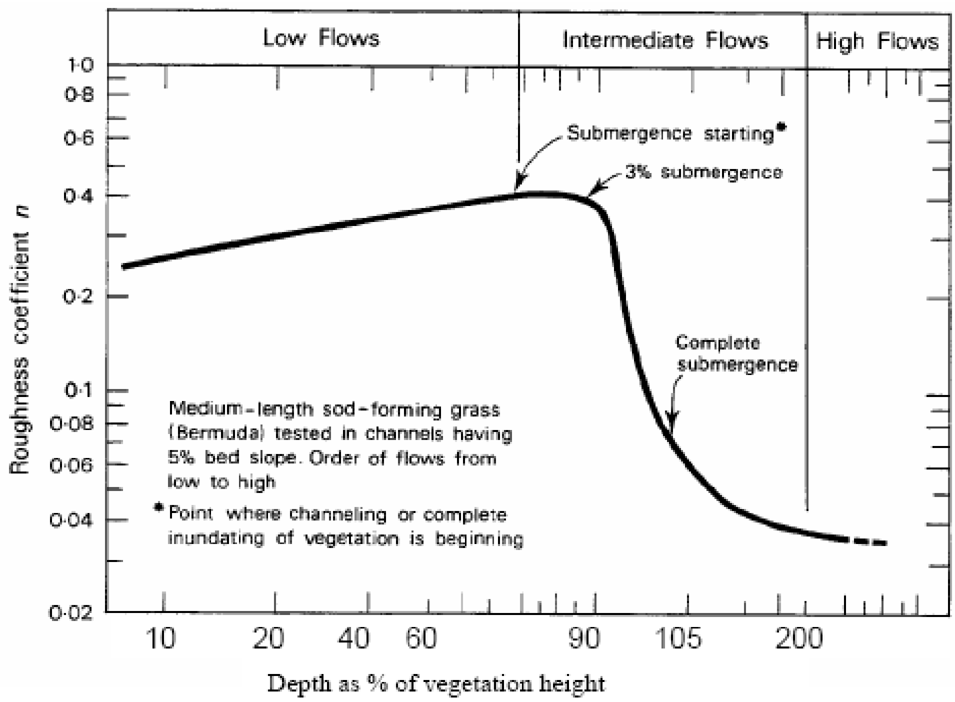
- Design 1 year ARI peak discharge; and
- Design 100 year ARI peak discharge.

Cross sectional area and hydraulic radius are variables that the designer must determine (according to the area available for the swale). This can then be calculated and trialled to determine its fitness for use.

Slope of the swale will usually be dependent on the adjacent infrastructure (road, rail, pathway etc). Slope is recommended to be between 2 and 4%. Lower slopes will require underdrains to prevent ponding, while larger slopes will require flow spreading to ensure uniform flow occurs across the swale (IE Aust. 2006). High slopes may also require velocity reduction measures such as check dams.

Manning's *n* is a critical variable in the Manning equation that relates to the roughness of the channel. It varies with flow depth, channel dimensions and vegetation type. For constructed swale systems, values are recommended to be between 0.15 and 0.3 for flow depths shallower than the vegetation height (preferable for treatment) and significantly lower for flows with greater depth than the vegetation (e.g. 0.03 for flow depth more than twice the vegetation height).

It is considered reasonable for Manning's *n* to have a maximum value at the vegetation height and then to sharply reduce as depths increase. The graph below is adapted from Barling and Moore (1993) and provides a useful reference for determining the Manning's *n* of a channel using the depth of flow.



Flow Velocity in the Swale

As a final check to ensure the integrity of the swale as a water quality treatment measure, flow velocity should be checked to determine that:

- 1 year ARI peak velocity does not exceed 0.5 metres per second; and
- 100 year ARI peak velocity does not exceed 1 metre per second.

Design of Bioretention Basins

A bioretention basin can be designed in much the same manner as a rain garden by using pre-determined hydrological effectiveness curves (see **Chapter 6**). It should be noted that an alternative, concise design procedure is provided in the document *Australian Runoff Quality* (IE Aust. 2006).

The performance of storage systems can be described in terms of hydrological effectiveness. Hydrological effectiveness takes account of EIA (equivalent impervious area), historical rainfall series, storage, infiltration (outflow), bypass and overflow characteristics, as illustrated in **Figure A1**.

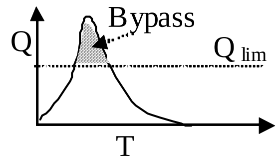
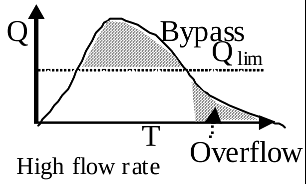
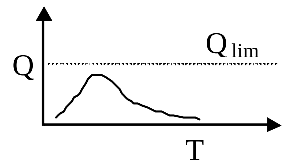
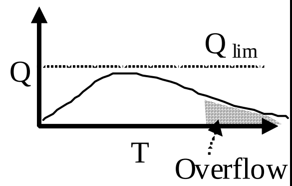
Runoff event type	**Loss mode :** bypass and/or overflow
 High flow rate Low runoff volume	**BYPASS and NO OVERFLOW***
 High flow rate High runoff volume	**BYPASS and OVERFLOW ****
 Low flow rate Low runoff volume	**NO BYPASS and NO OVERFLOW ***
 Low flow rate High runoff volume	**NO BYPASS and** *OVERFLOW***

Figure A1 Hydrological Event Processes

Hydrological effectiveness, R, is the ratio:

$$R = \frac{\text{Unshaded area in hydrographs}}{\text{Area under each hydrograph expressed as a percentage}}$$

Note: hydrological effectiveness is identical to the term retention efficiency, R used in Argue (Ed., 2009).

The equivalent impervious area, A_{EIA} is estimated by an adjusted runoff coefficient that is significantly less than that used in flood control design. The reason for this is the assessment needs to focus on the regular runoff events that usually flow through the bioretention system as a result of "normal" rainfall events rather than flood flows. Recordings indicate that these regular events have greater (relative) losses than a flood flow and hence the runoff coefficient needs to be less when assessing these smaller more regular events. A_{EIA} should therefore be calculated for use in the hydrological effectiveness graphs applying a factor of 0.83 to the conventional C10 values in flood control practice.

It is possible, using sets of hydrological effectiveness curves, to determine the storage requirement or discharge rate necessary to achieve a target efficiency for particular circumstances. Storage requirement is expressed in terms of mean annual runoff volume (% MARV); discharge refers to the flow rate leaving the device whether it be through, for example, infiltration or slow drainage to an aquifer or a combination of both. Each set of hydrological effectiveness curves takes account of all independent variables, as explained above. Therefore, a unit discharge rate, q, is introduced as a function of flow rate leaving the device and effective impervious area (EIA).

A set of hydrological effectiveness curves has been generated for the Greater Adelaide Region and this is presented in **Appendix B**. The curves allow the user to assess the approximate performance of basic systems such as rain gardens.

Most of the curves are based on simulation using more than 20 years of historical rainfall series at six minute intervals. The following assumptions were made:

- Equivalent impervious catchment area, $A_{EIA,}$ is determined incorporating an appropriate volumetric runoff coefficient. Typically, A_{EIA} includes those areas which are connected to the bioretention system;
- All runoff is directed to storage and the facility excludes a bypass passage;
- Overflow occurs when the storage component fills; and
- Infiltration rate (or supply to harvesting systems) is considered to be constant throughout the period of storage.

An example of the utilisation of the hydrological effectiveness curves for the design of a bioretention swale is contained in the design example below.

Design of Bioretention Swales

The design of bioretention swales must incorporate the design aspects of both vegetated swales for the conveyance component of the bioretention swale, and the storage/discharge requirements of the basin component of the bioretention swale. An example calculation is included below to familiarise the reader with the design of bioretention swales.

Example Design for a Bioretention Swale

The following example is adapted in part from IE Aust. (2006).

Task

Determine characteristics of a 100 m length trapezoidal channel needed to manage stormwater from a road catchment with the following characteristics:

- The channel is to have a bioretention system capable of filtering, by infiltration, 95% of the average annual runoff;
- The swale is vegetated up to a height of 0.3 m;
- The hydraulic conductivity of the bioretention media is equal to 50 mm/hr;
- An underlying pipe system is to collect water from the base of the bioretention system. Infiltration is to be discouraged on this site;
- The bioretention system is located in Adelaide, near the city centre, with an average annual rainfall of 545 mm/yr.;
- Soil is a prescribed sandy loam, k_h = 50 mm/hr, with a moderation factor, U = 1.0. The moderation factor is a factor introduced by Argue (Ed., 2009).

  When the hydraulic conductivity results from a small volume infiltration test are compared with field data from infiltration systems, it is found that field hydraulic conductivity is different. This observation has led to the introduction of a correction factor, Moderation Factor, U, which should be applied to hydraulic conductivity, k_h, in the formulae which follow (Argue 2004):

  Clay soils - U = 2.0

  Sandy clay soils - U = 1.0

  Sandy soils - U = 0.5

  For more information refer to Section 11.3.2 of Argue (Ed., 2009).
- Contributing catchment includes
  - Roof area A_{EIA} = 2000 m²
  - Paved area A_{EIA} = 1400 m²
- Storage is to be considered only as surface ponding, where porosity (e_S) = 1.
- Length of swale = 100 m
- Maximum width of swale = 6 m
- Average depth of bioretention component of swale is equal to 0.52 m

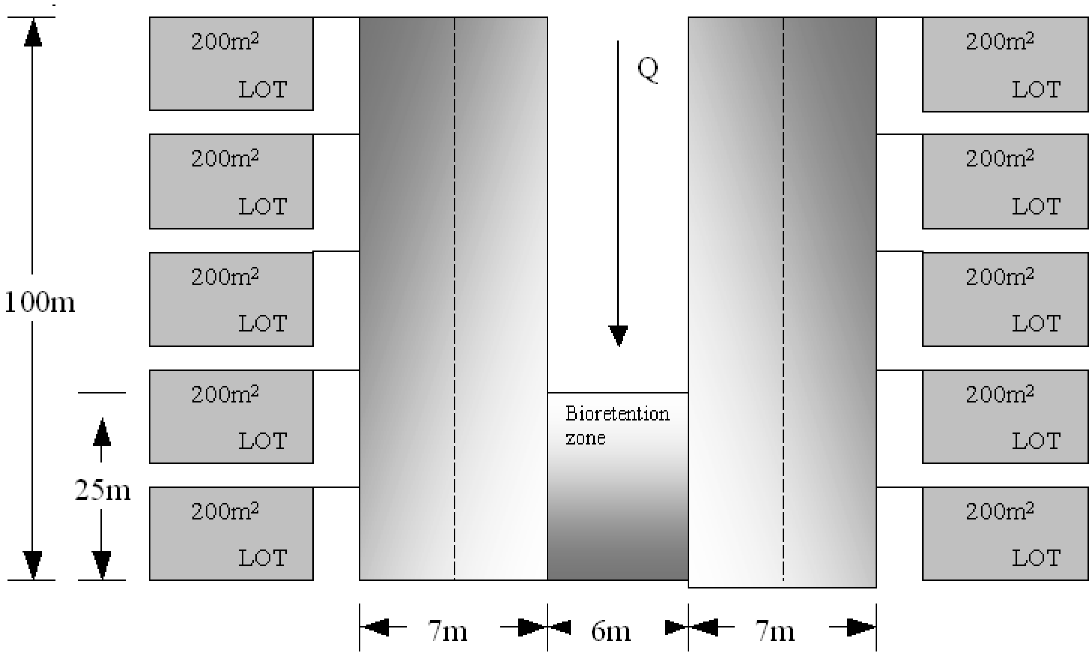


Figure A2 The Bioretention Swale Plan (not to scale)

Determine the Swale Dimensions

For the swale component, trial a trapezoidal channel of base width 2 m and side slopes 1(v):3(h). A slope of 2% will be used as the initial slope calculation. Assume that the annual peak discharge from the catchment is 0.3 m^3/s, and the 100 year ARI peak discharge is equal to 1.2 m^3/s. The procedures for determining these peak discharge figures are found in the document *Australian Rainfall and Runoff* (IE Aust. 1987). A Manning's n value of 0.2 is adopted for these calculations.

1 year ARI flow condition:

Trial y = 0.2m; A = 0.52 m^2; P = 3.26m

Q = 0.14 m^3/s

Trial y = 0.3m; A = 0.87 m^2; P = 3.90m

Q = 0.30 m^3/s ~ 1 year ARI peak flow

Where y = trial flow depth

100 year ARI flow condition:

Trial y = 0.5 m; A = 1.75 m^2; P = 5.16 m

Q = 0.80 m^3/s

Trial y = 0.60 m; A = 2.28 m^2; P = 5.79 m

Q = 1.15 m^3/s

Trial y = 0.65 m; A = 2.57 m^2; P = 6.11 m

Q = 1.35 m^3/s ~ 100 year ARI peak flow

Check Flow Velocities

1 year ARI event; v = 0.30/0.87 = 0.34 m/s

< 0.5 m/s, OK

100 year ARI event; v = 1.35/2.57 = 0.52 m/s

<1 m/s, OK

Therefore, a channel should be designed with a base width of 2 m, minimum depth 0.65 m, side slopes 1(v):3(h), and vegetation height roughly equivalent to 0.3 m.

Note that the swale has been designed for the entire 100 m length. In some cases, it may be necessary to design a swale in sections, with intermediate overflow zones.

Design of Bioretention Basin Component

The bioretention basin is located in the lower half of the swale.

Determine infiltration rate and unit discharge rate.

Moderated hydraulic conductivity:

The design infiltration media is characterised with the following hydraulic conductivity:

k_h = 50 mm/hr x U

= 50/3600 m/s x U

= $(5 \times 10^{-2}) \times U$

= $5.5 \times 10^{-2} \times 1.0$

= 5.5×10^{-2} m/s

Infiltration discharge unit rate, q,

$$q = \frac{k_h \times U \times A_{avail}}{A_{EIA}} \text{ L/s/m}^2 \text{ of EIA}$$

$$A_{EIA} = (6 \times 50)\ m^2 + (6 \times 50)\ m^2 + (10 \times 200)\ m^2 + (2 \times 100 \times 7)\ m^2$$

$$= 4000\ m^2$$

$$A_{avail} = 2m \times 25m$$

$$= 50\ m^2$$

$$q = 5.5 \times 10^{-2} \times 1.0 \times 50\ /4000$$

$$= 6.9 \times 10^{-4}\ L/s/\ m^2$$

Step 2: Determine Mean Annual Runoff Volume (MARV)

Locate q on **Figure A3:**

The value of q corresponds to a % mean annual rainfall volume (MARV) value equal to 1.1%. Therefore, the storage volume of the bioretention component of the swale must be equal to 1.1% of the MARV.

Mean annual runoff volume (MARV) is 545mm/yr

$= 0.545 \times 4000m^2$

$= 2180\ m^3$

Therefore, the storage required to treat 95% of runoff must be equal to *at least* 24.0 m^3. Using geometry, the volume of the storage, including swale channel, is equal to

21.1 m^3 and hence the hydrological efficiency is lower than 95% with the first trial design.

There are several ways to increase the hydrological effectiveness, such as using soil with a higher hydraulic conductivity rate, extending the length of the bioretention zone (with check dams, if necessary) or deepening the invert to increase the storage. To increase the storage of the bioretention system in this example, an extra 0.15 m^3 per linear metre will be added over the length of the 25 m bioretention system.

This yields a storage volume of 24.9 m^3, which is adequate for ensuring 95% of stormwater runoff passes through the bioretention system.

When using the hydrological effectiveness approach it is important to ensure that the unit discharge rate 'q' refers to the lowest flow capacity in the bioretention system, i.e. either at the surface or at the subsurface outlet.

In cases where the subsurface outlet discharge rate is less the surface infiltration rate, the total storage volume may include the voids space in the bioretention soil media.

Design of Base Pipe

The next step requires one to calculate the nature of the pipe collecting water from the base of the infiltration system. It is assumed that an insignificant amount will infiltrate to the in-situ soil for this step. The required flow rate within the subsoil pipe is:

q_{pipe} = 6.9 × 10^{-4} L/s/ m^2 x (EIA)

Q_{pipe} = 6.9 × 10^{-4} L/s/ m^2 x 4000

= 2.76 L/s

Water will exit the system in the sub-base pipe via perforations in the pipe(s). The pipe size required to discharge from such a pipe is determined using the sharp edged orifice equation:

$$Q_{perf} = B.C_d.A\sqrt{2.g.h}$$

Where:

Q_{perf}	= Flow through perforations, m^3/s
B	= Blockage factor, usually 0.5
C_d	= Orifice discharge coefficient – use 0.61 for a sharp edge orifice
A	= Total area of orifice (m^2)
g	= Acceleration due to gravity
h	= head above the perforated pipe

The number and size of perforations in the pipe must be found. These can be acquired from the pipe manufacturer and used to estimate the maximum flow rate into the pipes assuming a maximum value of head (depth from the top of the pipe to the surface of the bioretention system, plus any further storage depth).

The average *vertical* depth of the bioretention system over the 25 m length is:

Depth (d) ~ 0.52 m.

Here it is assumed that there is a commonly available slotted pipe in the base of the system with the following characteristics:

- The pipe has a clear opening 2100 mm^2/m;
- Slot width is equal to 1.5 mm;
- Slot length is equal to 7.5 mm;
- Number of rows – 6;
- Diameter of pipe – 100 mm.

Number of slots per metre = 2100/(1.5 x 7.5)

= 186.7

Using the orifice flow equation:

Q_{pipe} = (0.5)(0.61)(0.0075x0.0015)x(2x9.81x0.52) $^{1/2}$x186.7

$m^3/s/m$

= 2.04 x 10^{-3} $m^3/s/m$

= 2.04 x 10^{-3} (25)

= 5.1 x 10^{-2} m^3/s

= 51 L/s

Therefore, the sub-base pipe is adequate for the system. If there was any discrepancy, additional pipe(s) would be placed to increase the flow capacity in the base of the system.

Solution

According to the design calculations, a swale channel is to be designed and constructed with a height of 0.65 m, with an extra depth of 0.075 m over the last 25 m of the swale, over the top of the bioretention section, to achieve the requirements stormwater detention and treatment.

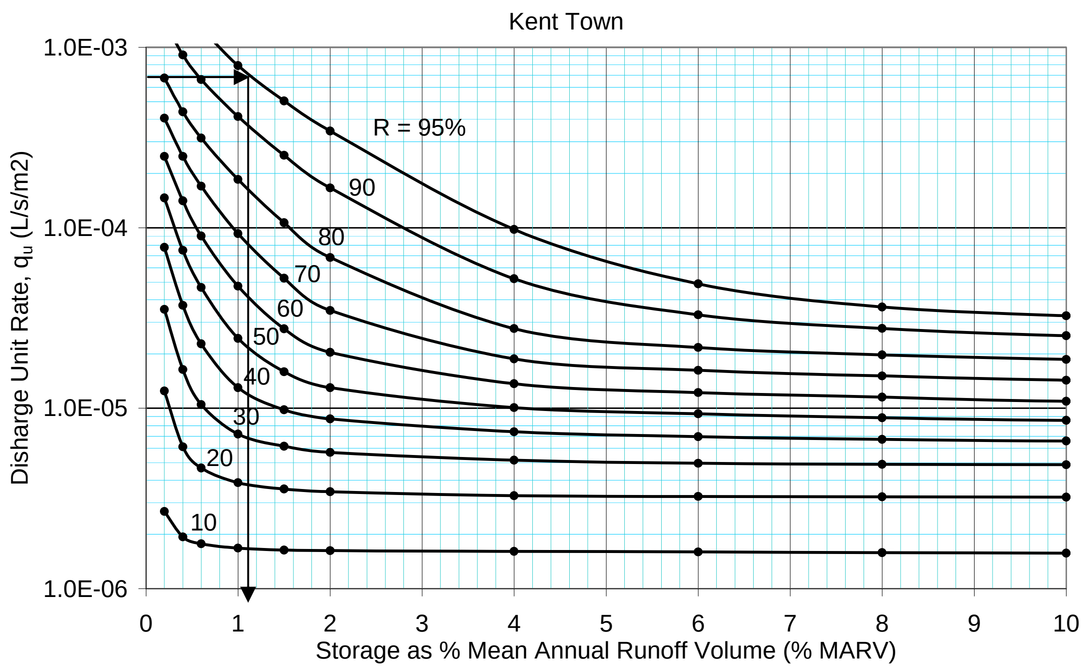


Figure A3 Hydrological Effectiveness Graph, Adelaide (Kent Town)

Appendix B
Checklists

Bioretention Swale

Design Calculation Summary

Calculation Task	Outcome	Units
Catchment Characteristics		
1. Catchment area		ha
2. Catchment land use (i.e. residential, commercial etc)		
Conceptual Design		
3. Bioretention area		m^2
4. Filter media saturated hydraulic conductivity		mm/hr
5. Extended detention depth		mm
Confirm Concept Design		
6. Bioretention area required to achieve water quality objectives		m^2
7. TSS removal (forecast)		%
8. TPP removal (forecast)		%
9. TN removal (forecast)		%
Estimate Design Flows for Swale Component (where applicable)		
10. Time of concentration		minutes
11. Identify rainfall intensities		
12. $I_{1\ year\ ARI}$		mm/hr
13. $I_{100\ year\ ARI}$		mm/hr
Design Runoff Coefficient		
14. $C_{1\ year\ ARI}$		
15. $C_{100\ year\ ARI}$		
Peak Design Flows		
16. One year ARI		m^3/s

Calculation Task	Outcome	Units
17. 100 year ARI		m^3/s
Dimension of Swale Component (where required)		
18. Swale width and side slopes		
19. Base width		m
20, Side slopes		
21. Longitudinal slope		%
22. Vegetation height		mm
23. Maximum length of swale		m
24. Manning's *n*		
25. Swale capacity		
Design Inflow Systems to Swale and Bioretention Components		
26. Swale kerb type		
27. Adequate erosion and scour protection (where required)		
Design of Bioretention Component		
28. Filter media hydraulic conductivity		mm/hr
29. Extended detention depth		
30. Filter media depth		
31. Drainage layer media (sand or fine screenings)		
32. Drainage layer depth		
33. Transition layer		
34. Transition layer depth		
Surrounding Soil for Infiltration Applications		
35. Hydraulic conductivity		m/s
36. Soil moderation factor		

Calculation Task	Outcome	Units
Hydrological Effectiveness		
37. Ave. annual rainfall		mm/yr
Underdrain Design and Capacity Checks		
38. Flow capacity of filter media (maximum infiltration rate)		m^3/s
39. Perforations inflow check		
40. Pipe diameter		mm
41. Number of pipes		
42. Capacity of perforations		m^3/s
Check Pipe > Filter Media Flow Capacity		
43. Perforated pipe capacity		
44. Pipe capacity		m^3/s
Check Pipe Capacity > Filter Media Capacity		
45. Check requirement for impermeable lining		
46. Soil hydraulic conductivity		mm/hr
47. Filter media hydraulic conductivity		mm/hr
48. More than 10 times higher than in-situ soils		
49. Verify design		
50. Velocity for 2-10 year ARI flows (<0.5m/s)		m/s
51. Velocity for 100 year ARI flows (<2 m/s)		m/s
52. Velocity x depth for 100 year ARI (<0.4 m^2)		m^2/s
53. Treatment performance consistent with Step 1		
54. Size overflow pits		
55. System to convey minor floods		L x W

Bioretention Swale

Design Assessment Checklist

Asset ID:		
Bioretention Location:		
Hydraulics:	Minor flood (m^3/s):	
	Major flood (m^3/s):	
Area:	Catchment area (ha):	
	Bioretention area (m^2):	

Concept Design	Y	N
1. Treatment performance verified		
2. Service location checked or appropriate allocation provided		
Swale Component (where applicable)	**Y**	**N**
3. Longitudinal slope of invert >1% and <4 %		
4. Manning's *n*; selected appropriate for proposed vegetation type		
5. Overall flow conveyance width does not impact on traffic requirements		
6. Overflow pits provided where flow capacity exceeded		
7. Energy dissipation provided at inlet points to the swale		
8. Velocities within bioretention cells will not cause scour		
9. Set down of a least 60 mm below kerb invert to top of vegetation incorporated		
Bioretention Component	**Y**	**N**
10. Design documents bioretention area and extended detention depth as defined by treatment performance requirements (i.e. MUSIC modelling performed is consistent with final design). Area approximately 1-3% of catchment. Extended detention depth up to 0.3m		
11. Overflow pit crest set at top of extended detention		
12. Maximum ponding depth and velocity will not impact on public safety (V x D < 0.4)		
13. Bioretention media specification includes details of filter media, drainage layer and transition layer (if required)		
14. Design saturated hydraulic conductivity included in specification		

15. Transition layer provided where drainage layer consists of gravel (rather than coarse sand)		
16. Perforated pipe capacity > infiltration capacity of filter media		
17. Selected filter media hydraulic conductivity > 10 x hydraulic conductivity of surrounding soil		
18. Maximum spacing of collection pipes <1.5m		
19. Collection pipes extended to surface to allow inspection and flushing		
20. Liner provided if selected filter media hydraulic conductivity > 10 x hydraulic conductivity of surrounding soil		
21. Maintenance access provided to invert of conveyance channel		
Landscape and Vegetation	**Y**	**N**
22. Plant species selected can tolerate periodic inundation and design velocities		
23. Bioretention swale landscape design integrates with surrounding natural and/or built environment		
24. Planting design conforms with acceptable sight line safety requirements		
25. Top soils are a minimum depth of 300 mm for plants and 100 mm for turf		
26. Existing trees in good condition are investigated for retention		
27. Detailed soil specification included in design		
28. Adequate access provided for maintenance of vegetation and filter material		
29. Timing of planting specified and appropriate		
Comments		

Source: Adapted from Gold Coast City Council (2007)

Bioretention Swale

Construction Inspection Form

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Constructed By:			
Weather:			

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
A. During Construction				
Preliminary works				
1. Erosion and sediment control plan adopted				
2. Temporary traffic/safety control measures				
3. Location same as plans				
4. Site protection from existing flows				
Earthworks and Filter Media				
5. Bed of swale correct shape and slope				
6. Batter slopes as plans				
7. Dimensions of bioretention area as plans				
8. Confirm surrounding soil type with design				
9. Confirm filter media specification in accordance with Step 4				
10. Provision of liner (if required)				
11. Underdrainage installed as designed				
12. Drainage layer media as designed				
13. Transition layer media as designed (if required)				
14. Extended detention depth as designed				

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
Structural Components				
15. Location and configuration of inflow systems as designed				
16. Location and levels of overflow pits as designed				
17. Underdrainage connected to overflow pits as designed				
18. Concrete and reinforcement as designed				
19. Set down to correct level for flush kerbs (streetscape applications only)				
B. Sediment and Erosion Control (if required)				
20. Stabilisation immediately following earthworks and planting of terrestrial landscape and around basin				
21. Silt fences and traffic control in place				
22. Temporary protection layers in place				
C. Operational Establishment				
23. Temporary protection layers and associated silt removed				
Vegetation				
24. Planting as designed (species and densities)				
25. Weed removal and watering as required				
Comments on Inspection				
Actions Required				
1.				
2.				
3.				

Source: Adapted from Gold Coast City Council (2007)

Bioretention Swale

Final Inspection Form

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Constructed By:			
Weather:			

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
1. Confirm levels of inlets and outlets				
2. Confirm structural element sizes				
3. Check batter slopes				
4. Vegetation as designed				
5. Bioretention filter media surface flat and free of clogging				
6. Check for uneven settling of banks				
7. Underdrainage installed as designed and working				
8. Inflow systems working (including erosion protection)				
9. Maintenance access provided				
10. Provision of liner (if required)				
12. Drainage layer media as designed				
13. Transition layer media as designed (if required)				
14. Extended detention depth as designed				
15. Traffic control in place				

Comments on Inspection
Actions Required
1.
2.
3.

Source: Adapted from Gold Coast City Council (2007) and Melbourne Water (2005)

Bioretention Swale

Maintenance Inspection Form

Asset ID:		**Date of Visit:**	
Location:			
Description:			
Inspected By:			
Weather:			

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
	Y	N	Y	N	
Debris Cleanout					
1. Sediment/debris accumulation at inflow points					
2. Litter/debris in swale (or basin)					
3. Overflow clear of debris					
4. Evidence of dumping (e.g. building waste)					
5. Clogging of drainage points (sediment or debris)					
Dewatering					
6. Trench dewatering between storms (i.e. is there any evidence of ponding)					
7. Surface clogging visible					
8. Drainage system inspected					
9. Set down from kerb still present					
Trench Surface Vegetation					
10. Erosion at inlet or other key structures (e.g. crossovers)					
11. Traffic damage present					
12. Vegetation condition satisfactory (density, weeds etc)					

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
	Y	N	Y	N	
13. Replanting required					
14. Mowing required					
15. Remulching of trees and shrubs required					
16. Soil additives or amendments required					
17. Pruning and/or removal of dead or diseased vegetation required					
18. Topsoil layer require replacing					
19. Resetting of system required (i.e. entire planting media require replacing)					
Outlet/Overflow Channel or Pit					
20. Pit/grate condition					
21. Evidence of cracking or spalling of concrete structures					
22. Evidence of erosion in downstream channel					
23. Damage/vandalism to structures present					
Comments					

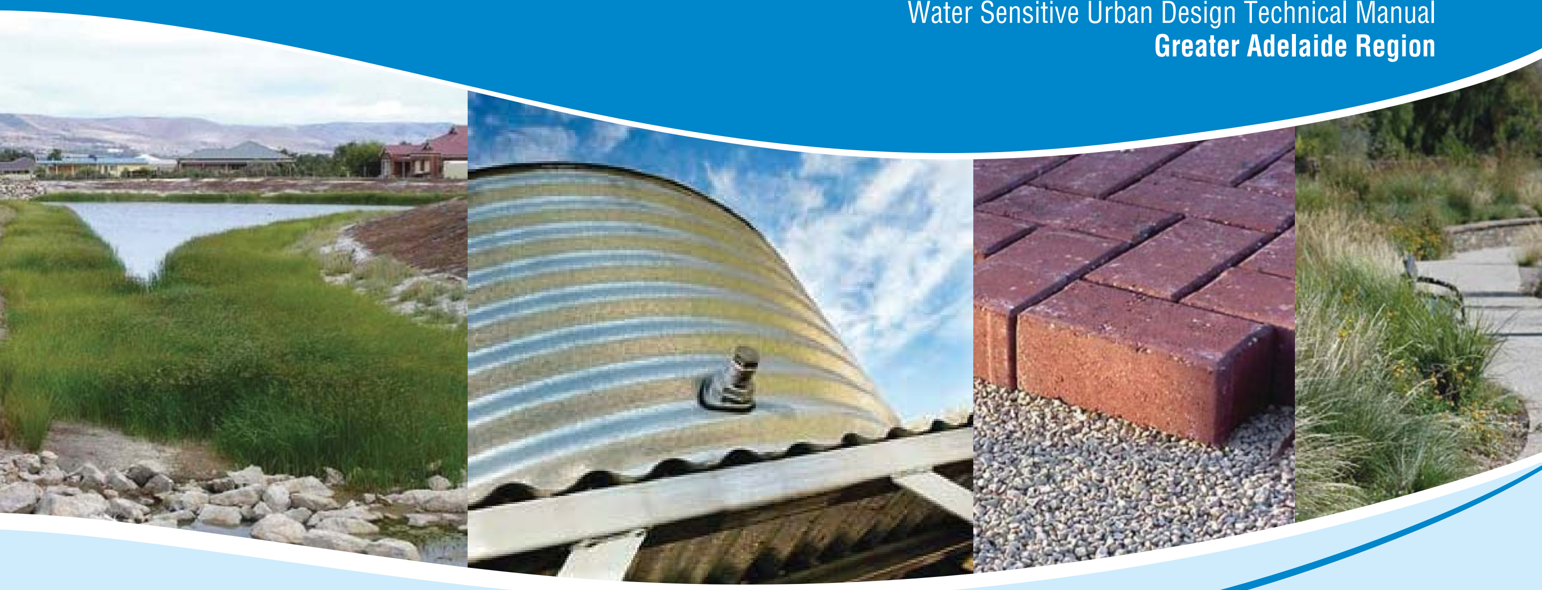
Source: Adapted from Gold Coast City Council (2007), Melbourne Water (2005) and Upper Parramatta River Catchment Trust (2004)

July 2009

Chapter 11

Swales and Buffer Strips

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 11
Swales and Buffer Strips

11.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Swales and buffer strips are two of those measures.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing a general overview of the benefits of swales and buffer strips, and how they can be utilised to achieve water quality and water quantity objectives and targets.

Further detailed design information can be obtained from the references included in the Useful Resources and Further Information section (see **Section 11.10**).

Description

Swales are formed, vegetated depressions (or channels) that are utilised for the conveyance of runoff from impervious areas. They are typically linear, shallow and wide. Swales can become features of a landscape, require minimal maintenance once established and are hardy enough to withstand large flows.

Buffer zones or strips, also known as filter strips, are grassed or vegetated areas that treat shallow overland flow before it enters the drainage network (or a discharge point). Buffer strips are broad, sloped open vegetated areas that accept shallow runoff from impervious areas as distributed or sheet flow.

Interaction with the vegetation tends to slow velocities, with a retention of coarse sediments.

Figure 11.1 Swale at Pine Lakes, City of Salisbury

Source: Courtesy of City of Salisbury

Purpose

Swales

Swales are used to convey runoff in lieu of, or in conjunction with, underground pipe drainage systems.

Swales provide a number of functions including:

- The removal of coarse to medium sized sediments (and attached pollutants) by filtration through the vegetated surface;
- Reducing runoff volumes (by promoting some infiltration to the subsoils) and even more so when coupled with an infiltration trench (see **Chapter 6)**;
- Delaying runoff peaks by reducing flow velocities;
- Accommodating pedestrian movement across and along them; and
- Providing pre-treatment for other runoff treatment measures, such as bioretention and infiltration systems, sedimentation basins and constructed wetlands.

Swales utilise overland flow and mild slopes to convey water slowly downstream. They provide a means of disconnecting impervious areas from downstream waterways, which assists in protecting waterways from damage by frequent storm events, by reducing flow velocity compared with piped systems.

To convey flood flows along swales, in excess of treatment design flow, pits draining to underground pipes can be used. This is particularly useful in areas that have narrow verges, where a swale can only accommodate flows associated with the minor drainage system.

In practice, swales are generally designed as conveyance devices. They do slow down (or attenuate) flood flows because of their increased hydraulic roughness which has a beneficial effect on downstream flooding. During low intensity rainfall events, swales also act to filter the flow and therefore have some water treatment functionality.

Buffer Strips

Buffer strips are primarily intended to remove sediment, as well as some nutrients and hydrocarbons. Buffer strips can be used as edges to swales, particularly where flows are distributed along the banks of the swale, as an alternative to kerb and gutter drainage systems.

Buffers strips provide a number of functions including:

- The removal of sediments by filtration through the vegetation;
- A reduction in runoff volumes (by promoting some infiltration to the subsoils);
- A delay in runoff peaks by reducing flow velocities;
- With appropriate vegetative cover and diversity, buffer strips can form part of a multi-use habitat (i.e. provide a habitat corridor for wildlife); and
- Effective pre-treatment for other WSUD measures such as bioretention and infiltration systems.

Buffer strips initially immobilise pollutants by binding them to organic matter and soil particles. Ultimate pollutant removal is achieved by settling, filtration and infiltration into the subsoil. Certain pollutants, such as nutrients and hydrocarbons, may be digested and processed by the soil microorganisms in the filter strip. Consequently, adequate contact time between the runoff and the vegetation and soil surface is required to optimise pollutant removal.

Scale and Application

Swales

Most swales are practical and cost effective when serving catchment areas up to 2 hectares and typically should not be used in catchments over 4 hectares in area. Larger than this, flow depths and velocities are such that the water quality improvement function of the swale, and its long-term function, may be compromised.

Swales are most applicable at the subdivision scale (i.e. along median strips or through parks) but can be applied at allotment level, depending on catchment area. Swales are generally most suited to areas with very low density housing with wide roadway verges, or overland flows in open space.

Figure 11.2 Palmer Street Swale Retrofit, Aldinga Beach

Source: Courtesy of City of Onkaparinga

Swales are often used in low density residential developments as an alternative to kerb and gutter, or as a pre-treatment to other measures. These are similar in many ways to buffer strips, but are used to convey runoff. They can also be used in:

- Road medians and verges;
- Carpark runoff areas; and
- Parks and recreation areas to convey stormwater flows.

Swales are best placed in central median strips rather than on the edge of a road where driveways and services are required. However, driveways and services can be accommodated with swales as needed.

Swales are commonly combined with bioretention systems (refer to **Chapter 10**) and used to convey runoff to sedimentation basins (refer to **Chapter 12**) and/or constructed wetlands (refer to **Chapter 13**).

Buffer Strips

While buffer strips are most applicable at the subdivision scale, with catchment areas less than 2 hectares, they can be applied at allotment level (e.g. buffering runoff from driveways, overflows from rainwater tanks etc) depending on the catchment area. Buffer strips are also worth considering where there are opportunities to make multiple uses of existing tracts of undeveloped land. For example, sport fields can serve as effective buffer strips where circumstances permit. However, some large tracts of land, such as golf courses, will be unsuitable where nutrient addition such as fertiliser may have a negative effect on the quality of runoff.

Removal Efficiencies

While essentially a conveyance based system, one of the major roles of swales is to provide disconnection from the receiving environment. Research and past experience suggest that swales represent a practical and potentially effective technique for controlling urban runoff (quantity and quality). While limited local Greater Adelaide Region performance data exists for swales, it is known that riffles, gentle slopes, permeable soil, dense vegetation cover and slow velocity all contribute to successful pollutant removal by the swale system.

The interaction between stormwater flow and vegetation within swale systems facilitates pollutant settlement and retention. Even swales with relatively low vegetation height can achieve significant sediment deposition rates provided flows travel at a 'low' velocity and are well distributed across the full width of the swale.

Swales can provide an important pre-treatment function for other WSUD measures in a treatment train, enabling water quality objectives to be met. Swales are particularly good at coarse sediment removal as a pre-treatment for tertiary treatment systems such as constructed wetlands and bioretention systems.

The estimated removal efficiencies for swales is summarised in **Table 11.1**.

Table 11.1 Estimated Removal Efficiency for Swales

Gross Pollutants*	Coarse Sediment*	Medium Sediment	Fine Sediment	Free Oil and Grease	Nutrients	Metals
-	50-80%	30-50%	10-50%	10-50%	10-50%	10-50%

** Assumes gross pollutant pre-treatment provided*

Source: Upper Parramatta River Catchment Trust (2004)

It should be noted that actual swale performance will vary depending on individual design parameters such as temporal variation in flow and pollutant input concentration, vegetation height, infiltration capacity, length of swale and detention (contact) time.

11.2 Legislative Requirements and Approvals

Before undertaking a concept design of a swale or buffer strip it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to swales or buffer strips in your area.

The legislation which is most applicable to the design and construction of sedimentation basins includes:

- *Development Act 1993* and Development Regulations 2008; and
- *Environment Protection Act 1993*.

Development Act 1993

While installation of a swale or buffer strip will generally be part of a larger development, whenever a swale or buffer strip is planned it is advised that the local council be contacted to determine whether development approval is required under the *Development Act 1993*.

Environment Protection Act 1993

Any development, including the construction of swales or buffer strips, has the potential for environmental impact which can result from vegetation removal, stormwater management, and construction processes. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on the whole site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when planning or installing a swale or buffer strip are discussed below.

Water Quality

Water quality in South Australia is protected using the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development. In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, construction sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise potential for environmental impact during construction of a swale or buffer strip.

Noise

Noise has the potential to cause nuisance during any construction works of swales or buffer strips. The noise level at the nearest sensitive receiver should be at least 5 dB(A) below the Environment Protection (Industrial Noise) Policy 1994 allowable noise level when measured and adjusted in accordance with that policy. Reference should be made to the EPA Information Sheets on Construction Noise and Environmental Noise respectively which will assist with complying with this policy (see **Section 11.10**).

Air Quality

Air quality may be affected during the construction of a swale or buffer strip. Dust generated by machinery and vehicular movement during site works, and any open stockpiling of soil or building materials at a site, must be managed to ensure that dust generation does not become a nuisance off site.

Waste

Any wastes arising from excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*. For example, during construction all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 11.10**).

11.3 Design Considerations

The operation of swales and buffer strips involves the interaction between runoff, vegetation and hydraulic structures, and the successful implementation of swales and buffer strips requires appropriate integration into the landscape design.

A number of the design considerations for swales and buffer strips include:

- Services
- Gradient
- Capacity
- Flow velocity
- Public safety
- Water source
- Catchment characteristics
- Driveway crossings
- Edge treatment
- Traffic control
- Landscape design
- Vegetation selection
- Maintenance
- Land and asset ownership

The following provides an overview of the key design issues that should be considered when conceptualising and designing swales and buffer strips.

Services

Swales located within road verges or within footpaths must consider the standard location for services (such as sewers and underground electricity). In general, a swale should not be in the line of other services, as these services will need regular maintenance. Therefore, it should be ensured that access for maintenance of services is possible without regular disruption or damage to the swale.

Gradient

The most important design consideration for a swale is the longitudinal slope. It is important to ensure flow velocities along a swale are kept sufficiently low to avoid scouring of vegetation and collected pollutants.

Swales typically operate best between longitudinal slopes of 1-4%, given that slopes milder than this can become waterlogged and have stagnant ponding (which can be remedied with subsoil drains) and steeper slopes can result in scour (which can be potentially prevented through check dams or equivalent measures).

Capacity

For water quality improvement, swales and buffer strips need only focus on treating/conveying frequent storms (typically up to the 3 month ARI). However, many swales may be required to provide a flow conveyance function as part of a minor and/or major drainage system, and it may be necessary to augment the capacity of the swale with overflow pits along the invert of the swale that discharge to the underground pipe drainage.

Flow Velocity

Velocities within swales should be kept low. IE Aust. (2006) recommends a flow velocity of less than 0.5 metres/second for the 1 year ARI flood flow to ensure adequate treatment up to this level of flow. A flow of less than 1.0 metres/second for the 100 year ARI is recommended to avoid scouring of collected pollutants and surface vegetation.

Public Safety

Swales located within road reserves must allow for the safe use of adjoining roadway, footpaths and bike paths by providing sufficient conveyance capacity to satisfy local infrastructure design requirements.

Checks should be undertaken to assess depth and velocity within the swale, at crossings and adjacent to pedestrian and bicycle pathways to ensure public safety.

Water Sources

Consideration should be given to the possible sources of water that could be directed to the swale or buffer strip.

Runoff directly from roof areas or overflow from rainwater tanks etc should be discharged to swales (if possible), which may require the use of a small surcharge pit (with perforations allowing drainage to the surrounding subsoil) in the invert of the swale to allow roof water to surcharge to the swale.

Catchment Characteristics

Silt build up can create difficulties for swale management as it impacts on gradients, creates flow channels, smothers vegetation and can destroy vegetation during the process of removing the silt. Off-site management of silt loads should be part of the design, assessment, establishment and management process.

Driveway Crossings

Driveway crossings for swales along roadways can be 'at grade' or 'elevated' and their applicability will be dependent on a number of factors (e.g. aesthetics, cost, requirement for ponding, public safety and traffic movement).

'At grade' crossings follow the profile of the swale (e.g. like a ford), while 'elevated' crossings are raised above the invert of the swale (e.g. like a bridge deck or culvert).

Crossings constructed 'at grade' require the maximum slopes to be approximately one in 10 to ensure vehicles can traverse the crossing without bottoming out. This means the entire swale will have a shallow profile, reducing its flow conveyance capacity.

'At grade' crossings are typically cheaper to construct than 'elevated' crossings, however they need to be constructed at the same time as the swale to avoid damaging the swale. This imposes a fixed driveway location on each allotment, which can potentially constrain future development of the site.

Elevated driveway crossings create a major impediment to verge maintenance mowing due to the disruption to mower paths and the necessity for careful manoeuvring to avoid infrastructure. This can add a considerable amount of time to the mowing/slashing program.

Edge Treatment

In order to avoid sediment accumulation on the edge of any impervious areas adjacent to buffer strips, a flush kerb arris (or drop down) should be used that sets the top of the vegetation 60 millimetres below the pavement edge. This requires the finished topsoil surface of the buffer strip (i.e. before turf is placed) to be approximately

100 millimetres below the pavement edge level.

Traffic Control

Traffic on swales can have an adverse influence on the long-term viability in street systems. This is an important design consideration, and could be an issue when on-street parking is intended.

To prevent vehicles driving on buffer strips and swales (and reducing treatment performance etc) appropriate traffic control measures should be considered (e.g. dense vegetation or physical barriers).

Kerb and channel should be used at all corners, intersections, cul-de-sac heads and at traffic calming devices to ensure a correct driving path is taken.

Wider road corridors may be required to incorporate swales, limiting off-street parking.

Landscape Design

Swales and buffer strips can be successfully integrated into a landscape such that functional runoff objectives, landscape aesthetics, biodiversity and amenity are achieved.

Landscape design of swales and buffer strips along the road edge can assist in defining the boundary of the road or street corridors as well as enhancing landscape character.

Consultation with landscape architects is recommended when designing a swale or buffer strip to ensure the treatment system complements the landscape of the area.

Vegetation Selection

Plant species selection needs to consider both aesthetic and functional requirements. The long dry periods in the Greater Adelaide Region are not conducive to vegetated swale establishment without additional irrigation, which is an important consideration in terms of viability.

Vegetation is required to:

- Cover the whole width of the swale and/or buffer strip;
- Be capable of withstanding design flows;
- Be of sufficient density to prevent preferred flow paths and scour of deposited sediments; and
- Be resilient to long periods of dry weather, commonly experienced in Adelaide.

Plant species should have the following features:

- A capability to tolerate short periods of inundation punctuated by longer dry periods;
- Spreading rather than clumped growth forms;
- A perennial rather than annual capability; and
- Drought tolerant.

Denser vegetated swales can offer improved sediment retention by slowing flows more and providing enhanced sedimentation for deeper flows.

Swales and buffer strips can use a variety of vegetation types including turf, sedges, and tufted grasses. Vegetated swales should be planted with local native plant species to enhance biodiversity, reduce the need for watering and reduce the spread of weed species to receiving environments via runoff.

Consideration should also be given to:

- Other WSUD objectives such as landscape, aesthetics, biodiversity, conservation and ecological value;
- Region, climate, soil type and abiotic factors;
- Roughness of the channel (Manning's *n* roughness factor);
- Establishment period for vegetation growth (and hence timing of planting);
- Access for maintenance of the vegetation; and
- Adequate sunlight for vegetation growth.

Maintenance

Regular inspections and maintenance are required during the establishment period of swales and buffer strips. Detailed information regarding the maintenance requirements are contained in **Section 11.7**.

The design should ensure that adequate access is available for maintenance of all aspects of the system.

Land and Asset Ownership

Land and asset ownership issues are key considerations prior to construction of a WSUD measure, including swales and buffer strips. A proposed design should clearly identify the asset owner and who is responsible for maintenance.

11.4 Design Process

The design process for swales and buffer strips includes the following steps:

- Site analysis (including determining any site constraints);
- Determine the design objectives;
- Meet with council and relevant authorities;
- Undertake a concept design:
  - Topographical survey of the site
  - Preliminary geotechnical survey
  - Design criteria based on water quality and quantity objectives
  - Design flows based on catchment characteristics
  - Consideration of gross pollutants
  - Verification of design performance (e.g. water quality or hydraulic modelling)
  - Maintenance and access
  - Identify and propose mitigation of environmental issues on site
  - Allowances to preclude traffic on swales or buffer strips
  - Selection of plant species
  - Cost estimate (including life cycle costing);
- Approvals process:
  - Local government
  - Environment Protection Authority
  - Natural Resources Management Board
  - Department of Water Land and Biodiversity Conservation;
- Detailed design:
  - Detailed design of civil works
  - Additional geotechnical/hydrogeological study
  - Detailed design drawings
  - Detailed design of relocation of services
  - Detailed cost estimate and schedule of quantities
  - Procurement plan
  - Planting plan
  - Maintenance plan
  - Design report;
- Check design objectives;
- Vegetation specification;
- Develop a maintenance plan.

It should be noted that not all of the steps detailed above will be required for each swale or buffer strip design.

Detailed swale and buffer strip design process information is contained in various publications (see **Section 11.10**) which will need to be adapted for the Greater Adelaide Region. However, a number of the design process elements are discussed briefly below.

The design process is also discussed in general in **Chapter 3** of the Technical Documents.

Site Analysis

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of site conditions is therefore a fundamental part of designing a development that effectively incorporates WSUD.

Factors which should be considered when undertaking a site suitability assessment include:

- Open space and landscape;
- Flora and fauna;
- Services;
- Catchment characteristics;
- Potential for site contamination; and
- Gradient.

Objectives and Targets

Before the commencement of the design process, the objectives and targets for the swale or buffer strip should be established. Objectives include environmental benefits (such as water quality improvement, detention and erosion control), habitat value (enhancing biodiversity and conservation), or aesthetic and recreational values.

If the objectives for designing a swale or buffer strip are clearly defined, the task is simplified.

The design approach for swales and buffer strips is generally based on achieving the following objectives:

- Providing sufficiently low flow velocities through the swale or buffer strip to limit surface erosion and scouring;
- Limiting the flow depth through the swale or buffer strip to maximise contact and filtration through the vegetation; and

- Meeting conveyance requirements for minor and major flow events.

Further information on the setting of objectives can be found in **Chapter 3** of the Technical Manual.

Meet with Council

Before designing or installing a swale or buffer strip, it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to swales or buffer strips in your area. A meeting with your local development assessment officer at council is therefore recommended.

The council will be able to advise whether:

- Development approval is required and, if so, what information should be provided with the development application;
- Any other approving authorities should be consulted; and
- Any specific council requirements need to be taken into consideration.

Land and asset ownership issues are key considerations prior to construction of a WSUD measure, including swales and buffer strips. A proposed design should clearly identify the asset owner and who is responsible for maintenance, and this issue should also be discussed during a meeting with the local council.

Concept Design

A detailed design process and example calculation for swale design is included in **Appendix B** of this chapter. Key points to consider in this design process are highlighted below. The design process outlined covers only the numerical calculations to ensure the swale operates effectively. The qualitative design aspects of buffer strips and swales is equally, if not more, important and should be addressed with reference to the rest of this chapter, and checked off using the design calculation sheets in **Appendix A** of this chapter.

Design Flows

Design of swales needs to consider two types of storm events:

- Minor storm flows (typically a 1 year ARI) for conveyance of nuisance flooding and applicability of water quality treatment functions. Design should be checked to ensure that flow velocity is less than 0.5 metres/second; and
- Major flood flows (typically the 100 year ARI) to check flow velocities, velocity depth criteria, conveyance within the road reserve and freeboard to the adjoining properties. Design should be checked to ensure that the maximum flow velocity is less than 1 metres/second.

Design Criteria

The following design criteria for swales should be met:

- Flow depths of less than 200 millimetres for a 1:10 year rainfall event;
- Ponding for no more than one hour after rainfall cessation is unlikely;
- Turf used is tolerant of submersion and resistant to scour and erosion; and
- Depth to width ratio of greater than 1:10.

Swale Geometry

The swale's geometrical design is an iterative process that needs to take into consideration the site's constraints including topography, development layout and density, how flow reaches the swale and available reserve width. The iterative process involves solving the Manning's equation and can be undertaken using a simple spreadsheet procedure.

Manning's *n* Value Selection

The selection of an appropriate Manning's *n* value is established by example in **Appendix B** of this document. Designers are also advised to take into account the reduction in Manning's *n* coefficient at high flow depths (i.e. at the 100 year ARI event) where the influence of roughness is reduced.

11.5 Design Tools

A range of design tools is available for the concept and detailed design of swales and buffer strips as detailed in **Chapter 15**. The modelling tools which are able to assist include:

- MUSIC;
- EPA SWMM;
- XP-SWMM;
- Hec-Ras; and
- E2.

In addition, design flows for particular storm events can be estimated using a range of hydrologic methods with varying complexity. For small simplistic catchments, the rational method is suitable for peak flow estimation, while for larger, more complex catchments, use of hydrologic/hydraulic models may be more appropriate for design.

Previous methods of sizing of a swale were based purely on hydraulic requirements and did not take into account the subsequent water quality effects. The parameters from the hydraulic calculations can be directly transferred to MUSIC to determine the water quality effect that the swale will have in the treatment train.

11.6 Construction Process

There are numerous challenges that must be appropriately considered to ensure successful construction and establishment of swales and buffer strips.

Protection During Construction

The risks to successful construction and establishment of swales or buffer strips are generally related to the construction activities which can generate large sediment loads in runoff which can smother vegetation. Construction traffic and other works can also result in damage to the swale or buffer strip.

If the swale or buffer strip is to be used during the development of other aspects of a site, the swale or buffer strip should be constructed well in advance of development to provide enough time for the swale vegetation to establish. Depending on the site runoff sediment loads and flow rates, swales may need to be restored once construction of the adjacent development site is complete.

If the swale (or buffer strip) is to be constructed for use after completion of the entire development, it should be protected from construction site runoff and should be fenced during the construction period to prevent damage from heavy plant and vehicles.

Temporary protection of swales and buffer strips can been achieved by using an arrangement of a suitable geofabric covered with shallow topsoil (e.g. 50 mm) and instant turf (laid perpendicular to flow path). This will allow the swale to function as a temporary erosion and sediment control facility throughout the building phase. At the completion of the building phase these temporary measures should be removed with all accumulated sediment and the swale reprofiled (if necessary) and planted in accordance with the proposed swale design. It may be possible to reuse the instant turf as part of the final planting if this is consistent with the proposed landscape design.

Landscaping

Topsoils

The preparation and installation of horticultural soils should follow environmental best practices and include:

- Preparation of soil survey reports including maps and test results at the design phase;
- Stripping and stockpiling of existing site topsoils prior to commencement of civil works for possible reuse as a plant growth medium;

- Testing of the quality of the local topsoil to determine the soil's suitability for reuse as a plant growth medium;
- Deep ripping of subsoils using a non-inversion plough;
- Reapplication of stockpiled topsoils;
- Remedial works, if necessary, to improve the soil's capacity to support plant growth and to suit the intended plant species; and
- Addition, where necessary, of imported topsoils (certified to AS 4419-2003 – Soils for Landscaping and Garden Use).

Soils applied must also be free from significant weed seed banks as labour intensive weeding can incur large costs in the initial plant establishment phase. On some sites, topsoils may be non-existent and material will need to be imported.

Sourcing Vegetation

Notifying nurseries early for contract growing is essential to ensure the specified species are available in the required numbers and of adequate maturity in time for swale (or buffer strip) planting. When this is not done and the planting specification is compromised (because of sourcing difficulties), poor vegetation establishment and increased initial maintenance costs may occur.

To ensure the planting specification can be accommodated, the minimum recommended lead time for ordering is three to six months.

Timing for Planting

Construction planning and phasing should endeavour to correspond with suitable planting months wherever possible. In some circumstances it may be appropriate to leave temporary planting in place (if this is used to protect the swale or buffer strip during the building phase (e.g. turf over geofabric)) and then remove this at a suitable time to allow the final swale planting to occur at the preferred time of year.

Weed Control

To combat weed invasion and reduce costly maintenance requirements for weed removal, high planting density rates should be adopted. A suitable biodegradable erosion control matting or a heavy application of seedless hydromulch can also be applied to swale batters (where appropriate) for short-term erosion and weed control.

Conventional surface mulching of swale (or buffer strip) systems with organic material should not be undertaken (for weed or moisture control). Most organic mulch floats and runoff typically causes this material to be washed away with a risk of causing drain blockage.

Watering

Regular watering of swale vegetation is essential for successful establishment and healthy growth. The frequency of watering to achieve successful plant establishment is dependent upon rainfall, maturity of planting stock and the water holding capacity of the soil.

After an initial three month period, watering may still be required. Watering requirements to sustain healthy vegetation should be determined during ongoing maintenance site visits.

However, water restrictions should be considered and the design should be undertaken to ensure that there are minimal water requirements and only species that can survive long dry periods are selected.

11.7 Maintenance Requirements

As the functionality of swales and buffer strips relies upon good vegetation establishment, adequate vegetation growth is a key maintenance objective. In addition, swales and buffer strips have a flood conveyance role that needs to be maintained to ensure adequate flood protection for local properties.

The most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required. It is also the time when large loads of sediments may impact on plant growth, particularly in developing catchments with an inadequate level of erosion and sediment control.

It is good practice to check the operation of inlet erosion protection measures following the first few rainfall events in order to avoid any long-term issues. Should problems be identified in these events, the erosion protection should be enhanced.

Following construction, swales and buffer strips should be inspected every one to three months (or after each major rainfall event) for the initial establishment period to determine whether or not the swale (or buffer strip) surface and vegetation requires immediate maintenance.

Swales and buffer strips require ongoing maintenance such as mowing, watering (in accordance with water restrictions), weeding, sediment and litter removal, and scour and erosion repair.

All maintenance activities should be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design procedure. Maintenance personnel and asset managers will use this plan to ensure that the swale or buffer strip continues to function as designed. An example Maintenance and Inspection Checklist for swales and buffer strips is contained in **Appendix A**.

Typical maintenance will involve:

- Routine inspection of the swale profile to identify any areas of obvious increased sediment deposition, or scouring of the swale invert from a storm;
- Routine inspection of the swale profile to identify any damage from vehicles;
- Routine inspection of swale batters to identify any rill erosion caused by lateral inflows;
- Routine inspection of inlet points (if the swale does not have distributed inflows), surcharge pits and field inlet pits to identify any areas of scour, litter build up or blockages;
- Removal of sediment where it is impeding the conveyance of the swale and/or smothering the swale vegetation and, if necessary, reprofiling of the swale and revegetating to original design specification;

- Repairing damage to the swale profile resulting from scour, rill erosion or vehicle damage;
- Clearing of blockages to inlets or outlets;
- Regular watering/irrigation of vegetation until plants are established and actively growing (in accordance with water restrictions);
- Mowing of turf or slashing of vegetation (if required) to preserve the optimal design height for the vegetation (although heavy machinery for mowing/slashing should be avoided);
- Removal and management of invasive weeds;
- Removal of plants that have died (from any cause) and replacement with plants of equivalent size and species as detailed in the plant schedule;
- Pruning to remove dead or diseased vegetation material and to stimulate new growth;
- Litter and debris removal;
- Vegetation pest monitoring and control; and
- Addressing nuisance problems such as mosquitoes and boggy areas.

Vegetation should be maintained preferably above 100 to 150 millimetres in height for swales and above 75 millimetres in height for buffer strips (Upper Parramatta River Catchment Trust 2004).

11.8 Education and Awareness

Any residents or employees located near a swale or buffer strip which has been constructed should be informed of the function of the WSUD measure and its benefits, to help prevent damage and/or misuse. The erection of signage near the swale or buffer strip is recommended to inform the public of its function and use.

11.9 Approximate Costs

Standard cost data for construction of swales and buffer strips in the Greater Adelaide Region is not readily available. The costs provided in this section have been obtained from a number of sources and are indicative only and may vary based on the region. It should also be noted that there may be additional costs associated with maintaining the swale or buffer strip during the construction and establishment phase.

Life cycle costing should be undertaken in the concept design phase.

Swales

The construction cost for swales depends on the surface area/width, type of vegetation and the steepness of the area (i.e. whether intermittent check dams are required). The essential unit rate construction for a nominal 3 metre wide swale is summarised in **Table 11.2**.

Table 11.2 Estimated Unit Rate Construction Cost for Swales

Works Description	Quantity	Unit	Rate	Cost ($/m)
Excavate and profiling swale channel	3	m^2/m	2.0	6
Supply and place topsoil layer (at least 100 mm thick)	3	m^2/m	7.0	21
Supply and apply grass seed, fertiliser and watering	3	m^2/m	1.0	3
TOTAL				30

Source: Upper Parramatta River Catchment Trust (2004)

Based on the above, the unit cost is approximately $30/metre length of swale or approximately $10/square metres of swale. For swales with an underlying subsoil drain (i.e. for grades less than 2%), include an additional $30/m for the construction of the subsoil drain, including excavation, perforated pipe, gravel and sand backfill and geofabric surround. If rolled turf is used instead of seed, the estimated unit cost of the swale would increase to approximately $18/square metres (excluding subsoil drain) (Upper Parramatta River Catchment Trust 2004).

Estimated swale maintenance costs are provided in **Table 11.3** and are derived from the Models Farm High School case study (Upper Parramatta River Catchment Trust 2004).

Table 11.3 Estimated Swale Maintenance Costs

Component	Estimated Cost ($)	Swale Size 1	Swale Size 2	Comments
		0.5 m deep, 0.3 m bottom, 3 m top width	1 m deep, 1 m bottom width, 7 m top width	
Mowing	1.62/100 m^2	264.6	440.1	Mow 2-3 times per year
General grass care	16.2/100 m^2	297	499.5	Grass maintenance area is top width + 3 m x length
Debris / litter removal	0.95/ m^2	170.1	170.1	
Reseeding / fertilisation	0.65/ m^2	10.8	18.9	Area revegetated is 1% of maintenance per area per year
Inspection and general administration	1.35/ m^2	421	421	Inspection once per year
TOTAL	3.13/ m^2	1164	1550	

Source: Upper Parramatta River Catchment Trust (2004)

Buffer Strips

The construction cost for buffer strips depends on the surface area and type of vegetation used. The construction cost for a buffer strip comprising surface preparation (grading, compacting and scarifying), topsoiling and seeding (with grasses) would be in the order of $10 to $15/square metres. The cost would increase to around $20 to $50/square metres if the area was planted with a ground cover of established and native grasses (Upper Parramatta River Catchment Trust 2004).

Maintenance of buffer strips in the form of the removal of litter and mowing is approximately $2.5/square metres (Upper Parramatta River Catchment Trust 2004).

11.10 Useful Resources and Further Information

Fact Sheets

www.melbourne.vic.gov.au/rsrc/PDFs/Water/WSUD_part3.pdf

City of Melbourne fact sheets

Legislation Information

www.epa.sa.gov.au/pdfs/epwq_report.pdf

Environment Protection (Water Quality) Policy 2003

www.epa.sa.gov.au/pdfs/epp_noise_ind.pdf

Environment Protection (Industrial Noise) Policy 1994

www.epa.sa.gov.au/pdfs/info_construction.pdf

EPA information sheet on Construction Noise

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA information sheet on Environmental Noise

www.epa.sa.gov.au/pdfs/building_sites.pdf

EPA Handbook for Pollution Avoidance on Building Sites

www.epa.sa.gov.au/pdfs/bccop1.pdf

Stormwater Pollution Prevention Code of Practice for the Building and Construction Industry

Design Information

www.wsud.org/tech.htm

Water Sensitive Urban Design Guidelines in the Sydney Region

www.healthywaterways.org/FileLibrary/wsud_tech_guidelines.pdf

Water Sensitive Urban Design Technical Design Guidelines for South East Queensland

www.goldcoast.qld.gov.au/t_standard2.aspx?PID=6866

Water Sensitive Urban Design Guidelines – Gold Coast City Council

http://portal.water.wa.gov.au/portal/page/portal/WaterManagement/Stormwater/StormwaterMgtManual/Content/Chapter%209_%20final%20version_web.pdf

Stormwater Management Manual for Western Australia – Structural Controls

11.11 References

CRC for Catchment Hydrology (2005). *MUSIC 3.0.1 Manual.* http://www.catchment.crc.org.au/cgi-bin/WebObjects/toolkit.woa/1/wa/productDetails?productID=1000000&section=DocumentationPage&wosid=PcwSaqX8RBlyg7QbrMewag.

Gold Coast City Council (2007). *Water Sensitive Urban Design Guidelines.* June. http://www.goldcoast.qld.gov.au/t_standard2.aspx?PID=6866.

IE Aust. (1987). *Australian Rainfall and Runoff - A Guide to Flood Estimation*. Barton, ACT. http://www.arq.org.au/arr/index.html.

IE Aust. (2006). *Australian Runoff Quality: A Guide to Water Sensitive Urban Design.* New South Wales.

Upper Parramatta River Catchment Trust (2004). *Water Sensitive Urban Design, Technical Guidelines for Western Sydney.* Prepared by URS Australia Pty Ltd. http://www.wsud.org/tech.htm.

Appendix A
Checklists

Swales or Buffer Strips

Design Assessment Checklist

Asset ID:	
Swale Location:	
Description:	
Major Flood – 100 yr ARI (m^3/s):	
Minor Flood – 1 yr ARI (m^3/s)	
Catchment Area (ha):	
Swale / Buffer Strip Area (m^2):	
Designed By:	
Checked By:	

Items Checked	Checked		Satisfactory	
	Y	N	Y	N
Concept Design				
1. Treatment performance verified				
2. Service location checked or appropriate allocation provided				
Inlet Zone / Hydraulics				
3. Station selected for IFD appropriate for location				
4, Longitudinal slope of invert > 1% and < 4%				
5. Manning's *n* selected appropriate for proposed vegetation type				
6. Overall flow conveyance width does not impact on traffic requirements				
7. Overflow pits provided where flow capacity exceeded				
8. Energy dissipation provided at inlet points to the swale and inlet flows appropriately distributed				
9. Velocities within swale cells will not cause scour				

Items Checked	Checked		Satisfactory	
	Y	N	Y	N
Cells				
10. Design states area and extended detention depth as defined by treatment performance requirements				
11. Overflow pit crest set at top of extended detention				
12. Maximum ponding depth and velocity will not impact on public safety				
13. Design saturated hydraulic conductivity included in specification				
14. Maintenance access provided to invert of conveyance channel				
Landscape and Vegetation				
15. Plant species selected can tolerate periodic inundation and design velocities				
16. Swale landscape design integrates with surrounding natural and/or built environment				
17. Planting design conforms with acceptable sight line safety requirements				
18. Existing trees in good condition are investigated for retention				
Comments on Design				
Actions Required				
1.				
2.				
3.				

Source: Gold Coast City Council (2007)

Swales or Buffer Strips

Maintenance Checklist

Asset ID:		**Date of Visit:**	
Inspection Frequency:	1 to 6 months	**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Weather:			

Items Inspected	Checked		Action Required (Details)	
	Y	N	Y	N
Debris Cleanout				
1. Swale and contributing areas clear of debris				
2. Observed domestic litter / debris in swale channel				
3. Inlet and outlet structures clear of obstructions				
Swale Surface				
4. Evidence of erosion or scour				
5. Vegetation condition				
6. Sediment deposition				
7. Evidence of vehicle damage				
Swale Vegetation				
8. Vegetation trimming / mowing				
9. Fertilisation where required				
10. Weed infestation				

Items Inspected	Checked		Action Required (Details)	
	Y	N	Y	N
Ponding				
11. Evidence of ponding water				
Comments on Inspection				
Actions Required				
1.				
2.				
3.				
4.				
5.				

Appendix B

Design Procedure and Example for Determining Swale Capacity

The following design procedure for a swale has been adapted from IE Aust. (2006) and Gold Coast City Council (2007). Please note that this considers the quantitative design process only – qualitative design features must be kept in mind during the design procedure. To ensure these features are followed it is recommended that practitioners make use of the design checklists in **Appendix A**.

The design process for a swale is as follows:

Step 1: Determine the Dimensions

Dimensions of a swale can be determined using Manning's equation, below. This allows the flow rate and flood levels within the swale to be determined for variations in the dimensions of the swale.

$$Q = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

$$R = \frac{A}{P}$$

Where: Q = Flow in the swale (m^3/s)

A = Cross sectional area of the swale (m^2)

P = Hydraulic Perimeter (m)

R = Hydraulic Radius (m)

S = Channel Slope (m/m)

n = Roughness coefficient (or Manning's *n*)

Flow in the swale should be determined according to the:

- Design 1 year ARI peak discharge; and
- Design 100 year ARI peak discharge.

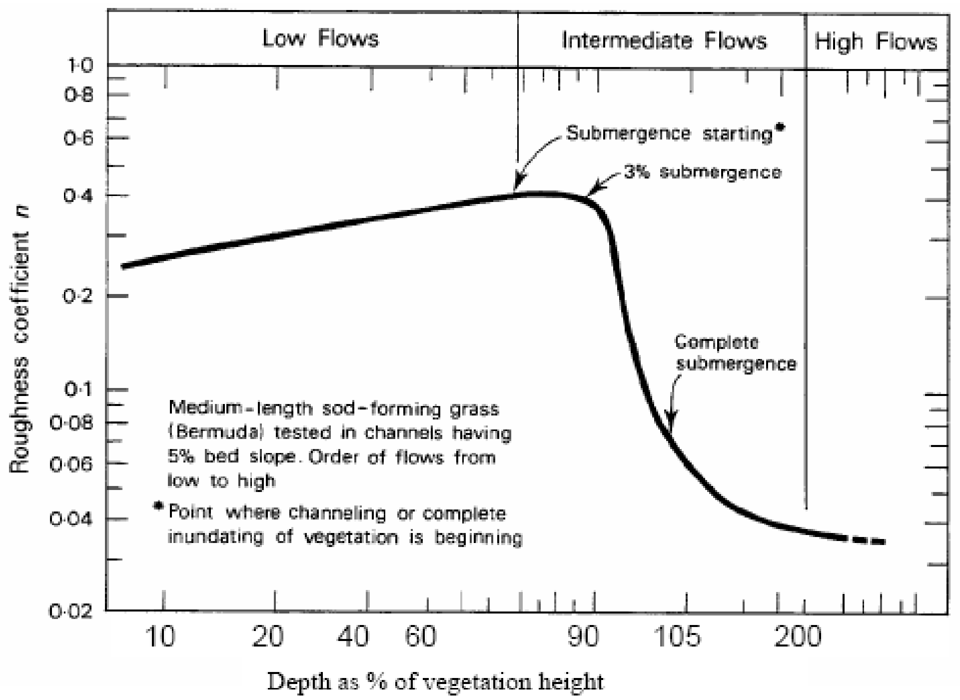
Cross sectional area and hydraulic radius are variables that the designer must determine (according to the area available for the swale). This can then be calculated and trialled to determine its fitness for use.

Slope of the swale will usually be dependent on the adjacent infrastructure (road, rail, pathway etc). Slope is recommended to be between 2-4%. Lower slopes will require underdrains to prevent ponding, while larger slopes will require flow spreading to ensure uniform flow occurs across the swale (IE Aust. 2006).

Manning's *n* is a critical variable in Manning's equation relating to roughness of the channel. It varies with flow depth, channel dimensions and vegetation type. For constructed swale systems, values are recommended to be between 0.15 and 0.3 for flow depths shallower than the vegetation height (preferable for treatment) and significantly lower for flows with greater depth than the vegetation (e.g. 0.03 for flow depth more than twice the vegetation height) (Gold Coast City Council 2007).

It is considered reasonable for Manning's *n* to have a maximum at the vegetation height and then to sharply reduce as depths increase. The graph below is a useful reference for determining the Manning's *n* of a channel using the depth of flow as a percentage of the height of vegetation. Designers are also advised to take into account the reduction in Manning's *n* coefficient at high flow depths (i.e. at the 100 year ARI event) where the influence of roughness is reduced.

Further discussion on selecting an appropriate Manning's *n* for a swale is provided in Appendix E of the *MUSIC User Guide* (CRC for Catchment Hydrology 2005).



Flow Velocity in the Swale

As a final check, to ensure the integrity of the swale as a water quality treatment measure, flow velocity should be checked to determine that:

- 1 year ARI peak velocity does not exceed 0.5 m/s; and
- 100 year ARI peak velocity does not exceed 1 m/s.

Sample Design for a Swale

The following example is adapted in part from IE Aust. (2006).

Task

Determine characteristics of a 100 m length trapezoidal channel needed to manage stormwater from a road catchment with the following characteristics:

- The swale is vegetated up to a height of 0.3 m;
- The swale is located in Adelaide, near the city centre, with an average annual rainfall of 545 mm/yr;
- Contributing catchment includes:
  - Roof area A_{EIA} = 2000 m^2
  - Paved area A_{EIA} = 1400 $m^{2;}$
- Length of Swale = 100 m; and
- Maximum width of swale = 6 m.

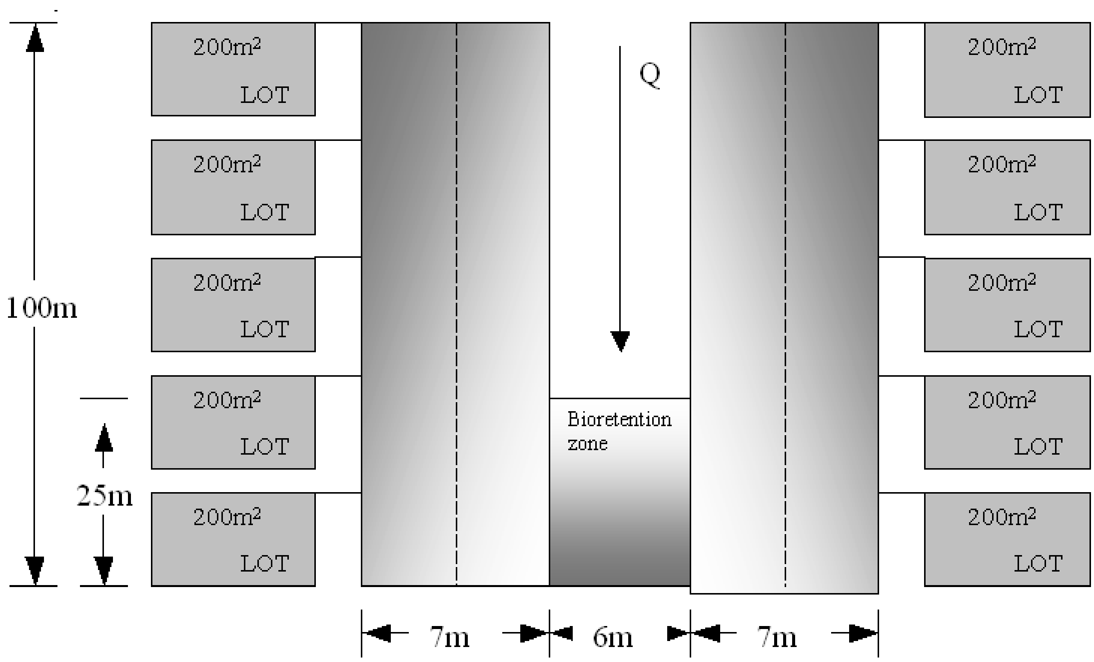


Figure B2 Bioretention Swale Plan (not to scale)

Determine Swale Dimensions

To start to design the swale, any values can be selected within the design limits. Here, we can trial a trapezoidal channel of base width 2 m and side slopes 1(v):3(h). A slope of 2% will be used as the initial slope calculation. Assume that the annual peak discharge from the catchment is 0.3 m^3/s, and the 100 year ARI peak discharge is equal to 1.2 m^3/s. The procedures for determining these peak discharge figures are found in the document *Australian Rainfall and Runoff* (IE Aust. 1987). A Manning's *n* value of 0.2 is adopted for these calculations.

1 year ARI flow condition:

Trial y = 0.2m; A = 0.52 m^2; P = 3.26m

Q = 0.14 m^3/s

Trial y = 0.3m; A = 0.87 m^2; P = 3.90m

Q = 0.30 m^3/s ~ 1 year ARI peak flow

Where y = trial flow depth (m).

100 year ARI flow condition:

Trial y = 0.5 m; A = 1.75 m^2; P = 5.16 m

Q = 0.80 m^3/s

Trial y = 0.60 m; A = 2.28 m^2; P = 5.79 m

Q = 1.15 m^3/s

Trial y = 0.65 m; A = 2.57 m^2; P = 6.11 m

Q = 1.35 m^3/s ~ 100 year ARI peak flow.

Check Flow Velocities

1 year ARI event; v = 0.30/0.87 = 0.34 m/s

< 0.5 m/s, OK

100 year ARI event; v = 1.35/2.57 = 0.52 m/s

<1 m/s, OK

Therefore, a channel should be designed with a base width of 2 m, minimum depth 0.65 m, side slopes 1(v):3(h), and vegetation height roughly equivalent to 0.3 m.

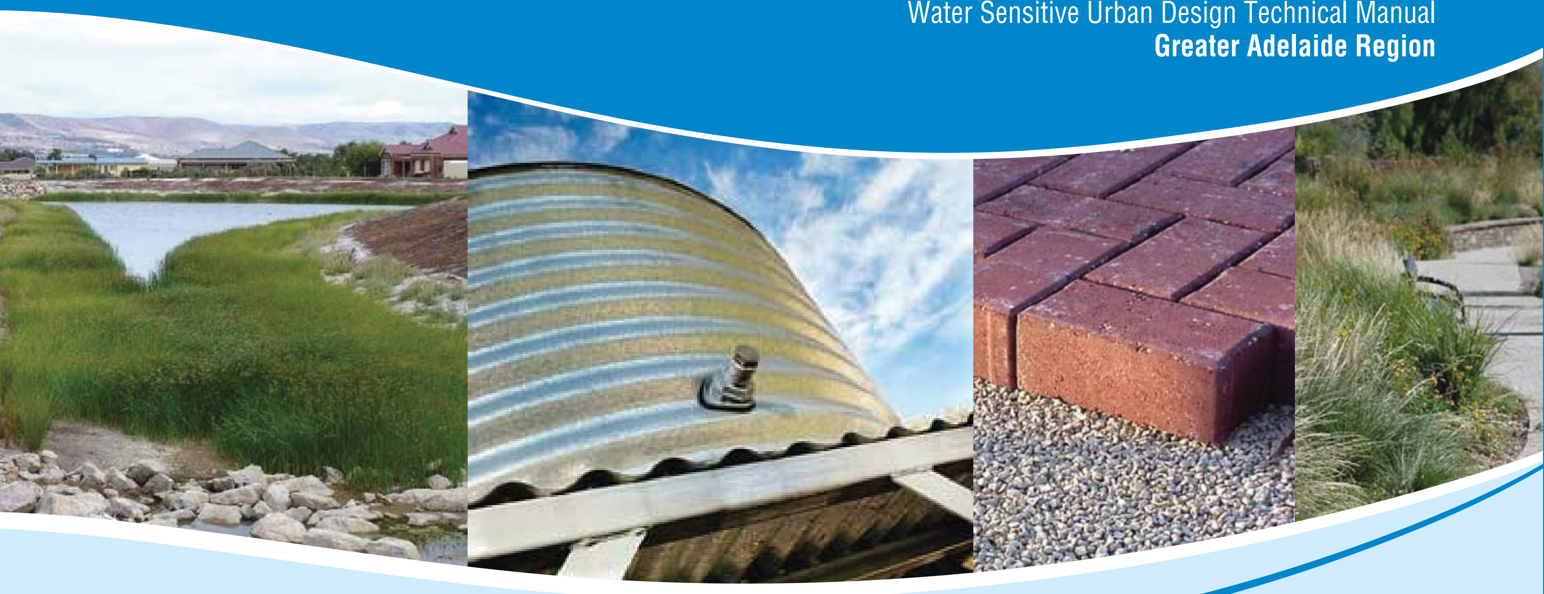
Note that the swale has been designed for the entire 100 m length. In some cases, it may be required to design a swale in sections, with intermediate overflow zones.

July 2009

Chapter 12

Sedimentation Basins

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Figures

Appendices

Chapter 12
Sedimentation Basins

12.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Sedimentation basins are one of those measures.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing an overview of sedimentation basins and how they can be utilised to assist in achieving the objectives and targets of WSUD. Further detailed design information can be obtained from the references included in the Useful Resources and Further Information section (see **Section 12.7**).

Description

Sedimentation basins are runoff detention systems that promote settling of sediments through the reduction of flow velocities and temporary detention. Key elements include:

- Purpose designed inlet and outlet structures;
- A settling pond; and
- High flow, overflow or bypass structures.

The storage volume consists of two components – the permanent pool settling zone and the sediment storage zone. Access for maintenance must be provided. These elements are shown below in **Figure 12.1** and **Figure 12.2**.

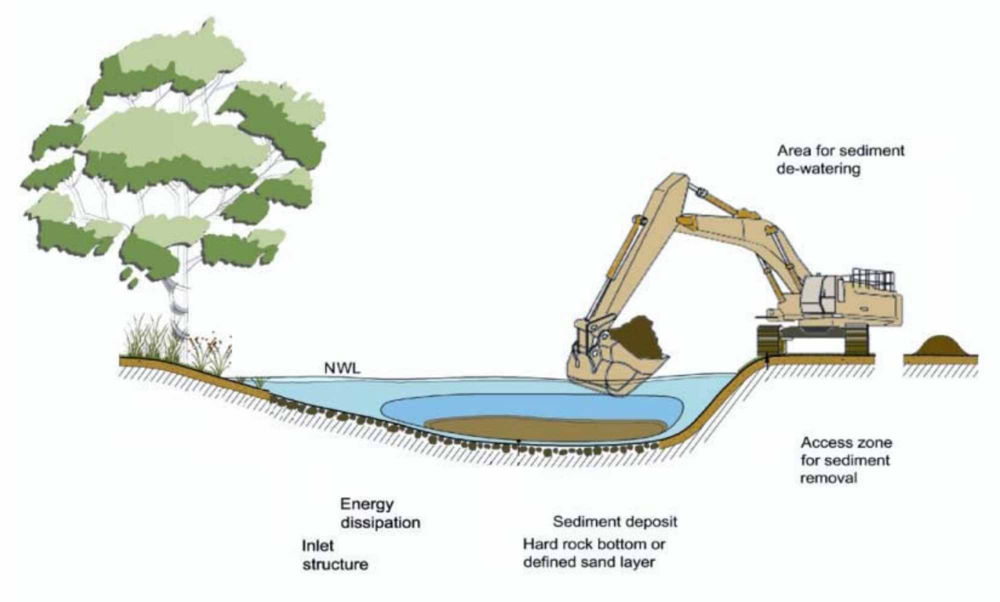


Figure 12.1 Elements of a Sedimentation Basin

Source: Gold Coast City Council (2007)

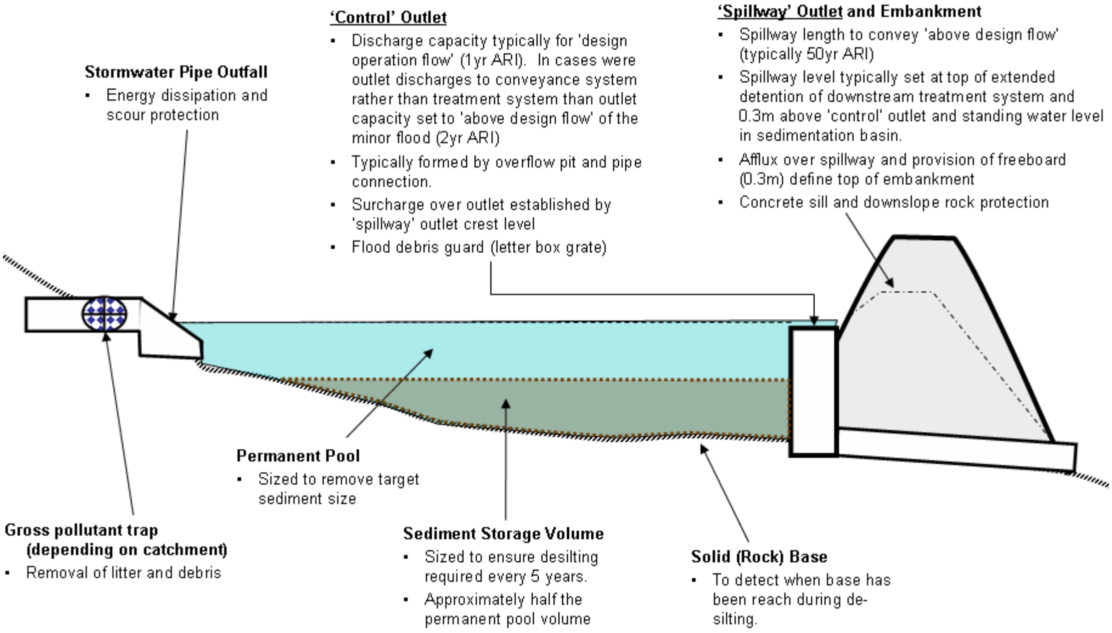


Figure 12.2 Cross Section of a Sedimentation Basin

Source: Gold Coast City Council (2007)

Purpose

The main function of sedimentation systems is water quality treatment.

Reducing sediment loads is an important component of improving the quality of runoff. Sedimentation basins have two keys roles:

- The primary function of a sedimentation basin is to target coarse to medium sized sediment (i.e. 125 µm[1] or larger) prior to waters entering the downstream treatment systems (e.g. macrophyte zone of a constructed wetland or a bioretention basin). This ensures that the vegetation in the downstream treatment system is not smothered by sediment and allows downstream treatment systems to target finer particulates, nutrients and other pollutants.
- The second function is the control or regulation of flows entering the downstream treatment system during 'design operation' and 'above design' conditions. The outlet structures from the sedimentation basin are designed such that flows up to the 'design operation flow' (typically the 1 year ARI) enter the downstream treatment system, whereas 'above design flows' are bypassed around the downstream treatment system. In providing this function, the sedimentation basin protects the vegetation in the downstream treatment system against scour during high flows. The configuration of outlet structures within sedimentation basins depends on the design flows entering the basin and the type of treatment systems located downstream.

Additional flood control can be achieved by incorporating a dedicated flood storage volume in the overall design.

Scale and Application

Sedimentation basins can take various forms (at a range of scales). They can be used as permanent systems integrated into an urban design, or temporary measures to control sediment discharge during construction.

Removal Efficiencies

Figure 12.3 shows the relationship between the required sedimentation basin area and design discharge for 125 µm sediment capture efficiencies of 70%, 80% and 90% using a typical shape configuration. This curve can be utilised to estimate the size of the sedimentation basin required.

---

[1] µm refers to micrometres, also called microns.

It should be noted that as sediment quantity builds up, sediment capture performance diminishes. Therefore, the design should treat the basin at full capacity case.

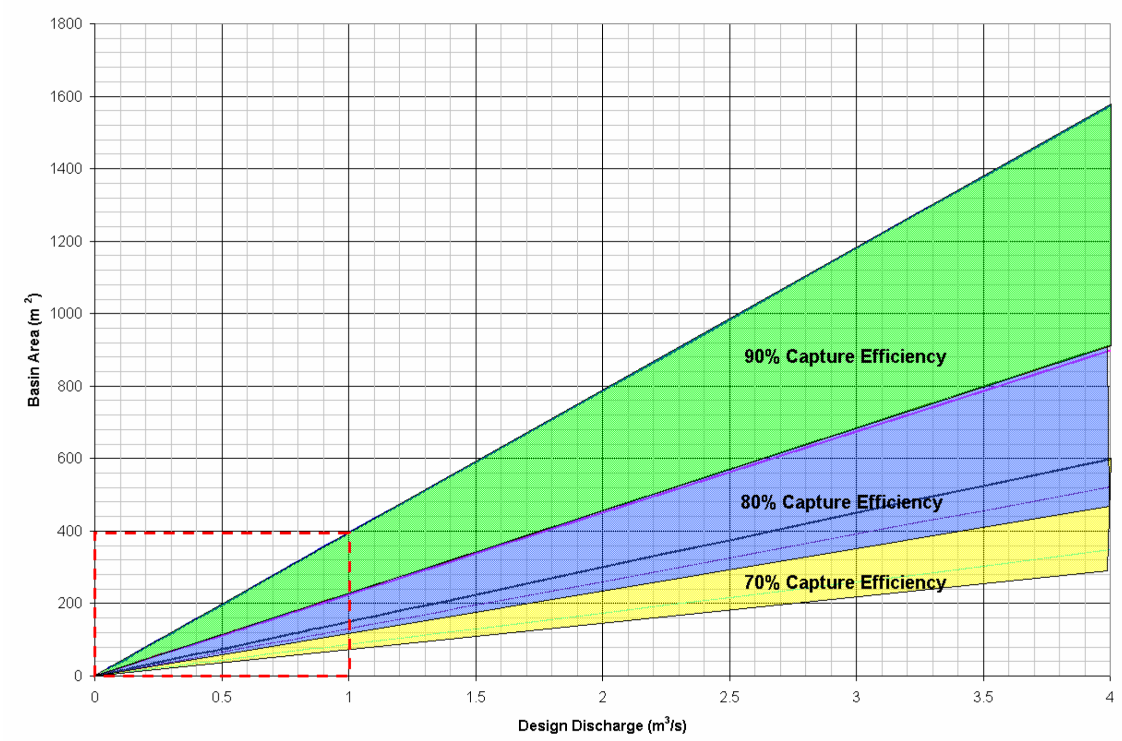


Figure 12.3 Sedimentation Basin Area vs Design Discharges for Varying Capture Efficiencies of 125 μm Sediment

Source: Moreton Bay Waterways and Catchments Partnership (2006)

12.2 Legislative Requirements and Approvals

Before undertaking a concept design of a sedimentation basin it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to sedimentation basins in your area.

The legislation which is most applicable to the design and construction of sedimentation basins includes:

- *Development Act 1993* and Development Regulations 2008; and
- *Environment Protection Act 1993*.

Development Act 1993

Installing a sedimentation basin will generally be part of a larger development, however whenever a sedimentation basin is planned, it is advised that the council be contacted to determine whether development approval is required under the *Development Act 1993*.

Environment Protection Act 1993

Any development, including the construction of a sedimentation basin, has the potential for environmental impact, which can result from vegetation removal, stormwater management and construction processes. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on the whole site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when planning on constructing a sedimentation basin are discussed below.

Water Quality

Water quality in South Australia is protected using the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development. In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, construction sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions need to be taken on a site to minimise potential for environmental impact during construction of a sedimentation basin.

It should also be noted that there is a high potential for anoxic conditions to occur in sedimentation basins due to high organic loading (in standing water). Therefore, public access to sedimentation basins should be restricted.

Noise

The issue of noise has the potential to cause nuisance during any construction works of sedimentation basins. The noise level at the nearest sensitive receiver should be at least 5 dB(A) below the Environment Protection (Industrial Noise) Policy 1994 allowable noise level when measured and adjusted in accordance with that policy. Reference should be made to the EPA Information Sheets on Construction Noise and Environmental Noise respectively and to assist in complying with this policy (see **Section 12.7**).

Air Quality

Air quality may be affected during the construction of a sedimentation basin. Dust generated by machinery and vehicular movement during site works, and any open stockpiling of soil or building materials at a site, must be managed to ensure that dust generation does not become a nuisance off site.

Waste

Any wastes arising from excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*. For example, during construction, all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 12.7**).

12.3 Design Considerations and Process

The general design process for sedimentation basins includes the following key steps:

- Site analysis (including determining any site constraints);
- Determine the design objectives and targets;
- Meet with council and other relevant authorities;
- Concept design:
  - Topographical survey of the site
  - Selecting a target sediment size
  - Estimating design flows
  - Landscaping opportunities
  - Determining the size and shape of the sedimentation basin
  - Provision of access for maintenance
  - Calculating the sediment storage volume
  - Determining the base material requirements of the basin
  - Producing cross sections of the basin;
- Approvals process:
  - Local government
  - Environment Protection Authority
  - Natural Resources Management Board
  - Department of Water Land and Biodiversity Conservation;
- Detailed design, including designing structures:
  - Hydraulic structures
  - Outlet pit
  - Discharge control structure
  - Overflow structure;
- Check design objectives;
- Vegetation specification;
- Develop a maintenance plan.

It should be noted that not all of the steps detailed above will be required for each sedimentation basin design.

A number of the design process elements are discussed briefly below.

Detailed sedimentation basin design process information is contained in various publications (see **Section 12.7** – Useful Resources and Further Information) and is not presented in this chapter. The information obtained from interstate references should be adapted for the Greater Adelaide Region.

Site Analysis

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of site conditions is therefore a fundamental part of designing a development that effectively incorporates WSUD.

Factors which should be considered when undertaking a site suitability assessment include:

- Open space and landscape;
- Flora and fauna;
- Services;
- Catchment characteristics;
- Potential site contamination;
- Soil properties; and
- Topography of the site.

Further information on site analysis can be found in **Chapter 3** of the Technical Manual.

Objectives and Targets

Before the commencement of the design process, the objectives and targets for the sedimentation basin should be established. Objectives include environmental benefits (such as water quality improvement, detention and erosion control), habitat value (enhancing biodiversity and conservation), or aesthetic and recreational values.

If the objectives for designing a sedimentation basin are clearly defined, the design task is simplified.

Further information on objectives and targets can be obtained from **Chapter 3** of the Technical Manual.

Meet with Local Council

Before designing or installing a sedimentation basin, it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to the construction and operation of sedimentation basins in your area. A meeting with your local development assessment officer at council is therefore recommended.

The council will also be able to advise whether:

- Development approval is required and, if so, what information should be provided with the development application;

- Any other approving authorities should be consulted; and
- Any specific council requirements need to be taken into consideration.

Land and asset ownership issues are key considerations prior to construction of a WSUD measure, including sedimentation basins. A proposed design should clearly identify the asset owner and who is responsible for maintenance, and this aspect should also be discussed during a meeting with the local council.

Concept Design

Target Sediment Size

Selecting a target sediment size is an important part of the design process. As a pre-treatment facility, it is recommended that particles of 125 μm or larger be the selected target sediment size because analysis of typical catchment sediment loads suggest that between 50-80% of suspended solids conveyed in urban stormwater are 125 μm or larger. Almost all sediment bed loads are larger than this target sediment size.

Removal of particles < 125 μm is best undertaken by treatment measures other than sedimentation basins (e.g. constructed wetlands and bioretention systems).

Landscaping Opportunities

Sedimentation basins are often located within public open space areas and can be landscaped to create a focal point for passive recreation. Landscape design can also include pathways and information signs.

However, the design must also consider access to the sedimentation basin and associated infrastructure for maintenance purposes as discussed below.

Estimating Design Flows

A range of hydrologic methods can be applied to estimate design flows for sedimentation basins. With typical catchment areas being relatively small, the rational method design procedure is considered to be the most suitable method. For sedimentation basins with large catchments (> 50 Ha), a runoff routing model should be used to estimate design flows.

Sizing a Sedimentation Basin

The required size of a sedimentation basin is calculated to match the settling velocity of a target sediment size with a design flow (typically 1 year ARI).

While a basin must be of an adequate size for capturing the target sediment size, it should not be grossly oversized. Conversely, a sedimentation basin that is too small could have limited effectiveness, resulting in sediment smothering of downstream treatment measures.

Where the sedimentation basin forms part of a treatment train and when available space is constrained, it is important to ensure that the size of the sedimentation basin (i.e. inlet zone of a constructed wetland) is not reduced. This ensures that the coarse sediments are effectively trapped and prevented from smothering the downstream treatment system. If the site constrains the total area available for the treatment train, the downstream treatment system should be reduced accordingly.

A further consideration in the design of a sedimentation basin is the provision of adequate storage for settled sediment to prevent the need for frequent desilting. Basin desilting is desirable once every five years and is generally triggered when sediment accumulates to half the basin depth. The volume of accumulated sediment can be estimated from regular monitoring of sediment levels with a measuring post and reference against the top water level.

A developing catchment can be expected to discharge between 50 m^3/ha and 200 m^3/ha of sediment each year. In a developed catchment, the annual sediment export is generally one to two orders of magnitude lower with an expected mean annual rate of 1.60 m^3/ha (Melbourne Water 2005a).

It should be noted that bed load should also be considered when calculating the total expected sediment load.

Figure 12.4 Brookes Bridge Sedimentation Basin

Source: Courtesy of Australian Water Environments

Access for Maintenance

Accessibility for maintenance is an important design consideration. If an excavator is able to reach all parts of the sedimentation basin from the top of the batter then an access ramp may not be required. However, an access track around the perimeter of the sedimentation basin will be required and will affect the overall landscape design.

If sediment collection requires earthmoving equipment to enter the sedimentation basin, a stable ramp will be required into the base of the sedimentation basin (maximum slope 1:10).

In terms of configuration, the basin should have a maximum width of 14 metres to allow access to the maintenance plant, unless approval is provided for long reach excavators or the construction of access ramps into the basin (Melbourne Water 2005a).

Maintenance of sedimentation basins is discussed further in **Section 12.6**.

Base Material of the Basin

Sedimentation basins are required to detain water (to enable settling of the sediments) and therefore the base must be of a suitable material to retain water (e.g. clay), typically overlain with a hard (e.g. rock) bottom to enable maintenance (see below). A lining for the sedimentation basin is particularly relevant where there are potential adverse impacts on the groundwater system.

It should be noted that wet sedimentation basins can be problematic to maintain and poor water quality (and odour and mosquito problems) can be an issue. An ideal scenario is for the sedimentation basin to drain fully over time.

Detailed Design – Outlet Structure

An outlet structure of a sedimentation basin can be configured in many ways and is generally dependant on the design flow entering the basin and the type of stormwater treatment system or conveyance system downstream of its outlet.

For example, a sedimentation basin forming the inlet zone of a constructed wetland would typically include an overflow pit located within the sedimentation basin with one or more pipes connecting the sedimentation basin to an open water zone at the head of the wetland macrophyte zone.

A sedimentation basin pre-treating runoff entering a bioretention basin would typically use a weir outlet to keep flows at surface, to enable the flow to discharge onto the surface of the bioretention filter media.

In most cases, the outlet design of a sedimentation basin will consist of a 'control' outlet structure and a 'spillway' outlet structure:

- The 'control' outlet can be either an overflow pit/pipe or weir which delivers flows up to the 'design operation flow' to the downstream treatment system(s);
- The 'spillway' outlet structure ensures that flows above the 'design operation flow' are discharged to a bypass channel or conveyance system; and
- The 'spillway' bypass weir level is set above the 'control' outlet structure and typically at the top of the extended detention depth of the downstream treatment system.

Where the sedimentation basin discharges to a conveyance system (e.g. swale or piped system), a 'control' outlet may not be required and one outlet can be designed to allow discharge of all flows including flood flows.

The outlets from sedimentation basins are to be designed such that access to the outlet does not require a water vessel (e.g. boat).

If controlled flow discharge or an upstream bypass diversion system is not provided, a means should be provided for emptying the sedimentation basin to facilitate drying and emptying.

Vegetation Specification

The role of vegetation in sedimentation basin design is to provide scour and erosion protection to the basin batters. In addition, dense planting of the littoral zones will restrict public access to the open water, reducing the potential safety risks posed by water bodies. The planting should ensure that 70-80% cover is achieved after two growing seasons (two years). Terrestrial planting may also be recommended to screen areas and provide a barrier to steeper batters.

Plant species should be selected based on:

- The water level regime;
- Soil types of the region; and
- The life histories, physiological and structural characteristics, natural distribution, and community groups of the plants.

Care needs to be taken in species selection to ensure vegetative growth will not spread to cover the deeper water zones. Similarly, floating or submerged macrophytes should be avoided. A sedimentation basin should primarily consist of open water to allow for settling of only the target sediments (e.g. > 125 μm) and to permit periodic sediment removal.

Plant species selection and placement should integrate with the surrounding landscape and community character, as well as providing or enhancing local habitat.

A vegetation specification therefore needs to be developed and it is recommended that this be undertaken in consultation with a landscape architect.

It should be noted that the timing of planting is critical to optimum establishment of plants. Poor timing can result in excessive erosion, plant losses and additional costs.

Maintenance

Maintenance access to all sediment removal areas must be ensured.

Hard stand areas must be provided adjacent to the inlet zone to allow for the maintenance and cleanout of this zone. The hard stand should be at least 3 metres wide and designed to be capable of supporting a 20 tonne excavation plant. Multiple areas should be considered where the pond is greater than 7 metres wide. Adequate space for dewatering should also be provided (Melbourne Water 2005a).

A method for identifying the base of the sedimentation basin when cleaning out collected sediment (e.g. concrete base, rock or identifiable sand) should be provided.

A maintenance plan for the sedimentation basin should be developed as part of the design process, as discussed in **Section 12.6**.

Checklist

The Design Assessment Checklist (in **Appendix A**) presents the key design features that should be reviewed when assessing the design of a sedimentation basin. These considerations include (but are not limited to):

- Configuration;
- Safety;
- Maintenance; and
- Operational issues.

12.4 Design Tools

A range of design tools is available to assist in the development of the concept and detailed design of sedimentation basins as detailed in **Chapter 15** of the Technical Manual.

The modelling tools which are able available include:

- MUSIC;
- EPA SWMM;
- XP SWMM;
- Drains;
- HecRas; and
- E2

In addition, a range of hydrologic methods can be applied to estimate design flows for sedimentation basins. With typical catchment areas being relatively small, the rational method design procedure is considered to be the most suitable method. For sedimentation basins with large catchments (greater than 50 hectares), a runoff routing model should be used to estimate design flows.

12.5 Construction Process

The risks to successful construction and establishment of a sedimentation basin during the construction process generally relate to the following:

- Construction activities which can generate large sediment loads in runoff; and
- Construction traffic and other works can result in damage to the sedimentation basins.

To overcome the challenges associated with delivering sedimentation basins, the basin should form part of the sediment and erosion control strategy.

Other aspects of the construction process are discussed below.

Construction Tolerances

It is important to emphasise the significance of tolerances in the construction of sedimentation basins. Ensuring the relative levels of the control structures are correct is particularly important to achieve appropriate hydraulic functions. Generally, control structure tolerance of plus or minus 5 mm is considered acceptable. Additionally, the bathymetry of the sedimentation basin must ensure appropriate storage is available for accumulated sediment. In this regard, an earthworks tolerance of plus or minus 25 mm is considered acceptable (Gold Coast City Council 2007).

Sourcing Sedimentation Basin Vegetation

In the majority of cases, the sedimentation basin will form an inlet pond to a constructed wetland or bioretention basin. If so, the landscape and vegetation design of the sedimentation basin will be undertaken in conjunction with the vegetation design of the other treatment measures and hence ordering of plant stock can be combined into one order.

Availability of vegetation is dependent upon many factors including demand, season and seed availability. To ensure the planting specification can be accommodated, the minimum recommended lead time for ordering plants is three to six months. This generally allows adequate time for plants to be grown to the required size.

Topsoil Specification and Preparation

During the sedimentation basin construction process, topsoil is to be stripped and stockpiled for possible reuse as a plant growth medium. It is important to test the quality of the local topsoil to determine the soil's suitability for reuse as a plant growth medium.

Remediation may be necessary to improve the soil's capacity to support plant growth and to suit the intended plant species. Soils applied to the littoral zones of sedimentation basins must also be free from significant weed seed banks as labour intensive weeding can incur large costs in the initial plant establishment phase.

On some sites, topsoils may be non-existent and material will need to be imported.

Checklist

The Construction Process Checklist (see **Appendix A**) presents the key items to be reviewed when inspecting the sedimentation basin during and at the completion of construction.

12.6 Maintenance Requirements

Typical maintenance of sedimentation basins will involve:

- Routine inspection of the sedimentation basin to identify depth of sediment accumulation, damage to vegetation, scouring, or litter and debris build up (after the first three significant storm events and then at least every three months);
- Routine inspection of inlet and outlet points to identify any areas of scour, litter build up and blockages;
- Removal of litter and debris;
- Removal and management of invasive weeds (both terrestrial and aquatic);
- Periodic (usually every five years) draining and desilting, which will require excavation and dewatering of removed sediment (and disposal to an approved location);
- Regular watering of littoral vegetation during plant establishment;
- Replacement of plants that have died (from any cause) with plants of equivalent size and species as detailed in the planting schedule; and
- Inspections are also recommended following large storm events to check for scour and damage.

Sedimentation basins are designed with a sediment storage capacity to ensure sediment removal is only required approximately every five years. However, as listed above, regular checks of sediment build up will be required as sediment loads from developing catchments vary significantly. The basin must be cleaned out when it becomes more than half full of accumulated sediment.

Provision to drain the sedimentation basin of water for maintenance must be considered in the design, or alternatively, a pump can be used to draw down the basin. Appropriate approvals should be obtained to discharge flows, depending on where the water is to be discharged.

Similar to other types of WSUD measures, debris removal is an ongoing maintenance requirement. Debris, if not removed, can block inlets or outlets, and can be unsightly if deposited in a visible location. Inspection and removal of debris should be done regularly and debris removed whenever it is observed on the site.

Analysis of the characteristics of particulate nutrients and metals indicates that coarse to medium sized sediments (i.e. > 125 µm) have low concentrations of attached pollutants (e.g. nutrients and heavy metals) when compared to finer sediment and colloidal particles. Basins sized to target coarse to medium sized sediment are therefore expected to capture sediment that has low levels of contamination and is unlikely to require special handling and disposal. However, this should be verified prior to the disposal of the material.

All maintenance activities should be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design process. Maintenance personnel and asset managers will use this plan to ensure the sedimentation basin continues to function as designed. The maintenance plan should include a clearly labelled schematic layout of the site identifying all structures, plantings, open space, water bodies and paths.

The maintenance plan and forms should address the following:

- Inspection frequency;
- Maintenance frequency;
- Data collection/storage requirements (i.e. during inspections);
- Detailed clean out procedures (main element of the plan) including:
  - Equipment needs
  - Maintenance techniques
  - Occupational health and safety
  - Public safety
  - Environmental management considerations
  - Disposal requirements (of material removed)
  - Access issues
- Stakeholder notification requirements;
- Data collection requirements (if any); and
- Design details.

An example Operation and Maintenance Inspection Checklist is included in **Appendix A**. This checklist should be developed on a site-specific basis as the configuration and nature of sedimentation basins varies significantly.

The maintenance checklist developed should be used whenever an inspection is conducted, and kept as a record on the asset condition and the quantity of removed pollutants over time. Inspections should occur every one to six months, depending on the size and complexity of the system.

More detailed site specific maintenance schedules should be developed for major sedimentation basins and include a brief overview of the operation of the system and key aspects to be checked during each inspection.

12.7 Useful Resources and Further Information

Fact Sheets

www.brisbane.qld.gov.au/bccwr/lib184/sedimentation_basin_72dpi_rgb_nobleed.pdf

Sedimentation Basin fact sheet, Brisbane City Council

www.brisbane.qld.gov.au/bccwr/lib184/wsud%20practice%20note%2004%20sedimentation%20basins.pdf

Practice Note 4 Sedimentation Basins, Brisbane City Council

Legislation Information

www.epa.sa.gov.au/pdfs/epwq_report.pdf

Environment Protection (Water Quality) Policy 2003

www.epa.sa.gov.au/pdfs/epp_noise_ind.pdf

Environment Protection (Industrial Noise) Policy 1994

www.epa.sa.gov.au/pdfs/info_construction.pdf

EPA information sheet on Construction Noise

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA information sheet on Environmental Noise

www.epa.sa.gov.au/pdfs/building_sites.pdf

EPA Handbook for Pollution Avoidance on Building Sites

www.epa.sa.gov.au/pdfs/bccop1.pdf

Stormwater Pollution Prevention Code of Practice for the Building and Construction Industry

Design Information

www.melbournewater.com.au/content/library/wsud/melbourne_water_wetland_design_guide.pdf

Constructed Wetland Systems – Design Guide for Developers

www.healthywaterways.org/FileLibrary/4_sediment_basin.pdf

Technical Design Guidelines for South East Queensland – Chapter 4 Sediment Basins

www.goldcoast.qld.gov.au/attachment/planningscheme/wsud_13_5_sedimentation.pdf

Water Sensitive Urban Design Guidelines – Gold Coast City Council – Section 13.5 Sedimentation Basins

12.8 References

Gold Coast City Council (2007). *Water Sensitive Urban Design Guidelines*. June. http://www.goldcoast.qld.gov.au/t_standard2.aspx?PID=6866.

Melbourne Water (2005a). *Constructed Wetland Systems - Design Guidelines for Developers.* Melbourne, Victoria. http://www.melbournewater.com.au/content/library/wsud/melbourne_water_wetland_design_guide.pdf.

Melbourne Water (2005b). *WSUD Engineering Procedures: Stormwater*. CSIRO Publishing.

Moreton Bay Waterways and Catchments Partnership (2006). *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland*. http://www.healthywaterways.org/FileLibrary/wsud_tech_guidelines.pdf.

Appendix A
Checklists

Sedimentation Basin

Design Assessment Checklist

Asset ID:	
Location:	
Description:	
Minor Flood (m^3/s):	
Major Flood (m^3/s):	
Catchment Area (ha):	
Basin Area (m^2):	
Designed By:	
Checked By:	

Items Checked	Checked		Satisfactory	
	Y	N	Y	N
Concept Design				
1. Treatment performance verified				
Basin Configuration				
2. Inlet pipe / structure sufficient for maximum design flow (minor and / or major flood event)				
3. Scour protection provided at inlet				
4. Basin capacity sufficient for maintenance period >= 5 years				
5. Configuration of basin (aspect, depth and flows) allows settling of particles > 125 µm				
6. Maintenance access into base of sedimentation basin				
7. Public access to inlet zone prevented through vegetation or other means				
8. Gross pollutant protection measures provided on inlet structures				
9. Freeboard provided above extended detention depth				
10. Batter slopes shallow or safety bench provided in case of accidental entry into basin				

Items Checked	Checked		Satisfactory	
	Y	N	Y	N
Hydraulic Structures				
11. Outlet perimeter > = design discharge of outlet pipe				
12. Outlet configuration suitable for basin type (e.g. riser for construction sediment, weir for wetland pre-treatment)				
13. Riser diameter sufficient to convey Q1 flows (ie 1year ARI flow)				
14. Maintenance drain provided				
15. Discharge pipe has sufficient capacity to convey the maintenance drain flows or Q1 flows (whichever is higher)				
16. Protection against clogging of orifice provided on outlet structure				
Comments on Design				
Actions Required				
1.				
2.				
3.				
4.				
5.				
6.				

Source: Gold Coast City Council (2007)

Sedimentation Basin

Construction Inspection Checklist

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Constructed By:			
Weather:			

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
Preliminary works				
1. Erosion and sediment control plan adopted				
2. Limit public access				
3. Location same as plan				
4. Site protection from existing flows				
5. All required permits and approvals in place				
Earthworks				
6. Integrity of banks				
7. Batter slopes as plans				
8. Impervious (e.g. clay) base installed				
9. Maintenance access to whole sedimentation basin				
10. Compaction process as designed				
11. Placement of adequate topsoil				
12. Levels as designed for base, benches, banks and spillway (including freeboard)				

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
13. Check for groundwater intrusion				
14. Stabilisation				
Structural Components				
15. Location and levels of outlet as designed				
16. Safety protection provided				
17. Pipe joints and connections as designed				
18. Concrete and reinforcement as designed				
19. Inlets appropriately installed				
20. Inlet energy dissipation installed				
21. No seepage through banks				
22. Ensure spillway is level				
23. Provision of maintenance drain(s)				
24. Collar installed on pipes				
25. Low flow channel is adequate				
26. Protection of riser from debris				
27. Bypass channel stabilised				
28. Erosion protection at outlet				
Vegetation				
29. Vegetation appropriate to zone (depth)				
30. Weed removal prior to planting				
31. Provision for water level control				
32. Vegetation layout and densities as designed				
33. Bypass channel vegetated				

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
Erosion and sediment control				
34. High flow bypass				
35. Inlet zone to be used as sediment basin during construction				
36. Stabilisation immediately following earthworks and planting of terrestrial landscape around basin				
37. Silt fences and traffic control in place				
Operational Establishment				
38. Inlet zone desilted				
39. Inlet zone disconnection removed				
Comments on Inspection				
Actions Required				
1.				
2.				
3.				
4.				
5.				
6.				

Source: Gold Coast City Council (2007)

Sedimentation Basin

Maintenance and Inspection Checklist

Asset ID:		**Date of Visit:**	
Inspection Frequency:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Weather:			

Items Inspected	Checked		Action Required (Details)	
	Y	N	Y	N
Debris				
1. Litter within inlet or open water zones				
2. Evidence of dumping (building waste, oils etc)				
Sediment				
3. Sediment within inlet zone requires removal (record depth, remove if >50%)				
Vegetation				
4. Terrestrial vegetation condition satisfactory (density, weeds etc)				
5. Weeds require removal from within basin				
Structures				
6. Overflow structure integrity satisfactory				
7. Settling or erosion of bunds/batters present				
8. Damage /vandalism to structures present				
9. Outlet structure free of debris				
10. Maintenance drains operational				

Comments on Inspection
Actions Required
1.
2.
3.
4.
5.
6.

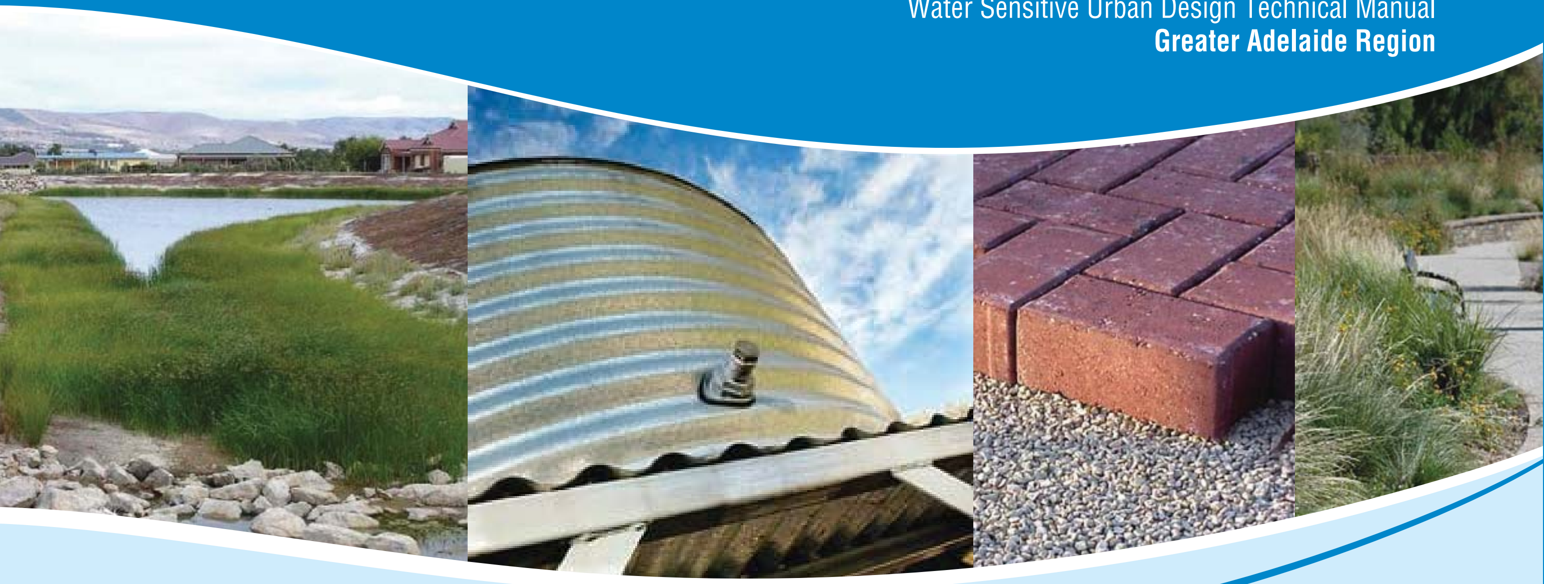
Source: Melbourne Water (2005)

July 2009

Chapter 13

Constructed Wetlands

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 13
Constructed Wetlands

13.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Constructed wetlands are one of those measures.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing a general overview of the benefits of constructed wetlands and how they can be utilised to achieve water quality and water quantity objectives and targets.

Further detailed design information can be obtained from the references included in the Useful Resources and Further Information section (see **Section 13.11**).

Description

Wetlands are complex, natural, shallow water environments that are dominated by hydrophytic (water loving) vegetation. This distinguishes them from deep water habitats that are dominated by large areas of open water.

Constructed wetlands are designed to utilise the benefits of natural wetland functions and processes for various purposes.

They are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from runoff.

In addition to treating water, constructed wetlands can also provide habitat, passive recreation, improved landscape amenity and temporary storage of treated water for reuse schemes.

Wetlands generally consist of:

- An inlet zone (sedimentation basin to remove coarse sediments (refer **Chapter 12 -** Sedimentation Basins));
- A macrophyte zone (a shallow heavily vegetated area to remove fine particulates and uptake soluble pollutants); and
- A high flow bypass channel (to protect the macrophyte zone from scour and vegetation damage).

Figure 13.1 shows the key elements of constructed wetland systems.

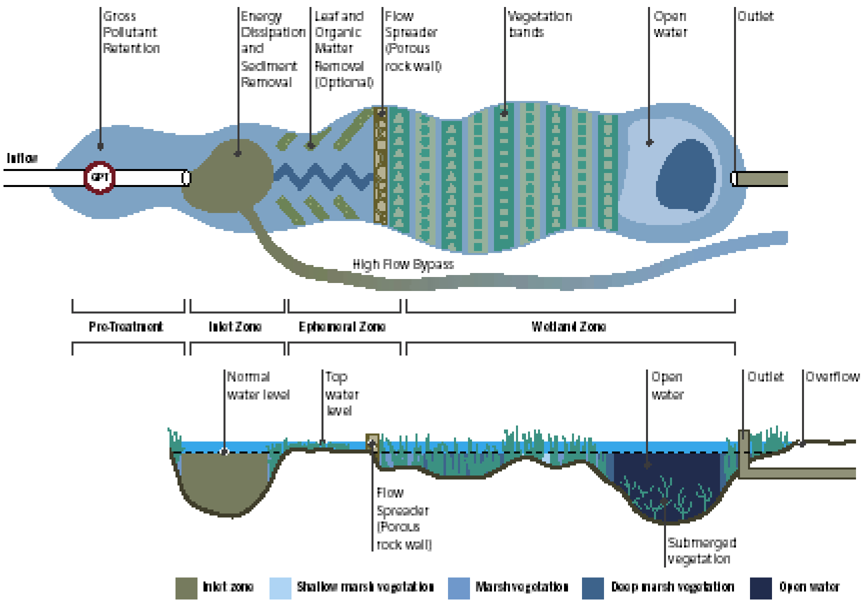


Figure 13.1 Long Section Schematic of a Typical Representation of a Constructed Wetland

Source: Melbourne Water (2005)

Constructed wetlands are particularly useful where runoff contains high concentrations of soluble material that is difficult to remove with other treatment methods.

Depending on their design, constructed wetlands can also serve to attenuate larger storm events, offsetting the changes to flow frequency relationships caused by increased catchment imperviousness. Constructed wetlands also increase flora and fauna habitat in already urbanised catchments where many natural wetlands have been cleared, drained or filled. They also provide passive recreation opportunities and can provide opportunities for educational and scientific studies.

Purpose

Scientific knowledge of the functions and values of wetlands has developed during the past 40 years. Until very recently, the filling and draining of wetlands was accepted practice to 'improve' the land. Wetlands are nature's 'kidney' system and the loss of this filtering function of wetlands can be correlated, at least in part, with the decline in the quality of our water resource systems.

The five principal purposes of constructed wetlands are:

- To compensate for and help offset the rate of loss of natural wetlands as a result of agriculture and urban development;
- To improve and maintain water quality;
- To provide attenuation of flood flows;
- To provide habitats which support aquatic life and wildlife; and
- To provide recreational amenity.

Multiple use constructed wetlands, which combine a number of purposes and benefits, are becoming more common in urban situations.

Generally, wetlands are designed for water quality control (to treat urban runoff to remove contaminants that would be potentially detrimental to the receiving water ecosystem). However, as for many catchment scale systems, wetlands can have significant flood control potential through the inclusion of specifically designed storage components.

Protecting existing wetlands – in conjunction with increasing the total extent of wetlands through restoration, creation, or construction for new developments – is an effective strategy for downstream aquatic resource protection.

Scale and Application

Wetlands are most appropriate on sites that meet or exceed the following criteria (Hobart City Council 2006):

- Catchment area more than approximately 1 hectare;
- Soils that are silty through clay;
- No steep slopes or slope stability issues; and
- No significant space limitations.

Constructed wetlands should only be used in areas that have enough inflow from rain, upstream runoff, treated wastewater or groundwater inflow to ensure the long-term viability of wetland processes.

Constructed wetlands are most applicable on the street scale and precinct or catchment/regional scale.

Figure 13.2 Brookes Bridge Wetland, Upper Cox Creek, Adelaide Hills

Source: Courtesy of Australian Water Environments

Performance Efficiency

Changes in environmental conditions can greatly influence wetland processes. These include diurnal changes in water temperature and dissolved oxygen, seasonal changes in daylight hours, water temperature, water depth, wetland vegetation growth, microbiological activity and chemical reactions. In areas with significant seasonal variation in water temperature, the treatment efficiency for a particular contaminant may vary markedly at different times of the year.

Indicative estimates for treatment efficiencies of a constructed wetland are provided in **Table 13.1**, however actual treatment efficiencies will depend on the hydraulic efficiency and the design of the wetland.

Table 13.1 Typical Annual Pollutant Load Removal Efficiencies for Constructed Wetlands

Pollutant	Expected Removal	Comments
Litter	> 95 %	Subject to appropriate hydrologic control
Total suspended solids	65-95 %	Depends on particle size distribution
Total nitrogen	40-80%	Depends on speciation and detention time
Total phosphorus	60-85 %	Depends on speciation and particle size distribution
Coarse sediment	> 95%	Subject to appropriate hydrologic control
Heavy metals	55-95%	Quite variable, dependent on particle size distribution, detention time etc

Source: Department of Environment WA (2004)

13.2 Legislative Requirements and Approvals

Before undertaking a concept design of a constructed wetland it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to constructed wetlands in your area. Refer to the suggested design process in **Section 13.5**.

The legislation which is most applicable to the design and installation of constructed wetlands in the Greater Adelaide Region includes:

- *Development Act 1993* and Development Regulations 2008; and
- *Environment Protection Act 1993*.

Development Act 1993

Installation of a constructed wetland will generally be part of a larger development, however whenever a constructed wetland is planned, it is advised that the local council be contacted to:

- Determine whether development approval is required under the *Development Act 1993*; and
- Determine what restrictions (if any) there may be on the installation of constructed wetlands in the area.

Environment Protection Act 1993

Any development, including the construction of wetlands, has the potential for environmental impact, which can result from vegetation removal, stormwater management and construction processes. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on the whole site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when considering the design and installation of a constructed wetland are discussed below.

Water Quality

Water quality in South Australia is protected using the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development.

In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, construction sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise potential for environmental impact during construction. Guidance can be found in the EPA Handbook for Pollution Avoidance on Building Sites (see **Section 13.11**).

Constructed wetlands will assist in improving the water quality that is discharged to receiving waters.

Noise

The issue of noise has the potential to cause nuisance during any construction works of wetlands. The noise level at the nearest sensitive receiver should be at least 5 dB(A) below the Environment Protection (Industrial Noise) Policy 1994 allowable noise level when measured and adjusted in accordance with that policy. Reference should be made to the EPA Information Sheets on Construction Noise and Environmental Noise respectively to assist in complying with this policy (see **Section 13.11**).

Air Quality

Air quality may be affected during the construction of a wetland. Dust generated by machinery and vehicular movement during site works and any open stockpiling of soil or building materials at the site must be managed to ensure that dust generation does not become a nuisance off site.

Waste

Any wastes arising from any excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*. For example, during construction, all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 13.11**).

13.3 Design Considerations

The operation of constructed wetlands involves the interaction between water (runoff or treated wastewater), vegetation and hydraulic structures. The successful implementation of constructed wetlands requires appropriate integration into the landscape design.

Wetland construction should only be considered when environmental and health concerns can be adequately addressed through design and realistic maintenance regimes.

Design considerations for constructed wetlands include:

- Hydrology;
- Water quality;
- Mosquitoes;
- Maintenance;
- Safety;
- Landscape and vegetation; and
- Services.

The following sections provide an overview of the key design issues that must be considered when conceptualising and designing constructed wetlands.

Detention Time and Hydrologic Effectiveness

Detention time is the time taken for each 'parcel' of water entering the wetland to travel through the macrophyte zone assuming 'plug' flow conditions. In highly constrained sites, simulations using computer models are often required to optimise the relationship between wetland detention time and wetland hydrologic effectiveness to maximise treatment performance.

It should be noted that detention time is rarely a constant and the term 'notional detention time' is used to provide a point of reference in modelling and determining the design criteria for riser outlet structures.

Hydrologic effectiveness is a measure of the mean annual volume of water captured and treated within the wetland and is expressed as a percentage of the mean annual runoff volume generated from the contributing catchment (it should be greater than 80% for well designed wetlands).

The relationship between notional detention time and pollutant removal efficiency is largely influenced by the settling velocity of the target particulates. It is recommended that a notional detention time should preferably be 72 hours (and not less than 48 hours) to remove nutrients effectively from urban runoff in the Greater Adelaide Region.

The range of detention times achieved in a constructed wetland is influenced by the type of outlet structure used. The volume of the permanent pool also has a significant effect on the range of detention times achieved as a result of operational conditions. The impact of these design choices needs to be taken into account during the concept design.

Water level control is desirable in wetland design to enable maintenance and to assist with vegetation establishment.

Inlet Zone Design Considerations

The inlet zone of a constructed wetland is designed as a sedimentation basin (see **Chapter 12**) and has two key functional roles. The primary role is to remove coarse to medium sized sediment (i.e. 125 µm or larger) prior to flows entering the macrophyte zone. This ensures the vegetation in the macrophyte zone is not smothered by coarse sediment and allows this zone to target finer particulates, nutrients and other pollutants.

The second role of the inlet zone is the control and regulation of flows entering the macrophyte zone and bypass of flows during 'above design flow' conditions. The outlet structures from the inlet zone (i.e. sedimentation basin) are designed such that flows up to the 'design flow' (typically the 1 year ARI) enter the macrophyte zone whereas 'above design flows' are bypassed around the macrophyte zone. In providing this function, the sedimentation basin protects the vegetation in the macrophyte zone against scour during high flows.

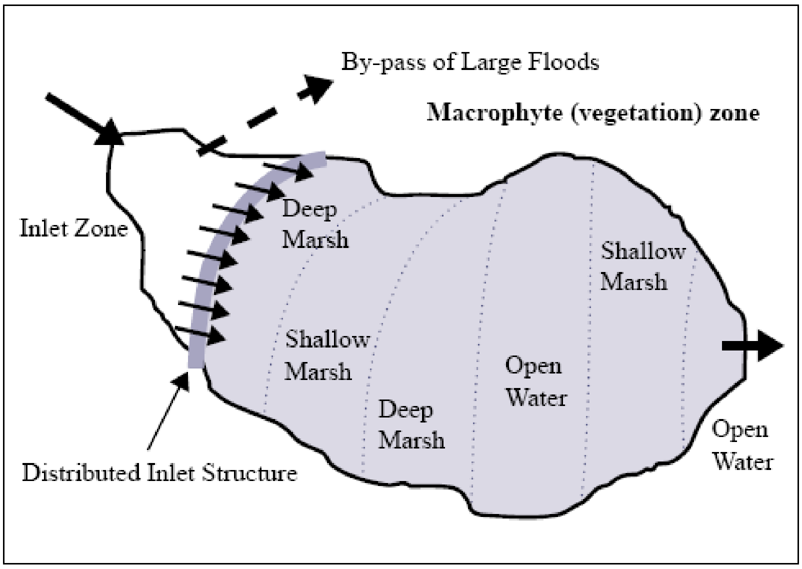


Figure 13.3 Illustration of Typical Constructed Wetland Layout

Source: Wong (1998)

Note that when the available space for a constructed wetland is constrained, it is important to ensure that the size of the inlet zone (i.e. sedimentation basin) is not reduced. This ensures the larger sediments are effectively trapped and prevented from smothering the macrophyte zone. When the site constrains the size of the constructed wetland it is the macrophyte zone of the wetland that should be reduced accordingly.

Large wetland systems usually require a gross pollutant trap (GPT) (see **Chapter 9**) as part of the inlet zone to protect the wetland from litter and debris. Determining whether a GPT is required or not depends on the presence of upstream GPT measures, the catchment size and catchment type.

The inlet zone is also required to remove high organic loads. It should be noted that high organic loads can be problematic for wetland systems.

Macrophyte Zone Design Considerations

The layout of the macrophyte zone needs to be configured such that system hydraulic efficiency is optimised and healthy vegetation sustained. Design considerations include:

- The range of suitable extended detention depths is 0.25-0.5 metres (providing suitable plant species are selected for deeper extended detention depths), depending on the desired operation of the wetland and target pollutant;
- The bathymetry (ground contours under the water) of the macrophyte zone should be designed to promote a sequence of ephemeral, shallow marsh, marsh and deep marsh zones in addition to small open water zones. The relative proportion of each zone will be dependent on the target pollutant and the wetland hydrologic effectiveness;
- The macrophyte zone is required to retain water permanently and therefore the base must be of suitable material to retain water (e.g. clay). If in-situ soils are unsuitable for water retention, a clay liner (e.g. compacted 300 millimetres thick) should be used to ensure there will be permanent water for vegetation and habitat;
- The bathymetry of the macrophyte zone should be designed so that all marsh zones are connected to a deeper open water zone to allow mosquito predators to seek refuge in the deeper open water zones during periods of extended dry weather;
- Particular attention should be given to the placement of the inlet and outlet structures, the length to width ratio of the macrophyte zone and flow control features to promote a high hydraulic efficiency within the macrophyte zone;
- Provision to drain the macrophyte zone for water level management during the plant establishment phase;

- For reed beds less than 100 metres in length, the gradient should be flat. For longer reed beds, the introduction of bed slope will compensate for the hydraulic gradient, and allow easier draining;
- The optimum treatment configuration is a wetland densely vegetated with species that provide a high density of stems in the submerged zone (thereby maximising the contact between the water and the surfaces on which microorganisms grow), while providing uniform flow conditions with no short circuiting;
- The main potential drawback to an overall densely vegetated system would be the reduction of dissolved oxygen in the near bottom water and the surface sediment layer. The presence of anaerobic sediment is desirable for denitrification, but careful consideration is required if densely planted systems can reduce dissolved oxygen so low that adverse effects can occur in freshwater receiving systems.

The macrophyte zone outlet structure needs to be designed to provide a notional detention time (usually 48 to 72 hours) for a wide range of flow depths. The outlet structure should also include measures to trap debris to prevent clogging.

Landscaping and Vegetation

Constructed wetlands are often located within accessible open space areas and can become interesting community features. Landscape design considerations are addressed further in **Section 13.4**.

Landscape design aims to ensure that the planting fulfils the intended treatment function as well as integrating with the surrounds.

Figure 13.4 Vegetation in the Grange Golf Course Wetland

Source: Courtesy of Adelaide and Mt Lofty Ranges Natural Resources Management Board

While individual plant species can have very specific water depth requirements, other species can be quite adaptive to growing across various zones over time. However, it is recommended that the suggested zones and plant groups are adhered to for planting purposes. Plant species suitable for the shallow marsh and ephemeral marsh wetland zones are equally suitable for edge planting (at equivalent depths) in sedimentation basins, ponds and lakes. Planting densities recommended should ensure that 70-80% cover is achieved after two growing seasons (two years).

The batters relate to the berms or embankments around the systems that may extend from the permanent pool water level to typically 0.5 metres above this design water level (i.e. within the extended detention depth). Plants that prefer a drier habitat should be planted towards the top of batters, whereas those that are adapted to more moist conditions should be planted closer to the water line.

It should be noted that the timing of planting is critical to optimise establishment of plants. Poor timing can result in excessive erosion, poor plant establishment, plant losses and additional costs.

Mosquitoes

To reduce the risk of high numbers of mosquitoes, there are a number of design features that can be considered. Not all of these will be feasible in any one situation, but they include (Gold Coast City Council 2007):

- Providing access for mosquito predators, such as fish and predatory insects, to all parts of the water body (avoid stagnant isolated areas of water);
- Providing a deep sump of permanent water (for long dry periods or for when water levels are artificially lowered) so that mosquito predators can seek refuge and maintain a presence in the wetland;
- Maintaining natural water level fluctuations that disturb the breeding cycle of some mosquito species, but be aware that this may suit other mosquito species;
- Where possible, incorporating a steep slope into the water, preferably greater than 30° or 3:1 horizontal to vertical. Note that steep edges may be unacceptable for public safety reasons, and a slope of up to 6:1 horizontal to vertical is generally used;
- Being aware that wave action from wind over open water will discourage mosquito egg laying and disrupt the ability of larvae to breathe;
- Providing a bathymetry such that regular wetting and drying is achieved and water draws down evenly so isolated pools are avoided;
- Providing sufficient gross pollutant control at the inlet such that human derived litter does not accumulate and provide a breeding habitat;
- Providing ready access for field operators to monitor and treat mosquito larvae;

- Ensuring maintenance procedures do not result in wheel rut and other localised depressions that create isolated pools when water levels fall;
- Ensuring overflow channels do not have depressions that will hold water after a storm event; and
- Immediately removing water weeds such as Water Hyacinth and Salvinia which can provide a breeding medium for some mosquito species whose larvae attach to these plants under water.

Each case has to be considered on its own merits. It may be possible that a well established constructed wetland will have no significant mosquito breeding associated with it, however changes in climatic and vegetation conditions could change that situation rapidly.

Maintaining awareness of mosquito problems and conducting regular monitoring for mosquito activity should be considered as a component of the management of constructed wetlands. Effective and environmentally sound control products are available for control of mosquito larvae in these situations.

Safety

Constructed wetlands need to be generally consistent with public safety requirements for new developments. These include reasonable batter profiles for edges to facilitate public egress from areas with standing water, and fencing where water depths and edge profile require physical barriers to public access.

The constructed fences can be substituted where possible by using dense edge plantings to deter public access to areas of open water. Children's playground equipment should not be located close to open water bodies.

The standard principles of informal surveillance, exclusion of places of concealment and open visible areas apply to the landscape design of wetlands. Where planting may create places of concealment or hinder informal surveillance, groundcovers and shrubs should not generally exceed 1 metre in height.

Maintenance Access

Maintenance access to a constructed wetland needs to be considered when determining the layout of a wetland system.

Inlet zones and gross pollutant traps require a track suitable for heavy machinery for removal of debris and desilting as well as an area for dewatering removed sediments.

Macrophyte zones require access to the areas for weeding and replanting as well as regular inspections.

Commonly, these access tracks can be incorporated with walking paths around a wetland system.

A defined hardstand area that provides for an 18-28 tonne excavator should be provided for full access to the inlet and macrophyte zones. It is critical to ensure the outlet for the macrophyte zone is located within easy reach of maintenance access and should not be located too far into the macrophyte zone.

Further information on the maintenance requirements of constructed wetlands is contained in **Section 13.7**.

Services

Wetlands tend to be located in or adjacent to open space or natural areas and are usually designed as large scale devices. Where they are located in open space areas, and within urban areas, designers should check the location of existing and proposed services including telecommunications, power, water and sewerage. Conflicts with existing or proposed services are to be avoided and can be addressed by changing the size, configuration and location of the wetland design or relocating the services.

13.4 Landscaping Considerations

Overview

If sited within accessible open space, constructed wetlands can be significant features within the built environment. Creative landscape design can enhance the appeal and sense of tranquillity that wetlands provide.

Landscape design aims to ensure that planting fulfils the intended water treatment function, as well as integrating with their surrounds.

Numerous opportunities are available for creative design solutions for specific elements. Close collaboration between landscape designer, hydraulic designer, civil/structural engineer and maintenance personnel is essential.

In parklands and residential areas, the aim is to ensure elements are sympathetic to their surroundings and are not overly engineered or industrial in style and appearance. Additionally, landscape design to specific elements should aim to create places that local residents and visitors will come to enjoy and regard as an asset.

Objectives

Landscape design of wetlands can have the following key objectives:

- Integrate the planning and design of constructed wetlands within the host natural and/or built environment;
- Ensure the wetland planting strategy is based on wetland design depths/zones to address runoff quality objectives and targets with the structural characteristics to perform particular treatment processes (e.g. well distributed flows, enhance sedimentation, maximise surface area for the adhesion of particles and provide a substratum for algal epiphytes and biofilms);
- Provide appropriate fringe plantings that promote habitat for fauna;
- Incorporate Crime Prevention Through Environmental Design (CPTED) principles;
- Provide other landscape values, such as shade, amenity, character and place making.

Context and Site Analysis

Comprehensive site analysis should inform the landscape design as well as road layouts, maintenance access points and civil works. Existing site factors such as roads, buildings, landforms, soils, plants, microclimates, services and views should be considered.

Constructed wetlands can have some impact on the available open space within new developments and considerable landscape planning needs to ensure that a balanced land use outcome is provided. Opportunities to enhance public amenity, education and safety with viewing areas, pathway links, picnic nodes, interpretive signage/art and other elements should be explored to further enhance the social context of constructed wetlands.

Landscape treatments should respond to the local context of the site within the Greater Adelaide Region, in particular planting types as they relate to the different vegetation communities in the region.

Wetland Siting and Shapes

Constructed wetlands need to integrate effectively into the surrounding existing landscape. The arrangement of the wetland basin and high flow bypass should be designed early in the concept design phase, to ensure that amenity of open space is enhanced.

The final shape of a wetland should provide landscape opportunities to create alternate useable spaces/recreation areas. Often different shapes to wetland edges can make pathway connections through and around these recreation areas more convenient and enhances the community perception of constructed wetlands.

Crossings

Given the size and location of wetland systems, it is important to consider if access is required across the wetland as part of an overall pathway network and maintenance requirement. Relevant Australian Standards should be referenced for access paths and decks within and around wetlands.

Pathways and bridges across planted earth bunds can be the best way of getting across or around wetlands. The materials on the bridge and pathways should be low maintenance and not impede hydrological flows. Recycled materials should be utilised where possible.

Figure 13.5 Boardwalk at Laratinga Wetland, Mt Barker

Source: Courtesy District Council of Mt Barker

High Flow Bypass Channel

The high flow bypass channel will convey flood waters during peak storm events. As these elements are generally turfed, it is worthwhile investigating the recreation opportunities offered at times outside of flood events. Designers should also investigate opportunities for locating trees and other vegetation types within the bypass channel. Provided hydraulic efficiencies can be accommodated, grassed mounds and landform grading of the embankment edge could also be explored to add variation and interest.

Viewing Areas

In parkland areas, turfed spaces within barrier fencing offer a simple low maintenance solution to incorporate a viewing area. Constructed decks may be appropriate in more urbanised areas. Hardwood timber construction should generally be avoided due to its inherent life cycle costs. Viewing areas should be located with a minimum distance of 5 metres separating the viewing area from the water body, so that wildlife feeding is discouraged.

Fencing

Where fences are required, layout and design of fencing is important in creating an overall attractive landscape solution. Fence styles need to respond to functional requirements but also the contextual setting (e.g. if it is an urban residential or open space/parkland area). Products designed for domestic gardens or industrial applications should generally be avoided. By specifying a black finish, and allowing for a screening garden in front of fences, the visual impact can be greatly reduced.

Appropriate Plant Selection

Between the macrophyte zone and the top of the embankment, trees, shrubs and groundcovers can be selected. Important considerations include:

- Selecting groundcovers, particularly for slopes greater than 1 in 3, with matting or rhizomataceous root systems to assist in binding the soil surface during the establishment phase;
- Preventing macrophyte zone plants from being shaded out by minimising tree densities at the water's edge and choosing species that allow sunlight to penetrate the tree canopy;
- Locating vegetation to allow views of the wetland and its surrounds while discouraging the public from accessing the water body;
- Selecting groundcovers which are capable of tolerating periodic inundation during extended detention.

Parkland vegetation may be of a similar species to the embankment's littoral vegetation and layout, to visually integrate the wetland with its surrounds. Alternatively, vegetation of contrasting species and/or layout may be selected to highlight the water body as a feature within the landscape.

13.5 Design Process

The design process and procedure for constructed wetlands includes a number of key steps, including:

- Assess site suitability (including site constraints and opportunities):
  - Open space, recreation and landscape linkages and requirements
  - Existing flora and fauna species
  - Services
  - Potential for site contamination
  - Soil properties
  - Catchment characteristics
  - Groundwater levels
  - Treated water reuse possibilities;
- Determine the design objectives and targets;
- Consult with council and other relevant authorities;
- Undertake a concept design:
  - Topographical survey of the site
  - Preliminary geotechnical survey
  - Design criteria based on water quality and quantity objectives and targets
  - Design flows based on catchment characteristics
  - Gross pollutants considered
  - Opportunities to minimise/negate greenhouse gas emissions of design and operation
  - Inlet zone layout (i.e. sedimentation basin design)
  - Macrophyte zone layout (i.e. extended detention depth, area of macrophyte zone, hydraulic efficiency)
  - Outlet and connection structures (including water level control)
  - Bypass weir
  - Verification of design performance (e.g. water quality or hydraulic modelling)
  - Recreational and educational aspects
  - Maintenance and access
  - Identify and propose mitigation of environmental issues on site
  - Cost estimate;

- Approvals process:
  - Local government
  - Environment Protection Authority
  - Natural Resources Management Board
  - Department of Water Land and Biodiversity Conservation
  - Department of Environment and Heritage;
- Undertake detailed design:
  - Detailed design of civil works
  - Additional geotechnical, hydrological and/or hydrogeological investigations
  - Detailed design drawings (including civil, landscape and recreational works)
  - Detailed design of relocation of services
  - Detailed cost estimate and schedule of quantities
  - Procurement plan
  - Planting plan and vegetation specification
  - Identify monitoring requirements
  - Design report;
- Check the design objectives;
- Prepare a construction plan; and
- Prepare a maintenance plan.

It should be noted that not all of the steps detailed above will be required for each wetland design.

Several elements of the design process are discussed briefly below. The general design process for all WSUD measures is discussed in **Chapter 3** of the Technical Manual.

Detailed constructed wetland design processes are contained in various publications contained in **Section 13.11**. The information obtained from interstate references should be adapted for the Greater Adelaide Region.

Site Suitability

WSUD responds to site conditions and land capability, and cannot be applied in a standard way. Careful assessment and interpretation of site conditions is therefore a fundamental part of designing a development that effectively incorporates WSUD.

Constraints and opportunities for the wetland must be identified and considered. In the Greater Adelaide Region, these factors are likely to include:

- Land availability, including future land use plans;
- Types and forms of pollutants generated in the catchment (e.g. dissolved nutrients, gross pollutants, toxicants, salinity and sediment);
- Pollutant delivery (e.g. mostly diffuse, base flows, first flush events, and timing of pollutant arrival);
- Geology/hydrogeology (e.g. groundwater levels and quality, aquifer suitability for MAR);
- Hydrology (e.g. rates, frequency and volume of runoff, environmental flow requirements)
- Topography (e.g. very flat or steep site);
- Site specific constraints (e.g. environmental, conservation and heritage issues, neighbouring land uses);
- Location of service infrastructure (e.g. roads, sewerage, water and gas pipelines, and telephone and power lines); and
- End use of the treated water (e.g. delivery into downstream waterways or reuse as irrigation water).

In particular, the proximity of the proposed wetland to residential areas needs to be considered in the selection and design of this WSUD measure.

Neighbouring communities will need to be consulted on the appearance, functionality and role of the constructed wetland. There are also safety concerns where the wetland is built in a publicly accessible area.

Objectives and Targets

Before the commencement of the design process, the objectives and targets for the constructed wetland should be established. Objectives include:

- Environmental benefits (such as water quality improvement, detention, retention and erosion control);
- Habitat value (enhancing biodiversity and conservation);
- Aesthetic, educational and recreational values; or
- Greenhouse gas emission minimisation/negation.

In setting objectives and targets, it is important to consider key State Government and council strategies and plans (such as strategic plans and stormwater management plans).

It is important to specify the contaminants that an urban water treatment wetland is designed to treat, as effective treatment of different contaminants can require markedly different detention times within the wetland.

The most common design priority for vegetated wetlands for the treatment of urban runoff will be the removal of:

- Sediments;
- Toxic substances including hydrocarbons and dissolved metals, and other toxic substances associated with fine particulate matter; and
- Nutrients.

Suspended solids are at one end of the treatability spectrum and require a relatively short detention time to achieve a high degree of removal, although fine particulate matter, which makes up a small proportion of suspended solids, is much more difficult to remove.

At the other end of the spectrum are nutrients. Given sufficient space and time, wetlands are capable of removing nutrients to very low levels, but like any other treatment system their efficiency depends on their design and water characteristics.

Designs that remove toxic substances will also achieve good aesthetic outcomes as well as meeting desirable discharge targets and some reduction of nutrients and human pathogens.

Further information on objectives and targets can be found in **Chapter 3** of the Technical Manual.

Consultation with Council and Other Relevant Authorities

The designer (or applicant) should liaise with civil designers and council officers prior to proceeding any further to ensure:

- The constructed wetland will not result in water damage to existing services or structures;
- Access for maintenance to existing services is maintained;
- No conflicts arise between the location of services and WSUD measures; and
- The objectives and targets are consistent with council directions stated in documents such as strategic plans and stormwater management plans.

The council will also be able to advise whether:

- Development approval is required and, if so, what information should be provided with the development application;
- Any other approving authorities should be consulted; and
- Any specific council requirements need to be taken into consideration.

Land and asset ownership issues are key considerations prior to construction of a WSUD measure, including wetlands. A proposed design should clearly identify the asset owner and who is responsible for maintenance, and this aspect should also be discussed during a meeting with the local council.

13.6 Design Tools

Numerous design tools are available for the concept and detailed design of constructed wetlands as detailed in **Chapter 15** of the Technical Manual.

The modelling tools which are able to assist include:

- MUSIC;
- EPA SWMM;
- XP-SWMM;
- WaterCress;
- Drains;
- Hec-Ras; and
- E2.

Design Flows

A range of hydrologic methods can be applied to estimate design flows.

If the typical catchment areas are relatively small, the rational method design procedure is considered to be a suitable method for estimating design flows.

However, if the constructed wetland is to form part of a retention basin, or if the catchment area to the wetland is large (> 50 ha), then a full flood routing computation method needs to be used to estimate design flows.

Simulations using computer models are often undertaken to optimise the relationship between detention time, wetland volume and hydrologic effectiveness of the constructed wetland, to maximise treatment given the volume constraints of the wetland site.

Water Quality Performance

The use of the model MUSIC can be utilised to optimise the conceptual design of a constructed wetland and to demonstrate its performance against the targets.

Further information on MUSIC is available in **Chapter 15**.

Figure 13.6 Greenfields Wetlands, City of Salisbury

Source: Courtesy of City of Salisbury

13.7 Construction Process

In the context of a large development site, and associated construction and building works, delivering constructed wetlands and establishing vegetation can be a challenging task. Constructed wetlands require a careful construction and establishment approach to ensure the wetland establishes in accordance with its design intent.

An example Construction Checklist is included in **Appendix A**. However, these forms should be adapted on a site-specific basis as the configuration and nature of constructed wetlands varies significantly.

Aspects of the construction process are discussed below.

Sediment and Erosion Control

Construction activities can generate large sediment loads in runoff which can smother wetland vegetation. Construction traffic and other works can also result in damage to constructed wetlands.

Sediment and erosion control is discussed below for those circumstance where the wetland has been constructed prior to or at the same time as other building activities on a site.

During the building phase of developments, temporary sediment and erosion control protective measures preserve the functional infrastructure of a constructed wetland against damage while also providing a temporary erosion and sediment control facility throughout the building phase to protect downstream aquatic ecosystems.

The inlet zone will essentially form a sedimentation basin which will reduce the load of coarse sediment discharging to the receiving environment. The inlet zone and the macrophyte zone should be disconnected to ensure the majority of flows from the catchment continue to bypass the macrophyte zone, thus allowing the wetland plants to reach full maturity without the risk of being smothered with coarse sediment. This means the macrophyte zone can be fully commissioned and made ready for operation once the building phase is complete.

At the completion of the building phase the inlet zone should be desilted, the disconnection between the inlet zone and macrophyte zone removed and the constructed wetland allowed to operate in accordance with the design.

Construction Tolerances

It is important to emphasise the significance of construction tolerances in the constructed wetland systems. Ensuring the relative levels of the control structures (inlet connection to macrophyte zone, bypass weir and macrophyte zone outlet) are correct is particularly important to achieve appropriate hydraulic functions.

Generally, control structure tolerance of plus or minus 5 millimetres is considered acceptable. Additionally, the bathymetry of the macrophyte zone must be free from localised depressions and low points resulting from earthworks. This is important to achieve a well distributed flow path and to prevent pools forming (potentially creating mosquito habitat) when the wetland drains. Generally, an earthworks tolerance of plus or minus 25 millimetres is considered acceptable.

Vegetation

The period of establishment and maintenance of vegetation within a wetland system is a critical phase of the wetland construction and operation process. To maximise the success of plant establishment in wetland macrophyte zones, specific procedures are required in site preparation, stock sourcing, vegetation establishment and maintenance including:

- Sourcing plant stock:
  - Lead times for ordering plants
  - Recommended planting systems/products;
- Topsoil specification and preparation:
  - Sourcing, testing and amendment
  - Topsoil treatments (e.g. gypsum, lime, fertiliser);
- Vegetation establishment:
  - Weed control
  - Watering
  - Water level manipulation.

Construction planning and phasing should endeavour to correspond with suitable planting months wherever possible. However, as lead times from earthworks to planting can often be long, temporary erosion controls (e.g. use of matting or sterile grasses to stabilise exposed batters) should always be used prior to planting.

To maximise the chances of successful vegetation establishment, the water level of the wetland system is to be manipulated in the early stages of vegetation growth.

Constructed wetlands, like most WSUD measures that employ soil and vegetation based treatment processes, require approximately two growing seasons (i.e. two years) before the vegetation in the systems has reached its design condition (i.e. height and density).

Bird Protection

During the early stages of wetland establishment, water birds can be a major nuisance due to their habit of pulling out recently planted species. Interlocking planting systems can be used, as water birds find it difficult to lift the interlocking plants out of the substrate unlike single plants grown in tubes.

13.8 Monitoring and Maintenance

Monitoring

To determine whether the wetland is performing as expected, a monitoring program detailing hydrology and the water quality of inflow and outflow is recommended. At a minimum, the following monitoring should be undertaken:

- Monitoring of surface water levels and flow pathways levels in the wetland to ascertain whether the actual wetland hydrology matches that of the design intent;
- Monitoring of the groundwater levels to identify any changes; and
- Monitoring of the inflow and outflows for total suspended solids and nutrients in low flow and high flow periods.

Maintenance

A detailed maintenance plan should be developed that specifies short and long-term maintenance of the constructed wetland. For simple wetlands, the plan may only need to specify how often to maintain and inspect the banks, when to inspect inlet and outlet structures for signs of clogging and when to remove sediment.

More complex wetland designs with mechanical devices, such as valves or pumps, may require much more detailed maintenance plans, including manufacturers' maintenance recommendations.

The most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required. It is also the time when large loads of sediments could impact on plant growth, particularly in developing catchments with poor building controls.

Operational maintenance falls into a number of different categories, but the two main areas are:

- Aesthetic/nuisance maintenance – important primarily for public acceptance of WSUD measures, and because it may also reduce functional maintenance activities; and
- Functional maintenance – includes routine (preventive) and corrective maintenance and is important for performance and safety reasons.

These two areas can overlap at times and are equally important. Both forms of maintenance should be combined into an overall maintenance program.

Aesthetic Maintenance

Aesthetic maintenance primarily enhances the visual appearance and appeal of a wetland. An attractive wetland will more easily become an integral part of a community. Aesthetic maintenance is obviously more important for those wetlands that are very visible. The following activities can be included in an aesthetic maintenance program:

- Graffiti removal – the timely removal of graffiti will improve the appearance of the area around a wetland. Timely removal will also tend to discourage further graffiti or other acts of vandalism;
- Grass trimming – trimming of grass around fences, outlet structures, hiker/biker paths, and structures will provide a more attractive appearance to the general public. As much as possible, the design of wetlands should incorporate natural landscaping elements which require less cutting and/or trimming.
- Control of weeds – in situations where vegetation has been established, undesirable plants can be expected. These undesirable plants can adversely impact on the aesthetics of a wetland and send the wrong signals to the public about weed control. These undesirable plants can be removed through mechanical or chemical means.
- Miscellaneous details – careful and frequent attention to performing maintenance tasks such as painting, tree pruning, leaf collection, debris removal and grass cutting (where intended) will ensure the wetland maintains an attractive appearance.

Functional Maintenance

Functional maintenance is necessary to keep a water management system operational at all times. It has two components – preventive and corrective maintenance.

- Preventive maintenance

  Preventative maintenance is done on a regular basis. Tasks include upkeep of any moving parts, such as outlet drain valves or hinges for grates or maintenance of locks. Other examples of preventive maintenance include:

  - Grass mowing – actual mowing requirements should be tailored to the specific site conditions and grass type;
  - Grass maintenance – grass areas require limited periodic fertilising and soil conditioning in order to maintain healthy growth. Provisions may have to be made to re-seed and re-establish grass cover in areas damaged by sediment accumulation, runoff or other causes;
  - Vegetative cover – trees, shrubs, and other landscaping ground cover may require periodic maintenance, including fertilising, pruning, and weed and pest control.

Wetlands should be inspected at least twice per year during the first three years during both growing and non-growing seasons to observe plant species presence, abundance, and condition, bottom contours, and water depths relative to plans, sediment, outlet and buffer conditions

Vegetation needs to be maintained such that the flow management role of the wetland is maintained to ensure adequate flood protection for local properties and protection of the wetland ecosystem;

- Trash and debris – a regularly scheduled program (monthly or after rainfall events) of debris and trash removal will reduce the potential for outlet structures, trash racks, and other wetland components from becoming clogged and inoperable during storm events. In addition, removal of trash and debris will prevent possible damage to vegetated areas and eliminate potential mosquito breeding habitats. Disposal of debris and trash must comply with all local and regional control programs;
- Sediment removal and disposal – accumulated sediments should be removed before they threaten the operation or storage volume of a wetland. A dewatering area will be needed to allow the sediment to dry before disposal. Disposal of sediments also must comply with local and regional requirements;
- Mechanical components – mechanical components, for example valves and gates, should remain functional at all times. Regularly scheduled maintenance should be performed in accordance with the manufacturers' recommendations; and
- Wetland maintenance program – a maintenance program for monitoring the overall performance of the wetland should be established. It is important to remember that potentially large problems can be avoided if preventive maintenance is done in a timely fashion.

- Corrective Maintenance:

  Corrective maintenance is required on an emergency or non-routine basis to correct problems and restore the intended operation and safe function of the wetland. Corrective maintenance activities include:

  - Removal of debris and sediment – sediment, debris and trash which threaten the ability of the wetland to store or convey water should be removed immediately and properly disposed of in order to restore proper wetland function. If sediments are clogging a wetland component, the lack of an available disposal site should not delay removal of the sediments. Temporary arrangements should be made for handling the sediments until a more permanent arrangement is made.

- Structural repairs – repairs to any structural component of the wetland should be made promptly. Equipment, materials and personnel must be readily available so repairs can be performed at short notice. Where structural damage has occurred, the design and conduct of repairs should be undertaken only by qualified personnel.
- Dam, embankment and slope repairs – damage to dams, embankments and slopes must be repaired quickly. Typical problems include settlement, scouring, cracking, sloughing, seepage and rilling. Repairs need to be made promptly. If the wetland is to be dewatered, pumps may be necessary if there is no drain valve.
- Erosion repair – vegetative cover is necessary to prevent soil loss, maintain the structural integrity of the wetland and maintain its contaminant removal benefits. Erosion problems are likely to start as small problems and grow into larger problems. Corrective action can include reseeding programs, erosion control blankets, riprap, sodding or reduced flow through the area.
- Fence repair – fences can be damaged by any number of factors, including vandalism and storms. Timely repair will maintain the security of the site.
- Elimination of trees or woody vegetation – woody vegetation can present problems for dams or embankments as the root system of such vegetation can undermine dam or embankment strength. Vegetation, including root systems, must be removed from dams or embankments and the excavated materials replaced with proper material at a specified compaction (normally 95% of the soil's maximum density).
- General facility maintenance – if one wetland component is undergoing corrective maintenance, other components should be inspected at the same time to see if they also need maintenance. This may yield cost savings if equipment is already on site.

Maintenance Plan

All maintenance should be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design procedure. Maintenance personnel and asset managers will use this plan to ensure the wetlands continue to function as designed. To ensure maintenance activities are appropriate for the wetland as it develops, maintenance plans should be updated a minimum of every three years.

The maintenance plans and forms should address the following:

- Inspection frequency;
- Maintenance frequency;

- Data collection/storage requirements (i.e. during inspections);
- Detailed clean out procedures including:
  - Equipment needs
  - Maintenance techniques
  - Occupational health and safety
  - Public safety
  - Environmental management considerations
  - Disposal requirements (of removed material)
  - Access issues
  - Stakeholder notification requirements
  - Data collection requirements (if any)
  - Design details.

An example Operation and Maintenance Inspection checklist is included in **Appendix A**. These forms should be developed on a site-specific basis as the configuration and nature of constructed wetlands varies significantly.

13.9 Approximate Costing

Costs for constructing wetlands can vary greatly depending on the configuration, location, site-specific condition (including hydrogeology, temporal patterns and seasonal temperature variations), volumes, flow rate and pollutant removal targets.

There is little available cost data for constructed wetlands in the Greater Adelaide Region. Typical construction costs presented in various reports range from approximately $500,000 to $750,000 per wetland hectare. The two key variables underpinning the construction costs are the extent of earthworks required and the types and extent of vegetation (Department of Environment WA 2004).

Annual maintenance costs have been reported to be approximately 2% of construction costs (Department of Environment WA 2004).

13.10 Case Studies

Breakout Creek Wetland, City of West Torrens

Breakout Creek is the last 3.5 km section of the River Torrens. It is an artificial channel constructed in 1938 to alleviate flooding caused in the wetlands and freshwater lagoons which formed behind the sand dunes where the Torrens meets the Patawalonga Creek and the Port River.

The riparian environment was used for horse grazing. The site was infested with feral and exotic plants and weeds, and the area was not available for community recreational use.

The area was therefore transformed into a wetland and community facility. The works extend approximately 500 metres up stream of the Henley Beach Road Bridge. Earthworks were completed in March 1999 and constructed with funding entirely from the former Torrens Catchment Water Management Board (now Adelaide and Mount Lofty Ranges Natural Resources Management Board).

Figure 13.7 Breakout Creek Wetland

The design of the wetland included detailed flood modelling to ensure there was no additional risk of flooding due to the works. Key features of the Breakout Creek instream wetland design are:

- A rock chute/weir at the downstream end to maintain a large pool of still water (deepest point 3 metres, approximate volume 20,000 cubic metres);
- Secured snags and partly submerged logs in the permanent water pool to provide habitat and refuge for fish and birds;
- Extensive landscaping including locally indigenous vegetation; and
- Walkways and access paths appropriate for the flood prone location.

The site is managed by the City of West Torrens. The instream wetland has provided improved water quality downstream, particularly under low flow conditions.

A second stage of the project is planned. This will extend from Henley Beach Road through to Tapleys Hill Road, a distance of approximately 700 metres.

Warriparinga Wetland, Bedford Park

Warriparinga Wetland is an offstream wetland located adjacent to the Sturt River, in Laffers Triangle between Main South Road, Sturt Road and Marion Road in Bedford Park. The objective of the project was to enhance Laffers Triangle, particularly the Warriparinga Reserve, and to improve the water quality of the Sturt River.

The wetland comprises a series of four ponds with shallow edges, gently grading to a depth of 3 metres at the centre. The permanent volume of the wetland is 23 megalitres. The water level fluctuates above the permanent water level when the Sturt River experiences a flow increase above its base flow. The second pond includes an island to act as a refuge for birdlife and to create visual interest to the wetland landscape.

The average annual flow entering the wetlands is 8400 megalitres.

Figure 13.8 Warriparinga Wetland with Inlet and Trash Rack in Background

Source: Planning SA (2005)

Water is drawn from the Sturt River upstream of an oxbow bend. The inlet was carefully designed to ensure existing significant eucalyptus trees in the area would not be affected by the wetland construction. Sufficient flows are maintained down the Sturt River channel adjacent to the wetland by means of a low flow bypass. This ensures that existing trees and reed beds in this section of the river are not affected by diversions into the wetland.

Water levels in the wetland remain close to full during the winter months. During summer, the level drops by 400 millimetres in an average year.

The outlet for the wetland is located on the western bank of the Sturt River, immediately upstream of the commencement of the concrete lined section of the channel and is formed as a rock riffle area. Within the wetland, a series of rock weirs are constructed to ensure flow is evenly distributed as it flows between the ponds.

The wetland traps and removes contaminants including silt, nutrients, bacteria, heavy metals, oils and floating rubbish such as leaves and litter. The wetland removes approximately 100 tonnes of sediment and 50 kilograms of phosphorus each year.

A timber boardwalk is located along the southern boundary of the site. The area around the wetland and the ponds themselves are planted and landscaped, with all plantings being indigenous. Twenty varieties of reeds and aquatic plants were placed in the ponds and have colonised the edges of the water bodies. More than 900 trees and scrubs were planted in the area around the wetland to create a natural landscape and provide habitat for birds and wildlife.

The wetland operates in conjunction with various gross pollutant removal and treatment facilities in the Sturt River catchment.

Urrbrae Wetland, City of Mitcham

The Urrbrae Wetland is located at Urrbrae Agricultural High School, Cross Road at Netherby.

In the early 1990s the City of Mitcham and the Urrbrae Agricultural High School were independently investigating a wetland project in the Urrbrae catchment. The council was seeking to alleviate a long standing flooding problem along Cross Road while the school was seeking to broaden its environmental studies curriculum, and address regular flooding on its farmland where the wetland is now situated.

A joint working party was created to prepare a concept plan for a teaching wetland which would also serve as a runoff detention basin.

Figure 13.9 Urrbrae Wetland

Work on the project commenced in June 1996.

Relevant facts about the project include:

- Urrbrae Agricultural High School and the City of Mitcham are joint operators of the wetland;
- Average annual volume of runoff treated is between 300-400 megalitres;
- The wetland was constructed in 1996 and first filled in 1997;
- Maximum depth of ponds is 3 metres;
- The ponds cover an area of 3 hectares; and
- The catchment area is approximately 3.75 square kilometres.

This unique urban wetland:

- Reduces the frequency of local flooding;
- Removes suspended solids by sedimentation;
- Physically filters runoff through dense reed beds;
- Removes pollutants such as agricultural fertilisers and other chemicals which attach to soil particles and are removed by sedimentation and filtration;
- Destroys pathogens through exposure to the ultraviolet rays of the sun and the feeding of zooplankton on pathogens;
- Filters out debris by operation of gross pollutants traps at the inlets;
- Improves the quality of water entering Brownhill Creek and ultimately the Patawalonga basin;
- Provides a valuable research and teaching resource for the school and community; and
- Creates a protected habitat for locally indigenous flora and fauna.

Since the initial construction of the wetland, modifications have been made to increase its performance. The first trash control systems installed at the wetland struggled to manage the amount of water and materials moving in the catchment. Water would often pour over the trash racks, taking much of the rubbish with it and also eroding the area around the racks.

After such events, quantities of organic material entered the wetland and moved through the catchment. Frequently the high velocities would carry sediments into the ponds.

To overcome these problems, work began in late 2003 on enlarging the inlet structures and installing more trash racks to improve collection of the organic litter and gross pollutants. To improve sediment capture, settling ponds external to the wetland proper were constructed at both of the inlets to the wetland.

To enable regular cleaning out of the sediment settling ponds, the flow of water is controlled at the point of entry from the street by the installation of drop log gates that can be slid down to bypass the ponds that are being worked on.

13.11 Useful Resources and Further Information

Fact Sheets

www.waterwatchadelaide.net.au/index.php?page=wetland-fact-sheets

Waterwatch Wetland fact sheets

www.goldcoast.qld.gov.au/attachment/wetlands_fact_sheet.pdf

Wetlands fact sheet (Gold Coast)

www.brisbane.qld.gov.au/bccwr/lib184/wsud%20practice%20note%2006%20constructed%20wetlands.pdf

Constructed Wetlands Practice Note (Brisbane)

Legislation Information

www.epa.sa.gov.au/pdfs/epwq_report.pdf

Environment Protection (Water Quality) Policy 2003

www.epa.sa.gov.au/pdfs/epp_noise_ind.pdf

Environment Protection (Industrial Noise) Policy 1994

www.epa.sa.gov.au/pdfs/info_construction.pdf

EPA information sheet on Construction Noise

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA information sheet on Environmental Noise

www.epa.sa.gov.au/pdfs/building_sites.pdf

EPA Handbook for Pollution Avoidance on Building Sites

www.epa.sa.gov.au/pdfs/bccop1.pdf

Stormwater Pollution Prevention Code of Practice for the Building and Construction Industry

Design Information

www.melbournewater.com.au/content/library/wsud/melbourne_water_wetland_design_guide.pdf

Constructed Wetland Systems Design Guide for Developers (Melbourne)

Modelling Information

www.goldcoast.qld.gov.au/attachment/music_modelling_guidelines.pdf

MUSIC Modelling Guidelines (Brisbane)

www.melbournewater.com.au/content/library/wsud/Guidelines_For_The_Use_Of_MUSIC.pdf

MUSIC Input Parameters (Melbourne)

General Information

www.cwmb.sa.gov.au/kwc/programs/why_wetlands/4.htm

Why Wetlands

www.dwlbc.sa.gov.au/urban/catchments/constructed_wetlands.html

Constructed Wetlands

www.environment.sa.gov.au/epa/pdfs/mosquitoes.pdf

Mosquitoes in Constructed Wetlands

www.arbovirus.health.nsw.gov.au/areas/arbovirus/mosquit/freshwet.htm

Freshwater Wetlands – Mosquito Production and Management

13.12 References

Department of Environment WA (2004). *Stormwater Management Manual for Western Australia*. Perth, Western Australia. http://portal.environment.wa.gov.au/portal/page?_pageid=55,1508622&_dad=portal&_schema=PORTAL.

Gold Coast City Council (2007). *Water Sensitive Urban Design Guidelines*. June. http://www.goldcoast.qld.gov.au/t_standard2.aspx?PID=6866.

Hobart City Council (2006). *Water Sensitive Urban Design Site Development Guidelines and Practice Notes.* Hobart. http://www.hobartcity.com.au/HCC/STANDARD/PC_1124.html.

Melbourne Water (2005). *Constructed Wetland Systems - Design Guidelines for Developers.* Melbourne, Victoria. http://www.melbournewater.com.au/content/library/wsud/melbourne_water_wetland_design_guide.pdf.

Planning SA (2005). *Guidelines for Urban Stormwater Management.* Adelaide, South Australia. http://dataserver.planning.sa.gov.au/publications/840p.pdf.

Wong, T. (1998). *Managing Urban Stormwater Using Constructed Wetlands.* Cooperative Research Centre for Catchment Hydrology. http://www.clearwater.asn.au/resources/302_1.pdf.

Appendix A
Checklists

Constructed Wetlands

Construction Inspection Checklist (During Construction)

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Constructed By:			
Weather:			

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
Preliminary works				
1. Erosion and sediment control plan adopted				
2. Limit public access				
3. Location same as plan				
4. Site protection from existing flows				
5. All required permits and approvals in place				
Earthworks				
6. Integrity of banks				
7. Batter slopes as plans				
8. Impervious (e.g. clay) base installed				
9. Maintenance access to whole wetland				
10. Compaction process as designed				
11. Placement of adequate topsoil				
12. Levels as designed for base, benches, banks and spillway (including freeboard)				

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
13. Check for groundwater intrusion				
14. Stabilisation				
Structural Components				
15. Location and levels of outlet as designed				
16. Safety protection provided				
17. Pipe joints and connections as designed				
18. Concrete and reinforcement as designed				
19. Inlets appropriately installed				
20. Inlet energy dissipation installed				
21. No seepage through banks				
22. Ensure spillway is level				
23. Provision of maintenance drain(s)				
24. Collar installed on pipes				
25. Low flow channel is adequate				
26. Protection of riser from debris				
27. Bypass channel stabilised				
28. Erosion protection at macrophyte outlet				
Vegetation				
29. Vegetation appropriate to zone (depth)				
30. Weed removal prior to planting				
31. Provision for water level control				
32. Vegetation layout and densities as designed				
33. Provision for bird protection				
34. Bypass channel vegetated				

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
Erosion and Sediment Control				
35. Disconnect inlet zone from macrophyte zone (flows via high bypass)				
36. Inlet zone to be used as sediment basin during construction				
37. Stabilisation immediately following earthworks and planting of terrestrial landscape around basin				
38. Silt fences and traffic control in place				
Operational Establishment				
39. Inlet zone desilted				
40. Inlet zone disconnection removed				
Comments on Inspection				
Actions Required				
1.				
2.				
3.				
4.				
5.				

Source: Gold Coast City Council (2007)

Constructed Wetlands

Construction Inspection Checklist (Final Inspection)

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Constructed By:			
Weather:			

Items Inspected	Checked		Satisfactory	
	Y	N	Y	N
1. Confirm levels of inlets and outlets				
2. Confirm structural element sizes				
3. Check batter slopes				
4. Vegetation planting as designed				
5. Erosion protection measures working				
6. Pre-treatment installed and operational				
7. Maintenance access provided				
8. Public safety adequate				
9. Check for uneven settling of banks				
10. Evidence of stagnant water, short circuiting or vegetation scouring				
11. Evidence of litter or excessive debris				
12. Provision of removed sediment drainage area				
13. Evidence of debris in high flow bypass				
14. Macrophyte outlet free of debris				

Comments on Inspection
Actions Required
1.
2.
3.
4.
5.
6.

Source: Gold Coast City Council (2007)

Constructed Wetlands

Maintenance Checklist

Asset ID:		**Date of Visit:**	
Inspection Frequency:		**Time of Visit:**	
Location:			
Description:			
Inspected By:			
Weather:			

Items Inspected	Checked		Action Required (Details)	
	Y	N	Y	N
1. Sediment accumulation at inflow points				
2. Litter within inlet or macrophyte zones				
3. Sediment within inlet zone requires removal (record depth, remove if >50%)				
4. Overflow structure integrity satisfactory				
5. Evidence of dumping (building waste, oils etc)				
6. Terrestrial vegetation condition satisfactory (density, weeds etc)				
7. Replanting required				
8. Settling of erosion of bunds/batters present				
9. Evidence of isolated shallow ponding				
10. Damage /vandalism to structures present				
11. Outlet structure free of debris				
12. Maintenance drain operational (check)				
13. Resetting of system required				

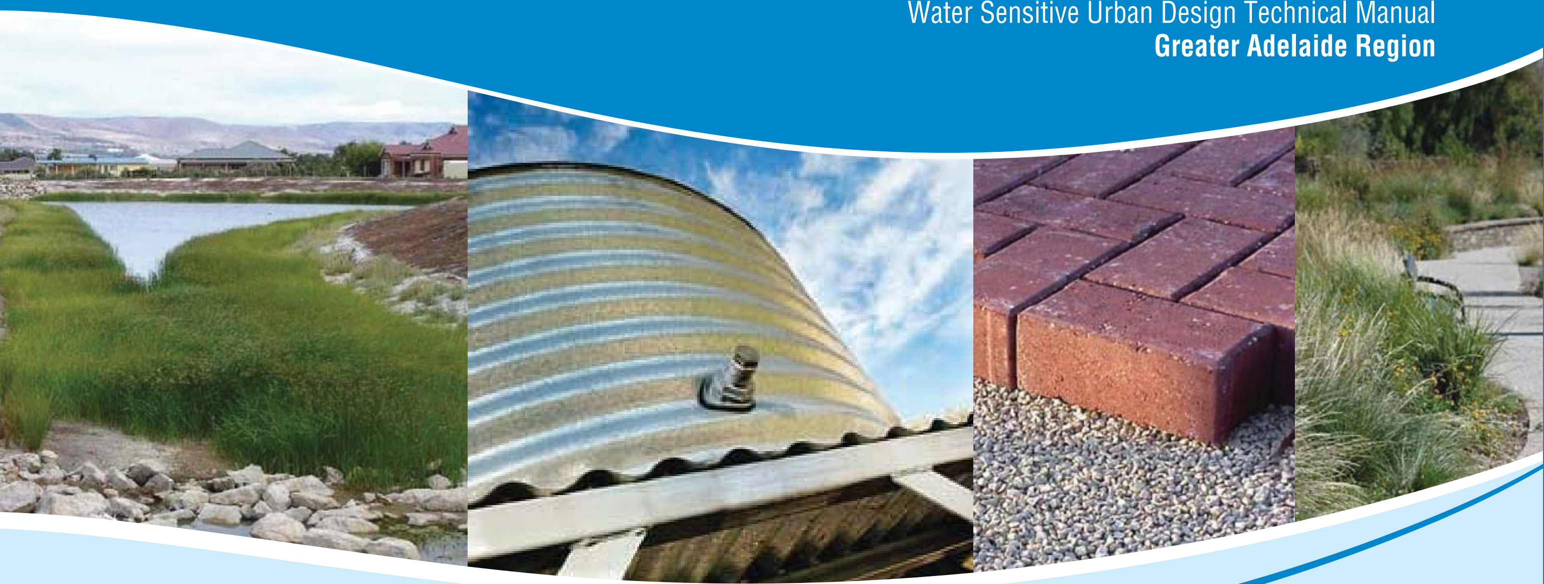
Comments on Inspection
Actions Required
1.
2.
3.
4.
5.
6.

July 2009

Chapter 14

Wastewater Management

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 14
Wastewater Management

14.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Wastewater management is one of those measures.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing a general overview of the benefits of wastewater management and how water quality and water quantity objectives can be met through treatment and reuse of wastewater on a site and community scale.

Other chapters of the Technical Manual for the Greater Adelaide Region to be read in conjunction with this chapter include:

- Introductory chapters (**Chapters 1-3**);
- Demand Reduction (**Chapter 4**);
- Urban Water Harvesting and Reuse (**Chapter 8**); and
- Modelling Process and Tools (**Chapter 15**).

On average, more than half of the mains water used in homes in the Greater Adelaide Region is returned to sewers as wastewater from toilets, showers, kitchens and washing machines. Added to this is wastewater from industrial, commercial and other sources. Over the last 5 years, on average about 95,000 megalitres of domestic wastewater was generated in the Greater Adelaide Region each year, of which around 75,000 megalitres of treated wastewater was discharged into Gulf St Vincent.

The Government plan, Water For Good (2009), will reduce the amount of wastewater generated by urban development in Greater Adelaide.

Already 30% of our treated wastewater is recycled each year for irrigation use, toilet flushing and garden watering. Wastewater reuse is expected to increase to nearly 45%, given a range of significant wastewater projects underway (Water For Good, 2009).

Description

There are two main types of domestic wastewater:

- Blackwater is wastewater containing, or likely to be contaminated by, human waste matter (e.g. toilet wastewater or waters contaminated by toilet wastewater); and
- Greywater is wastewater from the hand basin, shower, spa bath, washing machine, laundry tub, kitchen sink and dishwasher.

(It should be noted that water from the kitchen sink is generally too high in grease and oil to be reused successfully without significant treatment.)

A typical household discharges an average of approximately 35 litres of blackwater and 95 litres of greywater, per person per day. Typical greywater and wastewater quality is summarised in **Table 14.1**.

Table 14.1 Comparison of Greywater Quality and Wastewater

Parameter	Greywater	Wastewater
Thermotolerant coliforms (per 100 mL)	10^1 - 10^7	10^6 – 10^8
Suspended solids (mg/L)	2 – 1500	100 – 500
BOD (mg/L)	6 – 620	100 – 500
Nitrite	<0.1 – 4.9	1 – 10
Ammonia (mg/L)	0.06 – 25.4	10 – 30
Total kjeldahl nitrogen (mg/L)	0.06 – 50	20 – 80
Total phosphorus (mg/L)	0.04 – 42	5 – 30
pH	5.0 – 10.0	6.5 – 8.5

Source: Environment Protection and Heritage Council (2006)

Greywater may contain urine and faeces from nappy washing and showering, as well as kitchen scraps, soil, hair, detergents, cleaning products, personal care products, sunscreens, fats and oils. Cleaning products discharged in greywater can contain boron and phosphates, and the water is often alkaline and saline – all of which pose potential risks to the receiving environment. Greywater quality can be affected by inappropriate disposal of domestic wastes.

Treated wastewater (or recycled water) use describes the treatment of wastewater to a standard where it can be safely used (in a public health sense) within our community. The State Government agencies in South Australia with the primary responsibility for regulating reuse schemes are the Department of Health and the Environment Protection Authority. For further information see **Section 14.2**.

Wastewater Services

In the Greater Adelaide Region, there are two distinct areas of wastewater services – sewered and non-sewered areas.

SA Water is responsible for the provision of wastewater services in sewered areas, while some local councils provide wastewater services to most non-sewered areas (i.e. Community Wastewater Management Schemes (CWMS)).

Figure 14.1 Gumeracha Wastewater Treatment Plant

Source: Courtesy of Australian Water Environments

Sewered Areas

The conventional water management system in the Greater Adelaide Region consists of a large scale centralised water supply network and sewerage collection and treatment systems. Sewerage is treated at three major metropolitan coastal wastewater treatment plants (WWTPs) at Bolivar, Glenelg and Christies Beach, and several smaller WWTPs, including Hahndorf, Aldinga, and Gumeracha. Wastewater that is not reused is discharged from these plants to receiving waters (depending on the WWTP location, into river systems or directly into Gulf St Vincent).

The majority of the Greater Adelaide Region is serviced by a sewer system.

Non-sewered Areas

For the areas where a sewer system does not exist, the on-site treatment and reuse options include:

- Septic tanks and subsurface disposal systems with drainage trenches on individual properties;

- Septic tanks with a community wastewater management scheme (CWMS) collection system; and
- Aerobic treatment units with designated irrigation areas.

Composting toilets and greywater treatment systems are also options that are able to be utilised on site.

The Department of Health provides information regarding requirements and approval procedures for new applications, including a list of systems which are approved for use in the Greater Adelaide Region. Septic tank installations can be approved by the local council for that area.

In some cases, community scale WWTPs are provided by developers as part of the development. These are normally associated with larger land divisions in non-sewered areas, however they are also occurring in areas that are sewered. Treated wastewater is generally reused for community irrigation purposes with appropriate approvals. There is currently only one local example of treated wastewater being plumbed back in to dwellings for toilet flushing – Mawson Lakes in the City of Salisbury.

Purpose

On-site or community scale wastewater treatment and reuse has many economic and environmental benefits for the community.

In overall terms, sustainable water management is an important goal and a key element of sustainable urban development. Government authorities and the land development industry are increasingly seeking to use alternative sources, such as treated wastewater, to conserve drinking quality water supplies and minimise wastewater disposal (and associated contaminants) to the marine environment.

The Greater Adelaide Region has an extensive sewerage network, presently designed to transport water to large scale treatment plants. Rather than transport this water from the city, potential exists to reuse this water as a resource.

The reduction of wastewater discharged to reticulated sewerage systems by more efficient water use, greywater and wastewater reuse, and alternative toilet systems can produce significant economic and environmental advantages to the community. However, this needs to be balanced against potential health risk, as sewerage systems and safe drinking water supplies have had a larger positive impact on public health than any other intervention.

It is also possible that in some locations, properly managed and maintained decentralised reuse might be able to cost effectively augment or replace existing sewerage infrastructure that would otherwise need to be replaced or upgraded.

Scale and Application

The potential for treatment and reuse of wastewater will depend on:

- The scale and location of the development;
- The volume, quality and timing (i.e. seasonality) of wastewater generated; and
- The volume, quality and timing (i.e. seasonality) of treated wastewater demand.

For urban developments, treated wastewater is suitable (depending on the quality and utilising the precautionary approach) for:

- Toilet flushing;
- Public open space irrigation;
- Private garden irrigation/outdoor use;
- Environmental flows; and
- Ornamental water bodies integrated into the development.

In general, there is likely to be less overall risk where water is recycled to developments by a dedicated authority with ongoing capacity to properly manage, monitor and maintain the system. The Mawson Lakes development in the City of Salisbury is a good example of a centralised wastewater treatment with a third pipe system used to return treated wastewater to dwellings for reuse in toilets and for irrigation.

Scale and applications for blackwater and greywater treatment and reuse are discussed briefly below.

Blackwater

Options for treatment and reuse of blackwater are applicable to a range of scales including on-site, community and regional.

Methods of blackwater treatment and disposal include:

- A composting toilet or other type of blackwater treatment/disposal system (i.e. aerobic system) approved for installation in South Australia;
- A septic tank with effluent disposal by subsurface disposal or connection to a Community Wastewater Management Systems (CWMS) (formerly known as Septic Tank Effluent Disposal Systems (STEDS));
- Connection to a Community Wastewater Management Scheme (without a septic tank on the individual property); or

- Connection to an SA Water sewerage system or a private or council scheme.

The specific requirements are as stated in available reference material from the Department of Health (see **Section 14.8**).

The treatment system is generally required to (depending on the end use):

- Remove non-organic materials (e.g. toilet paper, hair etc);
- Remove suspended solids (SS) to defined levels (in South Australia less than 30 milligram/litre);
- Reduce BOD (Biological Oxygen Demand) to defined levels (in South Australia less than 20 milligram/litre); and
- Provide an acceptable level of disinfection – normally by chlorine tablets in domestic units, liquid chlorine dosing or UV systems in larger community units.

An alternative potential option is sewer mining. Sewer mining uses existing infrastructure for transport of household wastewater to a small treatment plant which abstracts and treats wastewater from the sewer at an appropriate location. Suitable locations have an appropriate end use nearby such as a park area, golf course or a building or development complex. Effective sewer mining matches required demand with available supply.

A range of treatment technologies can be employed for sewer mining including:

- Subsurface flow wetlands;
- Suspended growth systems (e.g. activated sludge systems);
- Fixed growth systems (e.g. trickle filters);
- Recirculating media filters (fixed film bioreactor);
- Sand and depth filtration;
- Membrane filtration (micro, ultra, nano filtration and reverse osmosis); and
- Membrane bioreactor.

This technology list is indicative only, with new technologies expected to become commercially viable as competition increases in the water market.

Appropriate applications for sewer mining are commercial high rise developments, where other potential water sources are limited (such as rainwater harvesting which is limited by the available roof catchment and storage space). Likewise, greywater production is limited by lack of showers in commercial buildings. Thus the sewer provides a consistent water resource and sewer mining can be a suitable treatment technology.

Greywater

Reuse of residential (and commercial) greywater (water from the laundry, bathroom taps and shower) along with industrial greywater (slightly polluted water which can be reused in manufacturing) can save significant quantities of drinking quality water and reduce the need for treatment of wastewater.

Greywater generation is essentially a regular continuous supply. The site needs to be capable of accommodating the annual greywater load as well as the seasonally distributed rainfall.

Greywater can be collected in an on-site system and distributed by gravity or a pump to underground (subsurface) lawn and garden watering. Alternatively, a greywater system can include a storage tank with treatment using various combinations of physical, chemical and biological processes that supplies greywater for toilet flushing and garden irrigation via a pump.

The systems listed below are referred to as alternative on-site wastewater systems. These are waste control/wastewater systems not covered under codes prescribed under the Public and Environmental Health Act (Waste Control) Regulations 1995. With individual assessment and approval these alternative on-site systems may be installed:

- Greywater/sullage systems (laundry, bath, wastewater, shower, kitchen etc);
- Reed bed systems; and
- Nutrient removal systems.

This document does not provide detailed information on the responsibilities of plumbers, installers or manufacturers of systems. Specific local, state (and federal) requirements exist for plumbers, installers and manufacturers of systems as defined in the relevant Department of Health Guidelines, the Australian Guidelines for Water Recycling and plumbing regulations.

14.2 Legislative Requirements and Approvals

Treatment and reuse of wastewater is subject to various requirements to meet defined wastewater quality, maintenance of systems and associated health issues.

Before developing a wastewater treatment and reuse system it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to wastewater reuse in your area.

The legislation which is most application to wastewater reuse in the Greater Adelaide Region includes:

- *Development Act 1993*;
- *Public and Environmental Health Act 1987*;
- *Environment Protection Act 1993*; and
- *Sewerage Act 1929.*

Development Act 1993

Installing a wastewater reuse system will generally be part of a larger development, however whenever a wastewater reuse system is planned, it is advised that the local council be contacted to determine whether development approval is required under the *Development Act 1993*.

Public and Environmental Health Act 1987

The Department of Health (Environmental Health Branch) is responsible for the implementation of the *Public and Environmental Health Act 1987* in South Australia. This agency provides information and assistance in establishing the requirements for installation of an on-site or community scale wastewater treatment system, whether black or greywater.

Installation of an on-site treatment system must take into account the Department of Health requirements for setback distances outlined in SAHC Code Waste Control Systems – Standard for Construction, Installation and Operation of Septic Tank Systems in South Australia and Supplement B – Aerobic Wastewater Treatment Systems (see **Section 14.8**).

Where it is intended to install a greywater treatment/diversion system in a sewered (or other reticulated system) area, approval must be obtained from the owner/operator of the system (i.e. SA Water for the majority of cases in the Greater Adelaide Region).

Permanent greywater systems such as diversion devices or treatment systems require installation approval from council or the Department of Health and all systems must be installed by a licensed plumber.

It is to be noted that the new On-site Wastewater Systems Code, presently in draft form, will be implemented late in 2008. This code will stipulate that all on-site wastewater related approvals for black and grey water will be addressed by the relevant local council (subject to some conditions and only up to 50 equivalent persons (EP)).

The Department of Health will assess and approve new treatment systems/devices for both classes of wastewater. This process involves:

- Engineering assessment of submission;
- Assessing compliance with relevant Australian Standard(s); and
- Preparation of Approval Conditions.

The unit can then be installed in accordance with manufacturer's specifications and conditions of approval.

Environment Protection Act 1993

Any development, including the installation of a wastewater reuse scheme, has the potential for environmental impact. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on a site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when planning on installing a wastewater reuse scheme are discussed below.

Water Quality

Water quality in South Australia is protected using the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development.

In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, construction sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise potential for environmental impact during construction of a wastewater reuse scheme.

The Environment Protection (Water Quality Policy) 2003 establishes thresholds above which it is an offence to discharge wastewaters to a water resource. This policy provides the legislative controls (*Environment Protection Act 1993*) to bring about improvements in the management of wastewaters, of which one method is the application of wastewater to a beneficial use.

The South Australian Reclaimed Water Guidelines (Environment Protection Authority South Australia 1999) describe methods by which reclaimed water can be used in a sustainable manner without imposing undue risks to public health or the environment.

The Australian Guidelines for Water Recycling (Environment Protection and Heritage Council 2006) are intended to replace the Reclaimed Water Guidelines and are now the primary reference for assessment of all reclaimed water/recycling projects.

Noise

The issue of noise has the potential to cause nuisance during any construction works and ongoing operation of wastewater reuse schemes. The noise level at the nearest sensitive receiver (which may be the nearest allotment for residential development purposes) should be at least 5 dB(A) below the Environment Protection (Industrial Noise) Policy 1994 allowable noise level when measured and adjusted in accordance with that policy. Reference should be made to the EPA Information Sheets on Construction Noise and Environmental Noise respectively to assist in complying with this policy (see **Section 14.9**).

Odour

The operation and maintenance of wastewater treatment and reuse schemes must be able to demonstrate that they will not cause significant adverse environmental impact or nuisance (e.g. odours).

Reference should be made to the EPA Guidelines for Separation Distances (see **Section 14.9**).

Licences

The EPA licenses wastewater treatment schemes that serve more than 1000 EP (equivalent persons) or 100 EP where the scheme is intended to operate in a sensitive environment. Advice on such large schemes should be sought from the Environment Protection Authority early in project development.

Sewerage Act 1929

SA Water administers the South Australian *Sewerage Act 1929* which is applicable to areas where there is a government sewerage system available. These areas are known as proclaimed drainage areas.

Areas where an SA Water sewerage system is not available are the responsibility of the local government authority and/or the Department of Health.

Section 36 of the *Sewerage Act 1929* provides for an exemption from the requirement to discharge to the sewerage system from a property. The Act allows for the exemption to be granted by SA Water and is used when application is made for the installation of a permanent greywater diversion system.

Exemption may be granted by SA Water in cases when they are satisfied that the proposal does not compromise the sewerage or drinking water systems.

In all cases within sewered areas, SA Water is to be contacted if on-site reuse is planned, particularly if seasonal (winter) discharges to sewer will/may be required.

In existing urban areas of the Greater Adelaide Region, each allotment generally has access to the sewerage system. A new home (single lot) development simply requires an application to SA Water for approval to connect to the system.

In the case of a larger land division (multiple lots) the process is the same with SA Water assessing the impacts of the hydraulic and organic loadings on the existing system. In general, the system will be able to handle the increases but if upgrading is necessary, the developer will be required to contribute to the required headworks.

For further information see www.sawater.com.au

National Guidelines and Standards

Any wastewater reuse projects will need to be undertaken in accordance with the Australian Guidelines for Water Recycling (Environment Protection and Heritage Council 2006). The guidelines include a risk-based approach to the reuse and recycling of wastewater and greywater from large scale centralised treatment facilities. Specific guidance is provided in Phase one for use of recycled water from centralised sewerage and greywater systems, and decentralised grey water. Phase two deals with stormwater, managed aquifer recharge (MAR) and drinking water augmentation.

Standards which are applicable to on-site wastewater management include:

- Standards Australia (1994). AS1547: Disposal Systems for Effluent from Domestic Premises, Standards Australia, Homebush, NSW;
- Standards Australia (1998). AS/NZS 1546: On-site Domestic Wastewater Treatment Units. Standards Australia, Homebush, NSW;

- Standards Australia (1994). AS/NZS 1319: Safety Signs for the Occupational Environment;
- Standards Australia (1996). AS/NZS 2700: Colour Standards for General Purposes; and
- Standards Australia (2003). AS/NZS 3500.1: Plumbing and Drainage – Water Services.

14.3 Design Considerations

When considering opportunities to develop treated wastewater reuse schemes, the interaction with the built environment and past investments should be taken into account. A sustainable approach aims to optimise the community's past investments with future requirements to deliver ecologically sustainable solutions. The ideal approach is to transfer investment from water transportation to the treatment, creating a useful resource.

Wastewater reuse schemes should only be considered when environmental and health concerns can be adequately addressed through design and realistic operation and maintenance regimes.

A number of the design considerations for wastewater reuse schemes include:

- Demand pattern and demand management;
- Infrastructure;
- Social and human health;
- Evaluation of the impact on the natural environment;
- Greenhouse gas emissions; and
- Sludge disposal.

The following sections provide an overview of the key design issues that should be considered when conceptualising and designing a wastewater reuse scheme.

Demand Pattern and Demand Management

A key consideration is the intended use of the treated wastewater and the associated demand profile for that application. For example, if the intended use is irrigation, less water will be required during the winter months.

Demand management is an important measure to reduce water consumption. Typically this applies to mains water but it also applies to reused water. A frequent misconception is that reused water is an inferior product that is cheaper and in plentiful supply. In fact, reused water is a high quality resource and should be considered as such.

To upgrade water quality, treatment is usually required. This process requires energy to remove pollutants. The reused water may then need to be pumped to the end user. By minimising consumption of reused water, energy is also minimised, ensuring a more efficient and sustainable water supply system.

Typical demand management strategies include the installation of water efficient taps and fittings (e.g. 6/3 litre dual flush toilets). These are cost effective and sustainable ways of minimising resource consumption. Further information on demand management can be found in **Chapter 4** of the Technical Manual.

Infrastructure

New developments will increase the demands on the existing water supply and wastewater collection, treatment and disposal infrastructure:

- Infill developments will increase the population density in that immediate area; and
- New land development areas will increase the overall population required to be serviced.

Sufficient capacity is required for conveyance of wastewater from the development site to the centralised or local treatment facilities. Typically, the surrounding infrastructure may need to be upgraded to accommodate this population growth.

The capacity of the existing infrastructure should therefore be considered for any development or redevelopment.

Social and Human Health Considerations

Treated wastewater is a safe and reliable alternative water source for our community as long as the use meets the requirements of the relevant codes and standards, particularly the Australian Guidelines for Water Recycling which are framed around a risk management approach.

Reliable treatment is essential to ensure health risks are minimised. Human risks from the use of treated wastewater are primarily associated with exposure to pathogenic microorganisms causing illness, in extreme cases possibly death. Pathogenic organisms can be discharged into waterways by humans and are typically in high concentrations in wastewater.

Adequate treatment is required to reduce pathogens with a risk based approach defining the water quality requirements for end uses. Generally a higher water quality is required as potential human exposure increases.

Guidelines and targets have been specified by regulatory authorities on national and state levels for water quality, receiving water body quality and a range of water reuse applications.

The social acceptance of water reuse is also an important consideration for urban development.

Public concerns regarding the use of treated wastewater may include:

- Perceived health risks;
- 'Yuck factor' or disgust of reusing water that once contained waste;
- Specific applications of treated wastewater;
- Source of water to be reused;

- Trust and knowledge;
- Attitudes about the environment; and
- Cost of treated wastewater.

The concept of treated wastewater reuse is becoming more widely accepted by the community for most applications including toilet flushing and outdoor use (garden irrigation and car washing). The current prolonged drought has increased community awareness of alternative water sources.

Figure 14.2 Treated Wastewater from the Hahndorf WWTP Utilised at The Cedars

Source: Courtesy of Australian Water Environments

In general, people are comfortable with reusing treated wastewater when the end use is not directly ingested. Community acceptance reduces as and when treated wastewater use comes closer to human contact or ingestion, for example, for use in the laundry for clothes washing.

The following approach can assist in gaining approval and social acceptance of a treated wastewater reuse scheme:

- Adopt a risk based approach to defining methods of delivery and corresponding water quality requirements as defined in the Australian Guidelines for Water Recycling;
- Define requirements for pre-commissioning monitoring and demonstration of compliance to current health standards for reused water; and
- Identify community receptiveness to different applications of reused water.

Evaluation of the Impact on the Natural Environment

Selection of wastewater treatment technologies must consider the broader environmental impact. The interaction between the wastewater treatment technology to the aquatic environment, land capability, greenhouse gas emissions and solids management is a key part of the decision making process.

Treated wastewater can have several associated environmental risks. These are site-specific and dependent on the topography, geography and location associated with specific water treatment technology and water end use. Key risks to the environment include:

- Impact on the aquatic environment (or receiving water body) (i.e. eutrophication);
- Impact on the land primarily from irrigation (i.e. waterlogging and impact on the soil and plant toxicity);
- Nutrient imbalance which may result in plant deficiencies and toxicities;
- Loss of biodiversity from mortality of native biota;
- Production of greenhouse gases; and
- Production of biosolids and other wastes.

Treated wastewater in urban settings can provide water for irrigation. The suitability of treated wastewater to specific environmental conditions depends on soil conditions, site topography and geology. The risks associated with applying reused water for land irrigation (both rural and urban) include:

- Elevated nutrient levels leading to eutrophication of water surface waters and soils;
- Elevated salinity levels which may cause corrosion of assets;
- Elevated chlorine disinfection residuals which can be toxic to plants;
- Elevated boron levels; and
- Excessive sodicity (soil with excessive exchangeable sodium (> 6%), leading to poor soil structure).

Increased salinity from using treated wastewater for irrigation has the potential to impede plant growth and degrade soil conditions. Soil sodicity due to the high presence of sodium ions relative to magnesium and calcium ions can also degrade the soil structure.

Increased nutrient levels will also be present in treated wastewater. The urban environment with an adjusted botanical landscape (from pre-development conditions) may benefit from the increased nutrient loading. Proper management is required to ensure minimal nutrients excretion to the groundwater, thereby protecting the groundwater quality.

Greenhouse Gas Emissions

A combination of factors determines greenhouse gas emissions including:

- The type of water treatment and its energy consumption;
- Organic loading in wastewater; and
- Transportation – energy requirements for reticulation.

The potential generation of greenhouse gas emissions from treating wastewater can be calculated. It is recommended that greenhouse gas emissions be incorporated into the final evaluation process for wastewater treatment and reuse technology selection.

On-site abatement of greenhouse gas emissions may not always be possible. To mitigate greenhouse gas emissions an option is off-site abatement.

Sludge Disposal

Wastewater contains solids, known as biosolids or sludge, which requires disposal. The site boundary and surrounding infrastructure determine the options for sludge disposal. Disposal options include through the conventional sewer system or by dedicated sludge processing facilities. Processed biosolids are used in compost and as soil additives.

14.4 Design Process

Overview

There is a range of scales and types of wastewater treatment and reuse schemes. The type of scheme can vary from a greywater diversion hose in a household yard for garden irrigation to a community scale dual reticulation system using tertiary treated wastewater. The scope and degree of complexity is dependent on the individual system.

The greater the treatment requirements, the more complex the treatment component and the more involved the monitoring and management systems will need to be.

The context of the system will influence the nature of the planning and design process.

The key steps in the design process for a wastewater treatment and reuse scheme include:

- Assess the site, catchment and appropriate regulatory requirements;
- Identify the objectives and targets;
- Undertake a water balance;
- Identify the potential options;
- Consult with key stakeholders and relevant authorities;
- Evaluate options;
- Undertake detailed design of selected option;
- Check the design objectives; and
- Develop a maintenance and monitoring plan.

The design process is likely to be iterative, requiring several rounds of review in the earlier stages as new information becomes available and negotiations progress with stakeholders that may alter the objectives and/or available options.

Detailed wastewater reuse systems design information is contained in various publications (see **Section 14.8**). However, a number of elements of the design process are discussed briefly below.

General information on the design process can be obtained in **Chapter 3** of the Technical Manual.

Assess Site, Catchment and Appropriate Regulatory Requirements

WSUD responds to site conditions and land capability and cannot be applied in a standard way. Careful assessment and interpretation of site conditions is therefore a fundamental part of designing a development that effectively incorporates WSUD.

To understand the drivers and appropriate end uses for the treated wastewater, an understanding of the development and the environment is required. This step identifies and assesses the potential constraints and opportunities of the proposed project site.

Development characteristics and location influence viable options for wastewater reuse. The factors influencing water reuse viability include:

- Size (equivalent tenancy, occupancy);
- Development density (subdivision, medium density, high rise);
- Development type (greenfield, brownfield, retrofit, infill for residential or commercial);
- Public open space requiring irrigation; and
- Integration with the surrounding environment.

Constraints for the wastewater reuse scheme must be identified and considered. In the Greater Adelaide Region, these constraints may include (depending on the intended form of reuse):

- Land availability, including future land use plans;
- Geology and soil properties;
- Depth to groundwater table or confining layers (e.g. bedrock);
- Topography (e.g. very flat or steep site);
- Site specific constraints (e.g. environmental, conservation and heritage issues, neighbouring land uses);
- Location and type of existing vegetation;
- Location of service infrastructure (e.g. roads, sewerage, scheme water and gas pipelines, and telephone and power lines);
- End use of the treated water (e.g. delivery into downstream waterways or reuse as irrigation water); and
- Availability of potential users of wastewater.

In particular, the proximity of the proposed wastewater reuse scheme to residential areas needs to be considered in the selection and design of this WSUD measure (see EPA's Guidelines for Separation Distances).

Neighbouring communities will need to be consulted on the appearance, functionality and role of the wastewater reuse scheme where appropriate (i.e. when above ground storage is involved). There are also safety concerns where the treated wastewater is utilised in a publicly accessible area.

The level of site and catchment investigation required should match the size and scale of the development and its potential impacts (i.e. larger developments having a greater impact would require greater site investigations).

A staged approach to site investigations can be adopted to minimise costs. This involves an initial screening level assessment using readily available information to identify major constraints and opportunities, then focusing efforts on any identified constraints.

For example, if the treated wastewater is intended to be used for irrigation, the proponents may be required to undertake a soil test to determine the capability of the soil to ensure that treated wastewater will not pool, or runoff irrigated areas. In addition, a soil assessment will assist in selecting vegetation types that will be suitable for the soil type and enhance treated wastewater absorption.

Identify Objectives and Targets

Design objectives and targets will vary from one location to another and will depend on site characteristics, development form and the requirements of the receiving ecosystems. It is essential that these objectives are established as part of the conceptual design process and discussed with the relevant council prior to commencing the engineering design.

Objectives include environmental benefits (such as water quality improvement, water conservation, detention and erosion control), habitat value (enhancing biodiversity and conservation) and/or aesthetic and recreational values.

Undertake a Water Balance

To estimate water requirements, a water balance can be undertaken to:

- Align recycled water uses with available water sources (including rainwater, stormwater, drinking water) on a fit-for-purpose basis;
- Assess water demands with an end-use analysis; and
- Align the demand profile with the supply profile.

The water balance provides a starting point to assess the viability of reusing water to complement other available water sources i.e. drinking water, rainwater harvesting and conventional large scale water management approaches. The availability of reused water is dependent on a combination of:

- The site boundary;
- Operation scale;
- Potential water resource (e.g. sewer carrier);
- Treatment capacity (average and peak flows);
- Treatment reliability; and
- On-site storage.

An end-use water approach should be utilised for the water balance. An end-use model enables specific water uses to be matched to appropriate water sources on a fit-for-purpose basis and calculates the water demand for each use. Relating water demands to specific activities and end uses provides a greater understanding of the demands on water services. The focus shifts from supplying a finite amount of water to the provision of appropriate and sustainable urban water services (including wastewater and stormwater management services). Within this framework, wastewater reuse opportunities are identified and quantified.

Quantifying wastewater reuse indicates the average wastewater reuse flow rate required and thus the operational scale. Operational scale provides a first assessment in the selection of viable wastewater reuse technologies. Commercially available wastewater treatment technologies have a defined operational scale.

The demand profile influences the technology selection. The sizing and selection of water treatment technologies must cater for peak as well as average demands. For example, water supplied for toilet flushing has a fairly constant demand throughout the year, whereas irrigation requirements fluctuate with seasonal requirements, peaking in the summer months. Satisfying peak demands requires a technology that can respond rapidly or provide adequate storage to buffer against fluctuating water demands.

Physical treatment systems are particularly well suited to meeting fluctuating demands by being able to respond quickly.

Biological systems require a greater lag time to respond to changing water demands, and often require storage volumes to cater for daily and seasonal variations in demands. Storages such as tanks, dams, wetlands and aquifers provide a buffer. This enables reused water to be processed at a constant rate despite variable water demand. The storage requirements can be high, especially to meet seasonal variations in water demands. In some such cases, it may be more sustainable to provide reused water for a base load and have this supplemented by other water sources during periods of high water demands.

Storage requirements must be considered in the evaluation, and sufficient land allocated during the masterplanning phase. Tanks can be incorporated into buildings, underground or within public open spaces. Managed aquifer recharge (MAR) is another viable option depending on the level of treatment of the wastewater and the suitability of the aquifer.

Often, ornamental water bodies and wetlands are also considered for on-site storage. The key factors in the evaluation of water bodies are:

- Nutrient loads from reused water;
- Appropriate algal management strategies to prevent algal blooms; and
- Draw down of water bodies impacting on aesthetics (typically the highest demand for water occurs during summer periods when evaporation rates are the greatest, exacerbating the water body draw down).

Select Appropriate Wastewater Management System

This step identifies various possible layouts for a scheme to meet its objectives. Each treatment train and associated technology option should be evaluated on a case-by-case basis.

Technology selection is dependent on several criteria including:

- Scale of the development (including site characteristics);
- How the water will be used and demand profile;
- Water quality and quantity before treatment;
- The quality and quantity of water needed following treatment;
- Available space for treatment and storage;
- Surrounding infrastructure;
- Social and human health considerations;
- Economic considerations, including life cycle costs;
- Other environmental objectives (e.g. greenhouse gas emissions, land capability, receiving water bodies);
- Climatic conditions;
- Operating and maintenance; and
- Ongoing ownership of the treatment system.

As stated above, there are various treatment technologies that can be selected depending on the scale and application of the scheme. Reference to the Department of Health approved unit register is recommended for on-site domestic or small community installations.

For single households, simple greywater reuse systems are preferable (in general). Larger systems are more appropriate for larger scale applications with associated management and maintenance.

Identify and Consult with Key Stakeholders

The designer (or applicant) should liaise with civil designers and council officers prior to proceeding any further to ensure:

- The wastewater reuse scheme will not have an adverse impact on existing services or structures;
- Access for maintenance to existing services is maintained;
- No conflicts arise between the location of services and WSUD devices; and
- The objectives and targets are consistent with council directions stated in documents such as strategic plans and stormwater management plans.

The council will also be able to advise whether:

- Development approval is required, and what information should be provided with the development application;
- Any other approving authorities should be consulted (e.g. SA Water, EPA, DoH); and
- Any specific council requirements need to be taken into consideration.

Land and asset ownership issues are key considerations prior to construction of a WSUD measure (including wastewater treatment systems). A proposed design should clearly identify the asset owner and who is responsible for maintenance and this aspect should also be discussed during a meeting with the local council.

If on-site treatment and reuse is proposed, two aspects require consideration by the proponent:

- If all wastewater can be reused on site all year round then the local council only need be consulted in project development stages; and
- If seasonal (winter) discharge to sewer is proposed, then approval of both SA Water and local council will be required.

Key stakeholders should also be consulted throughout the planning process (depending on the scale of the scheme), particularly during the setting of project objectives. Their engagement in the development of large scale schemes from the planning stage will:

- Allow for any concerns or misconceptions to be identified and addressed early in the process; and
- Provide opportunities for educating and informing the community and build user confidence in the scheme.

The key stakeholders will depend on the nature and location of the scheme.

Evaluate Options

Conventional evaluation of treatment technologies compares technical viability and cost effectiveness. The type of methodology for assessment depends on the scale of the development, but a simple cost-benefit analysis may not adequately assess the breadth of issues for considering wastewater reuse alternatives. Site characteristics, an integrated water management perspective and 'externalities' such as downstream infrastructure interactions and the impact on the natural environment should also be taken into account.

The selection of appropriate, sustainable and suitable water treatment technologies is dependent on economic, environmental and social considerations.

Detailed Design of Selected Option

During the detailed design of the selected scheme, a risk management strategy should be developed. This should, in particular, identify public health and environmental hazards and an appropriate mix of controls to be implemented during the design and operational phases.

14.5 Design Tools

Several design tools are available for the concept and detailed design of wastewater reuse schemes as detailed in **Chapter 15**.

The modelling tools which are able to assist include:

- MUSIC;
- WaterCress; and
- E2.

The local council will be able to advise whether modelling is required as part of the development application process.

14.6 Maintenance Requirements

Adequate maintenance of wastewater treatment and reuse schemes is important to ensure that the scheme continues to meet its design objectives in the long-term and does not present public health or environmental risks.

Each wastewater treatment system will have its own maintenance requirements with manufacturers and suppliers able to provide relevant maintenance regimes. A risk management plan is also required.

Adequate provision for downtime, such as scheduled maintenance, should be accounted for. For example, the greywater plumbing should be connected to the mains sewer, enabling immediate diversion and greywater disposal and provision for drinking (or mains) water to be temporarily used for toilet flushing.

All maintenance should be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design procedure. Maintenance personnel and asset managers (or the building owner) will use this plan to ensure the wastewater reuse scheme continues to function as designed. To ensure maintenance activities are appropriate for the scheme as it develops, maintenance plans should be updated a minimum of every three years.

The maintenance plans and forms should address the following:

- Inspection frequency;
- Maintenance frequency;
- Data collection/storage requirements (i.e. during inspections);
- Detailed clean-out procedures including:
  - Equipment needs
  - Maintenance techniques
  - Occupational health and safety
  - Public safety
  - Environmental management considerations
  - Disposal requirements (of material removed)
  - Access issues
  - Stakeholder notification requirements
  - Data collection requirements (if any)
  - Design details.

More complex designs with mechanical devices, such as valves or pumps, may require much more detailed maintenance plans, including manufacturers' maintenance recommendations.

For example, membrane filtration processes will require regular membrane cleaning either chemically or physically, with eventual membrane replacement. Operation can be affected by the variable wastewater quality which can potentially harm the system, for example a peak caustic load in the sewer from an industrial customer.

To determine whether the wastewater treatment process is performing as expected, a monitoring program detailing the water quality of inflow and outflow is recommended.

The recommended maintenance for a greywater treatment system is contained in **Appendix A**.

14.7 Approximate Costing

Due to the variability in the scale and type of wastewater treatment and reuse schemes, it is difficult to provide an indication of costs of construction and operation of such schemes. Local data should be obtained, wherever possible, when considering the design of a wastewater treatment and reuse scheme.

Life cycle provides an important economic indicator for the selection of wastewater treatment technologies. Life cycle costing enables the consideration of all costs including the capital expenditure, operating costs and ongoing replacement costs to be considered. The key components to a life cycle costing evaluation are:

- Capital expenditure;
- Ongoing maintenance and labour costs;
- Replacement costs and timing for significant expenditure;
- Life span; and
- Decommissioning costs.

As wastewater treatment and reuse technologies and their commercialisation are developing quickly, costs are expected to decrease.

14.8 Case Studies

Overview

There are many examples of wastewater treatment and reuse schemes in the Greater Adelaide Region including:

- The City of Holdfast Bay, where a small amount of treated wastewater from the Glenelg Wastewater Treatment Plant is used for reserve irrigation, Adelaide Airport, Adelaide Shores and a number of other sites;
- Onkaparinga Council (McLaren Vale and McLaren Flat), where treated wastewater is used to irrigate vineyards in McLaren Vale;
- City of West Torrens uses about 4 megalitres/year on the Adelaide Airport grounds plus 20-30 megalitres/year on the university sports playing fields; and
- City of Port Adelaide Enfield, where several industries are using treated wastewater for landscape irrigation.

The wastewater treatment and reuse schemes at Mawson Lakes and Laratinga Wetland are described briefly below.

Mawson Lakes, City of Salisbury

Mawson Lakes is a world-class third pipe greenfields development 12 km from Adelaide which has approximately 2000 residents and is expected to have over 10,000 residents by 2010. The scheme is innovative from both energy conservation and water perspectives. Mawson Lakes has been developed by a consortium of Delfin Lend Lease and the SA Government in cooperation with the City of Salisbury.

Residents have agreed to live there with the understanding that they have to use recycled water in their toilets and outside in the garden through a dual water supply system. Construction of this greenfields suburb began in 1997.

The recycled water is delivered through lilac taps (and a water meter) and these have been installed on all properties.

The supply of reclaimed water is achieved by treating wastewater from the Mawson Lakes community at the Bolivar WWTP and returning the reclaimed wastewater to mix with recycled stormwater from Parafield Wetlands in a mixing tank at Greenfields. The reclaimed water is then pumped back to the Mawson Lakes development. This whole system is called the Mawson Lakes Reclaimed Water Scheme.

This scheme reduces the environmental impact by reclaiming wastewater from the Bolivar WWTP and stormwater from the Dry Creek Catchment.

Laratinga Wetland, District Council of Mt Barker

Figure 14.3 Laratinga Wetland

The Laratinga Wetland, constructed in 1999, is a District Council of Mount Barker development, located in Mount Barker in the Adelaide Hills.

The main function of the wetland is to filter 'A class' water from the nearby wastewater treatment plant.

Wastewater from Littlehampton and Mount Barker is treated at this plant. With a growing population, the disposal of this treated water became a concern to council in 1993. For many years the treated water flowed into the Mount Barker Creek, and the impact on the ecology of the creek was becoming an issue. Upgrading of the treatment plant in the late 1990s included plans to build the large artificial wetland to filter the water further and reuse it for local irrigators, parks and gardens. Wastewater from nearby Nairne is now being pumped to the wastewater treatment plant and through the wetland, bypassing the Nairne oxidation lagoons, which is benefitting the health of the Nairne Creek. The improvements to the wastewater treatment plant, including the wetland, cost approximately $5 million.

The wetland has taken several years to resemble a natural ecosystem. Landscaping design with the use of indigenous plant species has encouraged birds to utilise the wetland.

Location: Corner of Springs Rd and Bald Hills Rd, Mount Barker

Elevation: 310 metres

Area: Total area of 16.7 hectares (10.7 hectares under water)

Wetland type: Storage basin/sedimentary pond to remove excess nutrients from the 'A class' water being released from the wastewater ponds.

14.9 Useful Resources and Further Information

Fact Sheets

http://cweb.salisbury.sa.gov.au/manifest/servlet/binaries?img=4044&stypen=html

Mawson Lakes Recycled Water Scheme fact sheet

www.dh.sa.gov.au/pehs/branches/wastewater/greywater-manual-bucketing-jan07.pdf

Department of Health Manual Bucketing fact sheet

www.waterforgood.sa.gov.au

Water For Good fact sheets

www.dwlbc.sa.gov.au/assets/files/fs5_asr_in_sa.pdf

ASR in South Australia (DWLBC)

www.deus.nsw.gov.au/Publications/dwe_greywater_factsheet_1.pdf

Greywater Fact Sheet 1 – Greywater Diversion Do's and Don'ts (NSW)

www.deus.nsw.gov.au/Publications/dwe_greywater_factsheet_2.pdf

Greywater Fact Sheet 2 – Choosing the Right Greywater System for Your Needs (NSW)

www.deus.nsw.gov.au/Publications/dwe_greywater_factsheet_3.pdf

Greywater Fact Sheet 3 – Irrigating with Greywater (NSW)

www.deus.nsw.gov.au/Publications/dwe_greywater_factsheet_4.pdf

Greywater Fact Sheet 4 – Keeping your Plants and Soils Healthy with Greywater (NSW)

www.deus.nsw.gov.au/Publications/dwe_greywater_factsheet_5.pdf

Greywater Fact Sheet 5 – Maintenance of Greywater Diversion Devices and Treatment Systems (NSW)

www.savethemurray.com/pdfs/WaterWise_LawnA3Final.pdf

WaterWise for Your Lawn … information sheet

Regulations and Legislation

www.dh.sa.gov.au/pehs/branches/wastewater/greywater-general-nov06.pdf

Department of Health Installation of Permanent On-site Domestic Greywater Systems www.dh.sa.gov.au/pehs/branches/wastewater/alt-onsite-ww-appform.pdf

Department of Health Application for Alternative On-Site Wastewater / Waste Control System Installation

www.health.sa.gov.au/PEHS/publications/Septic-tank-book.pdf

Department of Health Standard for the Construction, Installation and Operation of Septic Tank Systems in South Australia

www.sawater.com.au/NR/rdonlyres/7F6C9876-A17D-442F-9FA2-1DB007AA4729/0/greywater_factsheet.pdf

SA Water Greywater Guidelines Information Sheet

www.sawater.com.au/NR/rdonlyres/BB0228AF-6229-4997-AD09-7BC0F866CB42/0/Installationofgreywatersysteminseweredarea.pdf

SA Water Installation of a Greywater System in a Sewered Area

www.epa.sa.gov.au/pdfs/sepguidepcd.pdf

EPA Guidelines for Separation Distances

www.epa.sa.gov.au/pdfs/cop_aquifer.pdf

Code of Practice for Aquifer Storage and Recovery, EPA

www.epa.sa.gov.au/pdfs/guide_wws.pdf

Water and Wastewater Sampling Guideline, EPA

www.epa.sa.gov.au/pdfs/reclaimed.pdf

South Australian Reclaimed Water Guidelines

www.epa.sa.gov.au/pdfs/guide_lagoon.pdf

Wastewater and Evaporation Lagoon Construction Guideline

www.epa.sa.gov.au/pdfs/epp_noise_ind.pdf

Environment Protection (Industrial Noise) Policy 1994

www.epa.sa.gov.au/pdfs/info_construction.pdf

EPA Information Sheet on Construction Noise

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA Information Sheet on Environmental Noise

www.epa.sa.gov.au/pdfs/building_sites.pdf

EPA Handbook for Pollution Avoidance on Building Sites

http://dataserver.planning.sa.gov.au/publications/654p.pdf

Guide for Applicants, Planning SA

Products and Manufacturers

www.dh.sa.gov.au/pehs/branches/wastewater/071023-wwproducts-greywater.pdf

Department of Health Approved Greywater Diversion and Treatment Systems for Marketing, Sale & Installation in South Australia

www.watermark.standards.org.au

WaterMark

www.greywatersaver.com

Greywater diverter

www.everwater.com.au

Everwater

www.hrproducts.com.au

HR Products

www.newwater.com.au

New Water

www.nylexwater.com.au

Nylex Water

www.plasticplumbing.com.au

Plastic Plumbing

www.greenplumbers.com.au

Green Plumbers

General Information

www.sawater.com.au/NR/rdonlyres/04C0CB50-30AF-4A64-A902-020DBBD37F43/0/Recyledwaterplumbingguide.pdf

SA Water Recycled Water Plumbing Guide

www.lga.sa.gov.au/site/page.cfm?u=253

Community Wastewater Management Schemes Information

www.greenhouse.gov.au

Australian Greenhouse Office

www.lanfaxlabs.com.au

Review of detergents

www.dbce.csiro.au/urbanwater

CSIRO Urban Water Program

www.sustainablehouse.com.au

Michael Mobbs Sustainable House

www.waterrating.gov.au

Water Efficiency Labelling Standards

www.ata.org.au

Alternative Technology Association

www.healthywaterways.org/FileLibrary/9_aquifer_storage.pdf

Aquifer Storage and Recovery – WSUD Technical Guidelines for South East Queensland

www.brisbane.qld.gov.au/bccwr/lib78/wsud_chapt10_aquifer_storage_and_recovery.pdf

Aquifer Storage and Recovery – Brisbane City Council Draft WSUD Technical Guidelines

www.sydneywater.com.au/Publications/FactSheets/SewerMiningHowToEstablishASewerMiningOperation.pdf#Page=1

Sewer Mining - How to Establish a Sewer Mining Operation (note: relates to Sydney)

14.10 References

Department of Energy Utilities and Sustainability NSW (2007). *NSW Guideline for Greywater Use in Sewered, Single Household Residential Premises.* March. http://www.deus.nsw.gov.au/Publications/NSW%20Guidelines%20for%20Greywater%20Reuse%20in%20Sewered,%20Single%20Household%20Residential%20Premises.pdf.

Environment Protection and Heritage Council (2006). *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1).* November. http://www.ephc.gov.au/pdf/water/WaterRecyclingGuidelines-02_Nov06_.pdf.

Environment Protection Authority South Australia (1999). *South Australian Reclaimed Water Guidelines.* Adelaide, South Australia. http://www.dh.sa.gov.au/pehs/branches/wastewater/reclaimed-water.pdf.

Appendix A

Greywater Treatment Systems Recommended Maintenance

Greywater Treatment System

Recommended Maintenance

Greywater Diversion Device Component	Maintenance Required	Frequency
Filter	Clean filter - filter should be removed and cleaned, removing physical contaminants	Weekly
	Replace filter	As recommended by manufacturer or as required (usually every 6 – 12 months)
Surge tank	Clean out sludge from surge tank	Every 6 months
Subsurface irrigation distribution system	Check that water is dispersing - regularly monitor soil to ensure all areas are wet after an irrigation period	Weekly
Soil condition	Check that soil is healthy. Signs of unhealthy soil include: - damp and boggy ground hours after irrigation - surface ponding and runoff of irrigated water - poor vegetation growth - unusual odours - clumping of soil - fine sheet of clay covering surface	Monthly

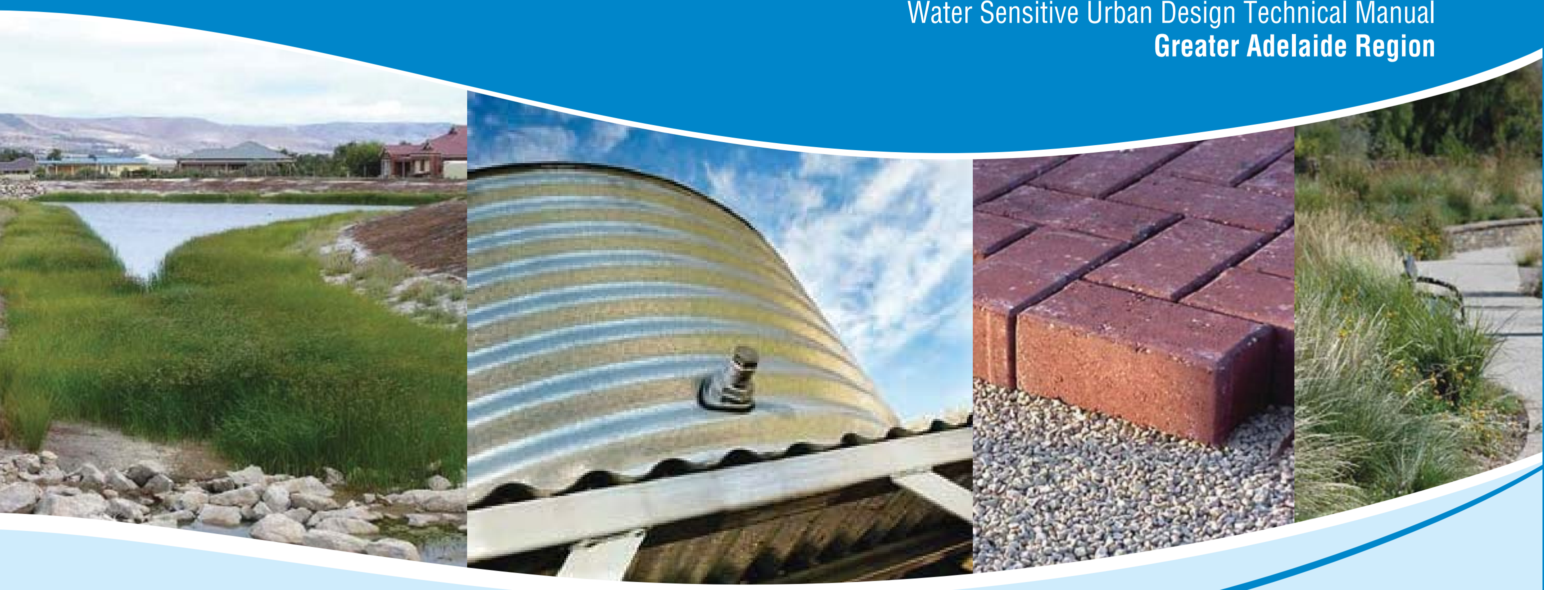
Source: Department of Energy Utilities and Sustainability NSW (2007)

July 2009

Chapter 15

Modelling Process and Tools

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region



Government of South Australia

Australian Government
Department of the Environment, Water, Heritage and the Arts

Securing tomorrow's water today.

Department of Planning and Local Government
Roma Mitchell House, 136 North Terrace, Adelaide SA 5000
GPO Box 1815, Adelaide SA 5001
phone: (08) 8303 0600

The Water Sensitive Urban Design documents can be downloaded from the following website:
http://www.planning.sa.gov.au/go/wsud

For hardcopy/CD ROM orders contact:
Planning Services Branch
phone: (08) 8303 0724
email: plnsa.orders@saugov.sa.gov.au

ISBN 978-1-876702-99-1

Preferred way to cite this publication

Department of Planning and Local Government, 2009, *Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region,* Government of South Australia, Adelaide

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED were engaged as the consultant team to prepare the Technical Manual given their specialist expertise and experience in water resources management.

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Project Management

The project manager for the consultant team is Dr Kylie Hyde (Australian Water Environments).

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), was also formed to review the technical and scientific aspects of the Technical Manual during development. This group includes representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

Contents

Tables

Figures

Appendices

Chapter 15 Modelling Process and Tools

15.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment).

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at supporting those using models for design and assessment of developments containing WSUD measures.

The objectives of this chapter are to:

- Ensure a consistent, scientifically based approach is applied to the use of models; and
- Provide guidance on modelling tools available for use in the Greater Adelaide Region, without inhibiting innovative modelling approaches.

This chapter assumes that the reader has some knowledge of modelling tools, techniques and processes.

Description and Purpose

Models are playing an increasing role in urban water resource management. There are several reasons why models are being used in the field, including:

- Systems being studied are often highly complex and difficult to understand without tools such as models, e.g. large catchments with varying land uses and a convoluted drainage network that delivers runoff from land uses within the catchment at different times and rates of flow;
- There is rarely one single solution to an urban water management problem. Models provide a way to investigate and rank alternative approaches to water management; and
- Water distribution and drainage systems are highly non-linear and exhibit characteristics that are probabilistic or dependent on antecedent conditions in some cases. This requires modelling to enable an adequate understanding and assessment to be undertaken.

A 'model' can be defined as any organised procedure for the analysis of a problem. A model is a representation, often of a system. It attempts to replicate significant attributes of the prototype, but is simpler and is easier to build, change or operate.

There are many existing computer models which are powerful tools that can be utilised to design and estimate the performance of various WSUD measures. This means that the performance of different development proposals can be assessed and compared using a common measurement system.

Essentially, models allow the extrapolation from existing systems and knowledge to analyse potential situations. They are only useful to the extent that they accurately model the real world. Unrealistic models, however internally consistent or persuasive they may be, are misleading and risky (O'Loughlin 2007).

Scale and Application

Models can be employed to meet many different objectives during the planning, design and operation of a water management system; different types of models can be more appropriate than others depending on the question at hand.

The modeller should always ensure that the appropriate model is being applied for the situation being assessed. For example:

- As soon as an area being modelled exceeds a few hectares, has more than one land use, or requires a treatment train of runoff quality management facilities, there will be a need to adopt a distributed model rather than a lumped conceptual or spreadsheet type model;
- The model should provide results that meet the objectives of the task at hand; and
- The time step should match the response of the system being simulated.

In all cases, primary responsibility for modelling rests with the modeller with respect to ensuring that models are used as they are intended and with appropriate input and parameters.

The level of modelling required to be undertaken will often be defined by council development assessment officers and will be based on factors including:

- The level of impact the development is likely to have on the receiving waterways/water bodies; and
- The scale of the development.

15.2 Modelling Philosophy

Overview

In order of importance, the accuracy of models depends on:

- The amount of data used to build and operate the model;
- The experience or skill of the analyst; and
- The quality of the model.

Models are ineffective without data and calibration. Model results are sometimes accepted without adequate scrutiny because they are generated through a computer. The axiom 'rubbish in – rubbish out' applies to all computer programs. Results must not be accepted uncritically, but should be checked for consistency and logic, and if possible, validated against additional data.

Various procedures for dealing with uncertainties in model development, input data and predictions are summarised by De Jongh (1988).

Models should always be considered to be provisional with the understanding that they can always be improved. At any particular time, the task is not to develop a perfect, once-and-for-all model, rather it is to develop an effective model with the available resources, expecting this to be revised and improved in the future (O'Loughlin 2007).

When is a Model Required?

For small developments and redevelopments there will be instances where detailed modelling is not required. In such cases, the consenting authority should have a clear understanding of the minimum WSUD measures required for such developments. One way to deal with such cases is to develop 'deemed to comply' requirements, which are often presented in a spreadsheet format. Parramatta City Council in NSW has undertaken such an exercise in order to introduce WSUD requirements into its current on-site detention (OSD) policy.

A typical deemed to comply system may incorporate a combination of WSUD measures such as rainwater tanks, pervious pavements and rain gardens that have been pre-designed and pre-assessed by the consenting authority. In such cases it is important that adequate treatment trains, including pre-filtering, and storage components are incorporated into the deemed to comply systems.

Another way for small developments to size WSUD measures without the development of a model is the utilisation of type curves.

Models would generally be required on larger scale developments and/or where there is likely to be an impact as a result of the development.

Modelling Procedure

O'Loughlin (2007) recommends the following approach relating to analysis of a drainage system:

- Preliminary consideration of objectives;
- Data collection and site inspections;
- Building a conceptual model of the existing system;
- Model refinement, checking and calibration;
- Detailed runs;
- Identification of problems;
- Scoping (identification and initial assessment) of remedies; and
- Preparation of a report.

Model Conceptualisation

Models cannot in detail describe the physical flow processes in a catchment because of:

- Scale; and
- Insufficient data.

To simplify the model, a conceptual model should be developed before the detailed numerical model is developed. This conceptual model includes:

- Identification of the major flow processes; and
- Assumptions to reduce the complexity.

It ensures that the overall response of the hydrological model corresponds to that of the actual physical system.

Model Calibration

The purpose of calibration is to obtain a model which simulates in accordance with field data, such as flow rates from river gauging stations. To determine what constitutes satisfactory calibration, targets or criteria are usually set.

The number of parameters and possible combinations is often large and restrictions on sets of parameters may be applied to obtain a successful calibration including:

- Reducing the number of locations of measured field data (keeping the most reliable data);
- Restricting parameter intervals by setting minimum and maximum values; and
- Identifying parameters of high uncertainty.

Model Verification

The purpose of model verification is to test whether the calibrated model simulates in accordance with field data. To verify a model the user undertakes further simulations using field data that preferably has not been used in the model calibration stage. The model parameters should not be adjusted during the verification exercise. An acceptable criterion for model fit needs to be established and a statistical comparison is then made between the model verification results and the collected field data.

Sensitivity Analysis

All models involve a number of input factors that have different degrees of uncertainty. These will influence the outcomes of the study to varying extents.

The inputs are usually selected as 'most likely' values. The relative response of outputs to changes in inputs is termed their sensitivity. If large changes in an input produce much smaller changes in an output, the output is insensitive to that input.

A basic test of sensitivity is whether a percentage change in an input factor produces a higher or lower percentage change in an output.

Sensitivity analysis is a powerful yet simple technique for determining the effects of individual factors and their variations on the overall results of an analysis. It can be applied to any analysis that can be visualised as a system of inputs and outputs, and merely involves the repetition of calculations.

There is no formal procedure for sensitivity analysis. It can be applied in a number of ways, for example:

- By examining factors one at a time, and determining the variation in outcomes due to changes to a single factor, keeping the others at their 'most likely' values;
- By taking the 'best' or 'worst' estimates of all factors, to see how a system performs under extreme conditions; and
- By varying a factor sufficiently to cause a reversal of the outcome given its most likely value.

It is useful to carry out sensitivity analyses at a preliminary stage of a large study, to identify which factors have the greatest bearing on results. Particular attention can then be given to data collection and estimation of these, so that they can be estimated as accurately as possible. The less important factors need only be estimated approximately.

15.3 Data Sources

A range of data sources and information is required to be able to run various models.

Information regarding a number of typical data sources or modelling WSUD measures is provided below, including:

- Meteorological data;
- Flow data;
- Fraction impervious;
- Annual volumetric runoff coefficients; and
- Baseline water quality data.

Meteorological Data

Accurate and locally specific meteorological data is essential for reliable water quantity and quality modelling. Within some areas there are significant local spatial variations in rainfall and evaporation that, if overlooked, can significantly affect the reliability of modelling results. For local scale applications (say less than 100 square kilometres) it is typically acceptable to use data from one locally specific meteorological station. However, for more widespread or regional studies, it is important to ensure that adequate spatial meteorological data coverage of the study area is provided.

Local evapotranspiration data is preferred where available. In most cases, local data will not be available in which case average monthly data can be derived from the Climatic Atlas of Australia – Evapotranspiration.

Rainfall and evaporation data is available from the Bureau of Meteorology (www.bom.gov.au). The rainfall distribution map can be used to determine the appropriate weather station.

Flow Data

Ideally models should be calibrated against local flow data, however in most cases information is not available to achieve this.

Surface water data can be obtained from the Surface Water Archive which is maintained by the Department of Water, Land and Biodiversity Conservation (DWLBC): www.dwlbc.sa.gov.au/subs/surface_water_archive/a1pgs/index.htm

Fraction Impervious

A number of models used to assess WSUD measures require the fraction impervious to be defined for the various land use types within the catchment.

Methods to determine the fraction impervious include:

- GIS data;
- Aerial photography; and
- Published local and national literature.

The following provides guidance on the fraction impervious information on the most typical source nodes in the Greater Adelaide Region:

- Residential = less than 50%;
- Commercial = approximately 70%;
- Industrial = approximately 85%; and
- Recreation = approximately 15%.

These figures are total fraction impervious, but actual runoff is related to the effective impervious area, which will depend on the percentage of the impervious area connected to the stormwater system (external to the site). The degree of connectivity with impervious and pervious areas can increase with high rainfall depth and intensity. This effective impervious area should be determined based on on-site stormwater management measures implemented.

Annual Volumetric Runoff Coefficients

For situations where no local data is available to calibrate the model, the selection and calibration of model input parameters should be based on replicating 'accepted' annual volumetric runoff coefficients (AVRC) – the ratio between the annual volume of runoff from a given catchment to the annual volume of rainfall that fell on that catchment, where appropriate, using the following equation:

$$\text{Annual Runoff Volume (ML)} = \frac{\text{Area (m}^2\text{) x Avg Rainfall (m) x AVRC}}{1000}$$

For example, if we assume that urban catchments have an AVRC of 0.4, a 1 hectare urban catchment with 500 mm average rainfall should be producing approximately (10,000m^2 x 0.5m x 0.4/1000) = 2 megalitres of runoff annually. The rainfall runoff model parameters should be selected and calibrated to approach this value where local data is unavailable.

Volumetric runoff coefficients are directly related to the effective impervious area, not the total impervious area. The volumetric runoff coefficient will depend on the form of development and on-site measures implemented.

It should be noted that in the Adelaide metropolitan area there is no significant contribution to runoff from pervious areas.

Baseline Water Quality Data

Stormwater Contamination

It is common for the processes of build up and washoff to be identified as being the main factors influencing the contamination of urban stormwater runoff. During dry weather, pollutants will accumulate in the catchment. These pollutants will build up on roads, pavements and any surface where pollutants can be transported. The amount of pollutant build up on a catchment depends on many factors. These include (Chiew et al. 1997):

- The rate of deposition of pollutants;
- The length of the antecedent dry period; and
- Any removal of pollutants by redistribution, decomposition, street sweeping or washoff.

Washoff is the removal of accumulated pollutants in a catchment area by rainfall and runoff. Falling raindrops and water runoff create turbulence during a storm event. This turbulence loosens particles and as a result suspends them in water and they are then carried into the drainage system. These particles may be dissolved pollutants or they may be sediments that are carrying pollutants. Pollutants that are washed out of the atmosphere by rainfall can add to the total load carried in the flow (Chiew et al. 1997).

Washoff is affected by factors such as:

- The overland velocity of runoff;
- Flow depth;
- Surface slope;
- Raindrop diameter;
- Rainfall intensity;
- Hydrologic roughness; and
- The amount of pollutants on the catchment surface.

The 'first flush' describes the washing action of the stormwater as it travels over the catchment during the early parts of the storm event. It is believed that the concentration of the pollutants in the runoff will be greatest in the early parts of the storm event. As the event continues, the level of contaminants in the runoff will reduce. The stormwater runoff from the later part of the storm event may dilute the contaminants that are present in the receiving water body.

Average Pollutant Levels

When no measured data is available for a WSUD study, it is important for modellers to be able to use average pollutant concentrations for given land uses. An initial study undertaken by Duncan (1999) was based on data obtained from various field investigations spanning back to before 1965. It was the intention of Duncan to investigate stormwater runoff quality in relation to land use and catchment characteristics. The findings of Duncan were modified and updated and then presented in Duncan (2005).

The figures that are contained in **Appendix A** are adapted from Duncan (2005). The mean pollutant concentration of the stormwater in Duncan's (2005) investigation for various land uses is represented by the centre line of the bar graphs. Plus and minus one standard deviation is represented by the grey bars.

15.4 Modelling Tools

There are numerous packages and approaches that can be applied to simulate water management systems.

A number of available modelling tools are described briefly below. They have been selected due to their availability and wide use through the industry, their applicability to WSUD and South Australian conditions.

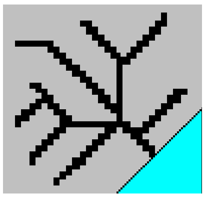
A summary of the modelling tools available and the WSUD measures that they model is included in **Table 15.1**.

It is important to note that the information provided below on any modelling system neither endorses any of these modelling systems, nor assures the quality of results that will be obtained from their use.

Table 15.1 Summary of Model Applications

WSUD Element	MUSIC	EPA SWMM	XP-SWMM	Water Cress	Drains	Hec-Ras	SWITCH	Switch2	PermPave	Raintank Analyser	E2
On-site detention	Y	Y	Y	Y	Y	N	N	Y	Y	N	N
On-site retention	Y	Y	Y	Y	N	N	Y	Y	Y	N	N
Rainwater tanks	Y	Y	Y	Y	N	N	N	Y	N	Y	Y
Pervious pavements	Y	N	N	N	N	N	Y	Y	Y	N	N
Buffer strips	Y	N	N	N	N	Y	N	N	N	N	Y
Swales	Y	Y	Y	N	N	Y	N	N	N	N	Y
Bioretention systems	Y	Y	Y	N	Y	Y	N	Y	N	N	Y
Sedimentation basins	Y	Y	Y	N	Y	Y	N	N	N	N	Y
Ponds	Y	Y	Y	N	N	Y	N	N	N	N	Y
Constructed wetlands	Y	Y	Y	Y	Y	Y	N	N	N	N	Y
Infiltration systems	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N
Gross pollutant traps	Y	N	N	N	N	N	N	N	N	N	Y
Oil and grit separators	N	N	N	N	N	N	N	N	N	N	N
Stormwater harvesting	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y
Rain gardens	Y	N	Y	Y	N	N	N	Y	N	N	N
Green roofs	N	N	Y	N	N	N	N	N	N	N	N
Street sweeping	N	N	Y	N	N	N	N	N	N	N	N
On-site wastewater management	N	N	N	N	N	N	N	N	N	N	N
Community wastewater management schemes	N	N	N	N	N	N	N	N	N	N	N
Demand reduction	N	N	N	Y	N	N	N	Y	N	N	Y

DRAINS



DRAINS is a multi-purpose Windows program for designing and analysing urban stormwater drainage systems and catchments.

The program can be used to analyse peak flows, volumes and system deficiencies.

DRAINS simulates the conversion of rainfall patterns to stormwater runoff hydrographs and routes these through networks of pipes, channels and streams, integrating:

- Design and analysis tasks;
- Hydrology (four alternative models) and hydraulics (two alternative procedures);
- Closed conduit and open channel systems;
- Headwalls, culverts and other structures;
- Stormwater detention systems; and
- Large scale urban and rural catchments.

DRAINS can carry out hydrological modelling using ILSAX, rational method and storage routing models, together with quasi-unsteady and unsteady hydraulic modelling of systems of pipes, open channels and surface overflow routes. It includes two automatic design procedures for piped drainage systems, connections to CAD and GIS programs, and an in-built Help system.

The runoff routing modelling facilities in DRAINS can be configured to emulate the RORB, RAFTS and WBNM modelling structures.

E2

E2 is a software product for whole-of-catchment modelling. It is designed to allow modellers and researchers to construct models by selecting and linking component models from a range of available choices. E2 enables a flexible modelling approach, allowing the attributes and detail of the model to vary in accordance with modelling objectives.

In E2, the model structure and algorithms are not fixed. They are defined by the user, who can choose from a suite of available options. Model selection requires the user to be familiar with the detail, applicability and data requirements of component models, and the implications of joining component models. E2 is therefore intended to be a tool for experienced catchment modellers.

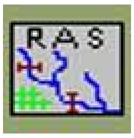
Environment Protection Agency StormWater Management Model (EPA SWMM)

The US Environment Protection Agency (EPA) Storm Water Management Model (SWMM) is a dynamic rainfall runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. SWMM 5 is a complete rewrite of the first version developed in 1971 and offers GIS based input formats and extensive graphical outputs, including colour coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses. While free, there is no support from the EPA, only a SWMM Users Forum.

SWMM accounts for various hydrologic processes that produce runoff from urban areas. These include:

- Time varying rainfall;
- Evaporation of standing surface water;
- Rainfall interception from depression storage;
- Infiltration of rainfall into unsaturated soil layers;
- Percolation of infiltrated water into groundwater layers;
- Interflow between groundwater and the drainage system; and
- Non-linear reservoir routing of overland flow.

Hydraulic Engineering Centre River Analysis System (HecRas)



HecRas performs one dimensional hydraulic calculations for a full network of natural and constructed channels for steady and unsteady flow scenarios, sediment transfer/mobile bed computations and water temperature modelling.

Model for Urban Stormwater Improvement Conceptualisation (MUSIC)

MUSIC is designed to simulate urban runoff systems operating at a range of temporal and spatial scales and provides a user friendly interface to allow complex stormwater management scenarios to be quickly and efficiently created, with results viewed using a range of graphical and tabular formats. MUSIC provides the ability to simulate both quantity and quality of runoff from catchments and the effect of treatment facilities on these components.

MUSIC is an aid to decision making. It enables users to evaluate conceptual designs of stormwater management systems to ensure they are appropriate for their catchments. By simulating the performance of stormwater quality improvement measures, MUSIC determines if proposed systems can meet specified water quality objectives.

MUSIC will simulate the performance of a group of stormwater management measures, configured in series or in parallel to form a treatment train. MUSIC runs on an event or continuous basis, allowing rigorous analysis of the merit of proposed strategies over the short-term and long-term.

Specifically, the software enables users to:

- Determine the likely water quality emanating from urban catchments;
- Predict the likely performance of specific structural best management practices (BMPs) in protecting receiving water quality;
- Design an integrated stormwater management scheme; and
- Evaluate the success of structural BMPs, or a stormwater management scheme, against a range of water quality standards.

PermPave

PermPave analyses and designs pervious pavement systems for stormwater runoff quantity (flood), quality and harvesting:

- Flood mitigation – using the design rainfall approach according to Australian Rainfall and Runoff. Outputs include inflow and outflow hydrographs, required storage capacity of pavement and depth;
- Water quality improvement – a simple water quality improvement analysis is based on hydrological effectiveness, derived from continuous time series modelling using 6 minute historical rainfall data; and
- Water harvesting – yields-storage relationship and suggested storage, based on unit storage volume benefit and disbenefit approach.

The program is able to design a system for each of the capital cities.

Rainfall Runoff Library

The Rainfall Runoff Library is designed to simulate catchment runoff and is typically used to fill gaps in data and extend streamflow records.

The Rainfall Runoff Library includes the following models:

- AWBM

  The AWBM is a catchment water balance model that can relate runoff to rainfall with daily or hourly data, and calculates losses from rainfall for flood hydrograph modelling.

- Sacramento

  The Sacramento model is a continuous rainfall runoff model used to generate daily streamflow from rainfall and evaporation records.

- SimHyd

  SimHyd is a daily conceptual rainfall runoff model that estimates daily stream flow from daily rainfall and areal potential evapotranspiration data.

- SMAR

  The soil moisture and accounting model (SMAR) is a lumped conceptual rainfall runoff water balance model with soil moisture as a central theme. The model provides daily estimates of surface runoff, groundwater discharge, evapotranspiration and leakage from the soil profile for the catchment as a whole. The surface runoff component comprises overland flow, saturation excess runoff and saturated throughflow from perched groundwater conditions with a quick response time.

- Tank

  The tank model is a very simple model, composed of four tanks laid vertically in series. Precipitation is put into the top tank, and evaporation is subtracted sequentially from the top tank downwards. As each tank is emptied the evaporation shortfall is taken from the next tank down until all tanks are empty.

  The tank model is applied to analyse daily discharge from daily precipitation and evaporation inputs.

Raintank Analyser

The Raintank Analyser program can be utilised to assess the following various aspects of rainfall harvesting:

- Yields;
- Cost analysis; and
- Tank size selection.

This software is primarily intended for sizing raintanks for domestic use of water inhouse as well as outdoors, if required. However, there is a 20,000 litre limit to storage volumes in the model.

The model can also be applied to commercial/industrial situations provided the 20,000 litre limit is recognised. In these situations where very large catchment (roof) areas are available, then a solution to the problem of 'sizing' can be found by segmenting the catchment so that each segment requires a rainwater tank of capacity not exceeding 20,000 litres.

Stormwater Infiltration Techniques: Community Homepage (SWITCH)

SWITCH enables hydrologic analysis and sizing of infiltration systems to be undertaken.

This model was originally developed as a design tool to size stormwater infiltration systems. It has since been expanded to design other WSUD components such as:

- Rainwater tanks;
- Swales;
- Bioretention systems; and
- Sand filters.

SWITCH is a design storm based model.

The SWITCH design model uses the CIRIA method (Butler and Davies 2000) for the sizing of infiltration systems. This is a design storm approach that requires the determination of the worst or critical storm. To facilitate this, SWITCH includes a routine that can automatically run design storms from 1 to 100 years ARI and durations from five minutes to 72 hours for a number of locations across Australia. The program selects the critical storm and proceeds to size the infiltration system. It also estimates the time to empty the device following the occurrence of the critical duration design storm.

Switch2

Switch2 is a total water balance model that is able to take into account end user demands and compute water supply (conservation) and stormwater discharges at six minute time intervals using continuous simulation modelling. Switch2 has a spatial resolution ranging from 50 m^2 to 5 ha.

The SWITCH model was originally developed as a design tool to size stormwater infiltration systems. The Switch2 program has been expanded to enable design of other WSUD measures such as rainwater tanks, swales and bioretention systems.

The original SWITCH software is a design storm based model while Switch2 is a continuous simulation model (CSM) that uses observed or disaggregated rainfall down to one minute time intervals. The Switch2 model can process more than 100 years of rainfall data at one minute time intervals.

Both versions currently use deterministic loss modelling and water balance computational techniques, although it is planned that future versions of Switch2 will incorporate both deterministic and stochastic rainfall disaggregation capabilities. Water quality and life cycle costing modules are also currently under development.

The SWITCH and Switch2 models have recently been integrated into a common, Windows based graphical user interface, the opening splash screen for which is shown in **Figure 15.1**. A purpose designed browser application object provides connectivity between the two models and an Education and Design Guideline package. From this website users can look up design data such as soil infiltration rates or geofabric specifications.

The design guidelines, which are presented through a web based system, include topics such as feasibility, site evaluation, detailed design methodologies, construction and installation, operation and maintenance requirements, and performance review.

For Switch2, the data entry also includes an end user model to estimate both inside and outside water consumption.

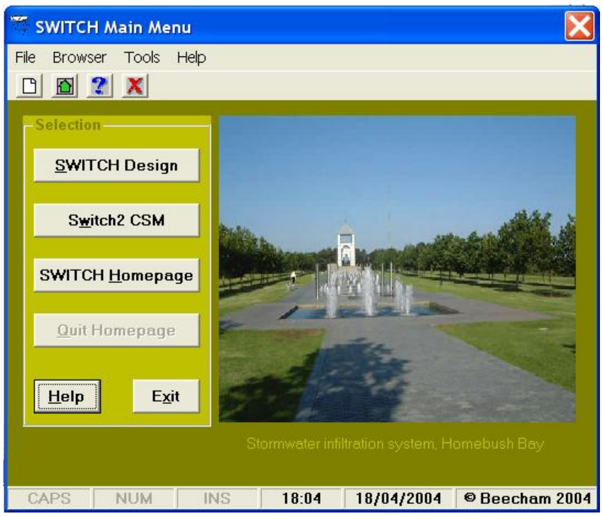


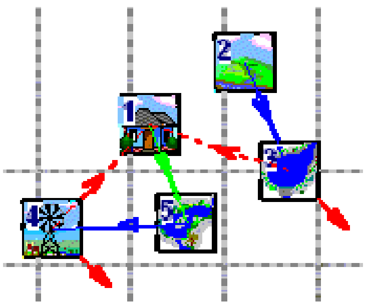
Figure 15.1 Opening SWITCH Screen

Once a daily consumption has been established, a graphically adjustable diurnal distribution is then applied.

The model outputs include system dimensioning, performance statistics, rainfall data and loss estimations at the selected time scales. Loss estimations are categorised as depression storage, evapotranspiration, vegetation interception and soil infiltration. In addition, the Switch2 model is able to calculate both rainwater tank overflow volumes and the replenishing of supplies using municipal drinking (potable) water during extended dry periods. Topping up of the system can be specified to occur when the storage volume falls below a nominal volume (for example, 20% of the tank capacity for systems collecting surface water for irrigation and 30% of the tank capacity for systems harvesting rainwater for toilet flushing).

Supplementation using municipal drinking water can be converted to a water supply cost. The program can therefore provide an estimate of the potential cost savings associated with various types of WSUD systems.

WATER-Community Resource Evaluation and Simulation System (WaterCress)



WaterCress is a PC based water balance model for designing and testing trial layouts of water systems using multiple sources of water. WaterCress is designed to meet the problems of exploring alternative systems layout at the feasibility stage. The model uses a trial and error approach to determine the feasibility of water resource projects.

WaterCress is particularly useful in evaluating and designing water systems for:

- Subdivisions where alternatives to connection to existing water supply mains and sewers may be costly and/or opportunities are sought to utilise drainage water for amenity enhancement or supply;
- Isolated communities in drier areas where water use efficiency is particularly important; and/or
- Design situations where environmental impacts must be minimised.

WaterCress allows you to simulate real life water system layout as an assembly of nodes joined by drainage links. The nodes represent all conventional water supplies such as catchments, dams, groundwater bores, inhouse demands, irrigation areas and pumps, but also include non-conventional supply sources and management processes involved in such processes as the recycling of treated wastewater at local and regional scales, and capture, treatment and storage of urban stormwater in rainwater tanks, wetlands and aquifers.

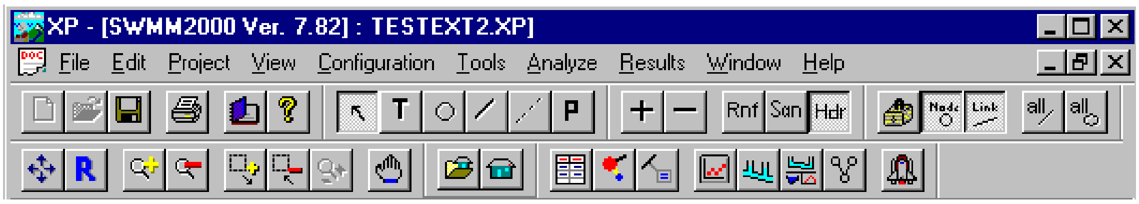
WaterCress's wastewater treatment system representation is qualitative rather than quantitative. WaterCress's separation of wastewater streams occurs in the town node.

The strengths of WaterCress lie in its storage and water reuse modelling, with its development originating from the requirement to more accurately model farm dams within rural catchments and the need to incorporate custom water reuse layouts to lot or subdivision scale models.

XP StormWater Management Model (XP-SWMM)

XP-SWMM is a friendly, graphics based stormwater and wastewater decision support system. It is a link node model that performs hydrology, hydraulics and quality analysis of stormwater and wastewater drainage systems including wastewater treatment plants, water quality control devices and best management practices (BMPs).

Links represent hydraulic elements for flow and constituent transport through the system (for example: pipe, channel, pump, weir, orifice regulator, real time control device, etc). There are more than 30 different types of conduits available in XP-SWMM.



XP-SWMM can be used in a wide variety of water quality studies. Processes that can optionally be simulated within the software include pollutant build up, washoff during rainfall, transport, advection, sedimentation and biochemical processes. In all cases the user will need to choose suitable values for the process parameters.

XP-SWMM and its predecessor US EPA SWMM were created to provide a tool capable of modelling the total water cycle from stormwater and wastewater flow, and pollutant generation to simulation of the hydraulics in any combined system of open and/or closed conduits with any boundary conditions.

Some of the many applications for which XP-SWMM is well suited include:

- Urban stormwater hydrology;
- Rural stormwater hydrology;
- Subdivision drainage;
- Major and minor drainage system hydraulics;
- Hydraulics of open channels and watercourses;
- Stormwater quality modelling;
- Wastewater Dry Weather Flow and Wet Weather Flow generation;
- Pollutant routing;
- Analysis of best management practices for treatment of stormwater runoff; and
- Treatment analysis.

15.5 Case Studies

Modelling Potential Phosphorus Reduction in the River Torrens by Assessment of Various WSUD Strategies

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) was developed by the CRC for Catchment Hydrology as a tool for simulating urban stormwater systems for a range of catchment scales and application.

MUSIC is particularly useful as conceptual design tool which allows for water quality improvement assessment in relative terms.

This model was applied in a case study conducted for the Torrens Taskforce Committee, assessing the capacity of several WSUD treatment options and strategies for reducing nutrient load into the River Torrens within the City of Adelaide. The assessment was carried out on the Hectorville subcatchment, which is one of several typical urban subcatchments draining into the River Torrens.

Figure 15.2 MUSIC Model Subcatchments Representation

Source: University of South Australia

The 62 hectare Hectorville subcatchment was modelled by dividing the area into 12 areas of approximately 5 hectare, each having 23% of roadway coverage and the remaining as residential land. The model subcatchments are illustrated in **Figure 15.2**.

The imperviousness and connectivity of the residential area and other catchment specific characteristics were determined from multiple sources including:

- GIS data;
- Aerial photography; and
- Published local and national literature.

Water quality improvements of the modelled technologies were based on the default trends available in MUSIC, using a six minute time step.

Potential WSUD strategies which could assist the ultimate objective of runoff nutrient reduction were assessed. The effectiveness of the strategies was assessed from allotment to catchment scale:

- Allotment scale – source control such as rainwater tanks, rain gardens and soakways treating 25%, 50% and 75% of the catchment;
- Street scale – swales, bioretention systems and pervious pavements treating 25%, 50% and 75% of the catchment; and
- Catchment scale – infiltration basin (1000 m^2) and Wetland (1000 m^2).

In addition, assessment was also conducted by applying the treatment train approach, combining several WSUD strategies at different scales. The effects of an increase in urban density were also considered.

Assessment was also undertaken of the potential benefits associated with:

- Harvesting and reuse;
- Flood mitigation;
- Economics; and
- Social acceptance and values.

This was conducted as part of a multi-criteria decision analysis aimed at identifying the most appropriate strategies for addressing the wide scope of objectives in the changing urban environment. Economic assessment was conducted using the life cycle cost analysis feature in MUSIC.

Overall, the model provided comparable quality data which is suitable for initial stormwater management strategy assessment. The model could potentially be utilised for more detailed planning but would require accurate, catchment specific data and monitoring.

Modelling Stormwater Runoff Quantity and Quality in the Parafield Catchment

In 2004, the Urban Water Resources Centre at the University of South Australia conducted a study into the feasibility of modelling stormwater runoff and quality in the Parafield Drain in the City of Salisbury. The main feature explored in this study was the ability of build up and washoff models to accurately predict the concentration of heavy metals in the runoff.

SWMM is a comprehensive modelling tool, commonly used for stormwater, sanitary and river systems. XP-SWMM, a commercially available extended version of the model originally developed by the US EPA, was utilised to perform the analysis.

The XP-SWMM program consists of several modules, each designed to represent specific processes in the catchment. The modules implemented in this project were:

- The rainfall runoff module;
- The hydraulic module; and
- The water quality module.

The Parafield Drain model was developed in several stages, addressing the issues of catchment characteristics, hydraulic system representation and pollutant build up and washoff processes. Although the program allows for a very accurate physical representation of the system modelled, in this particular application a more conceptual approach was adopted as described below:

- Catchment – the 1600 hectares catchment was represented in the model by three subareas. The first subarea accounted for the 400 hectares of rural land in the catchment, while the small commercial area was incorporated into the surrounding residential area and divided into an additional two subareas. Catchment characteristics such as depression storage, infiltration rates and overland flow were based on recommended typical values.
- Hydraulic system – the drainage system was simplified to only assess the main channel leading to the harvesting location.
- Pollutant functions – the suitability of several functions and parameters was considered in order to determine the most suitable representation of heavy metals in the runoff. The selected approach was based on a combination of a typical build-up/washoff model combined with an assumed concentration in precipitation. Although this is not the correct physical representation, it resulted in quite accurate predication of the total mass of pollutants.

Both runoff and pollutant loads were analysed using local 6 minute rainfall data and calibrated using historical monitoring data. The model was then validated using six months of rainfall runoff and quality data, and provided a good prediction of cumulative pollutant accumulation in the receiving system.

Modelling Supply, Demand and Operation for the Non-potable Water System in Mawson Lakes

Mawson Lakes is a world class sustainable development, incorporating dual reticulated water systems for drinking and non-drinking supply.

Drinking water is used for the following indoor uses:

- Drinking;
- Kitchen;

- Laundry; and
- Bathroom.

The non-drinking water is used for:

- Toilet flushing;
- Garden;
- Park irrigation; and
- Top up of the constructed lakes.

The non-drinking water supply is based on treated wastewater and supplemented by captured stormwater runoff, both from immediate or adjacent sources. This combined, innovative approach resulted in a unique scheme.

A WaterCress model of the Mawson Lakes development in the City of Salisbury was constructed in 2002 in order to simulate the operation of the local non-drinking water system.

WaterCress is a locally developed, total water balance model widely used in a range of projects in South Australia. The model is suitable for a variety of planning and water resource management applications.

The model utilised many of the unique features of the program and was used to estimate:

- Stormwater and wastewater production and storages;
- Non-drinking water supply and demand;
- The salinity of the water; and
- The reliability of supply in terms of volume and quality.

The WaterCress model assessed the performance of the system based on a 100 year historical rainfall record and was used to estimate the ability of the system to sustainably meet demands. The node layout of the WaterCress model is illustrated in **Figure 15.3**.

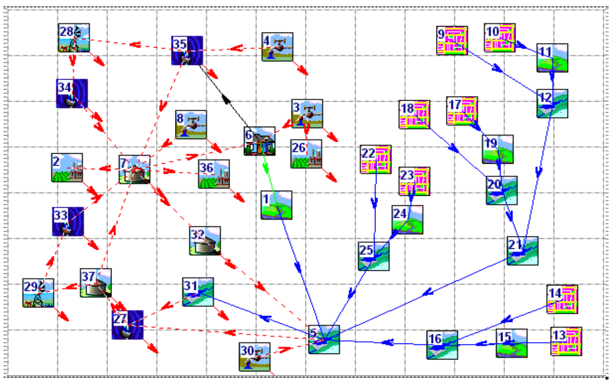


Figure 15.3 Mawson Lakes WaterCress Node Layout

The model considered the following matters:

- Non-drinking water demand – combination of constant toilet flushing demand, seasonal public and private irrigation demand and lake evaporation replacements. Rainfall and evaporation relations and their implications were also considered and resulted in a realistic, variable annual demand.
- Stormwater runoff and capture – modelled assuming both partial and full development conditions. Intercatchment connection was also considered to augment supplies in dry years.
- Wastewater reclamation – modelled based on inhouse use and incorporated losses and increased salinity. Constant groundwater infiltration was also considered and affected both volumes and water quality (salinity).
- Reliability of supply – determined by the ability of the system to meet annual demands under the specific rainfall, evaporation and volumes held in storage. Maximum and average shortfalls were determined based on historical records and provided an estimate of the development's reliance on mains water.
- Quality of supply – quality deterioration of recycled water and wetland salinity issues were considered and control methods were suggested.

Modelling the Mawson Lakes non-drinking water system resulted in estimates of system efficiency and better understanding of the long-term management challenges of this unique system. The model was also useful for determining a pre-commissioning strategy for drought proofing the aquifer storage systems against salinisation processes.

Estimating Catchment Yield for the Parafield Aquifer Storage and Recovery Scheme

The Parafield Drain Scheme in the City of Salisbury is a world class system designed for harvesting urban stormwater for industrial and domestic reuse applications.

Runoff from the Parafield and Ayfield catchments is diverted into a series of instream storage and treatment basins.

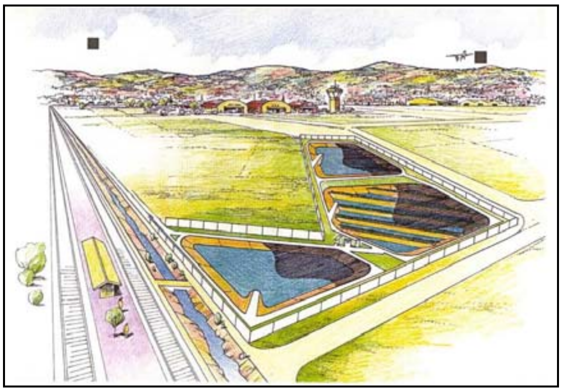


Figure 15.4 Conceptual Layout of the Parafield Drain Scheme

Treated water is directly reused by local industry and the Mawson Lakes development while excess water is stored in a tertiary aquifer.

The storage of water in the underlying aquifer enables continuous water supply during dry periods. The capture, treatment and reuse of urban stormwater, previously free flowing into Gulf St Vincent, also significantly reduces the environmental footprint of urban catchments on the aquatic system.

A WaterCress model of the Parafield Drain and managed aquifer recharge (MAR) scheme was constructed by Richard Clark and Associates in 2001, in order to estimate the harvesting yields and performance of the system. WaterCress is a locally developed, complete water balance model which is widely used for numerous applications in South Australia.

The WaterCress model was used to:

- Estimate runoff yield and salinity;
- Determine the initial aquifer buffer storage requirements; and
- Conclude on the expected water supply from the system.

Modelling was conducted based on historical, 95 year daily rainfall records and calibrated with an estimated long-term average annual runoff. The model consisted of three components representing the catchment, the capture and treatment system, and the aquifer injection and recovery storage zone.

Land use within the Ayfield and Parafield catchments was assessed and divided into five individual classifications, based on typical runoff coefficients. The average runoff from historical data and average annual rainfall was determined and verified by available records of similar, nearby catchments. The model was also used to determine the expected salinity levels based on a typical log linear relationship with runoff volumes.

Modelling of the operation of the instream storage and treatment system was also conducted in order to analyse the actual harvesting capacity of the system. The limiting factors adopted were based on:

- The basins storage levels;
- The capacity of the pumps; and
- Maximum allowable supply salinity level lower than 1000 milligrams/litre.

The efficiency of the system was determined by comparing catchment yields with subsequent direct supply or aquifer storage.

The WaterCress model was also used to:

- Analyse the water losses due to mixing and migration within the storage aquifer;
- Determine the volume required to establish an initial buffer zone; and
- Estimate the time required to inject this volume.

Modelling the Parafield system revealed the average system supply efficiency based on historical records and the sensitivity of this estimate to variations in recharge rate and accepted supply salinity levels. This information significantly assisted in understanding the potential response of the system to annual variation in rainfall, runoff and stormwater quality.

15.6 Useful Resources and Further Information

General

www.stormwater.asn.au/sa/

Stormwater Industry Association South Australia

www.urbanwater.info/engineering/modelling.cfm

Urban Water Information

Guidelines (Interstate)

www.goldcoast.qld.gov.au/attachment/music_modelling_guidelines.pdf

MUSIC Modelling Guidelines, Gold Coast City Council

www.melbournewater.com.au/content/library/wsud/Guidelines_For_The_Use_Of_MUSIC.pdf

MUSIC Input Parameters, Melbourne Water

Models

www.toolkit.net.au/cgi-bin/WebObjects/toolkit.woa/1/wa/products?wosid=rQ6FU5PiTotw09P5pHZk4w#

Catchment Modelling Toolkit

www.hec.usace.army.mil/software/hec-ras/hecras-hecras.html

HecRas

www.cmaa.com.au/html/TechInfo/TechInfoSaleDetail.html#LockpaveAnchor

PermPave

www.unisa.edu.au/water/UWRG/publication/raintankanalyser.asp

Raintank Analyser

www.watercom.com.au/index.html

Watercom

www.waterselect.com.au

WaterSelect

15.7 References

Butler, D., Davies, J. W. (2000). *Urban Drainage*. London, E & F.N. Spon.

Chiew, F. H. S., Mudgway, L. B., Duncan, H. P., McMahon, T. A. (1997). *Urban Stormwater Pollution*. Cooperative Research Centre for Catchment Hydrology.

De Jongh, P. (1988). *Uncertainty in Environmental Impact Assessment, Theory and Practice*. London.

Duncan, H. (1999). *Urban Stormwater Quality: A Statistical Overview.* Cooperative Research Centre for Catchment Hydrology. Melbourne.

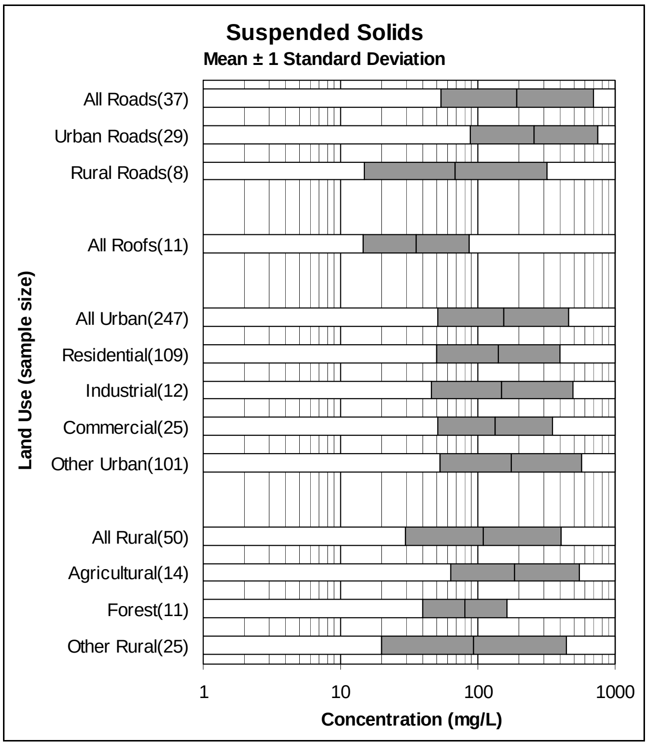
Duncan, H. (2005). *Urban Stormwater Pollutant Characteristics.* Australian Runoff Quality - A Guide to Water Sensitive Urban Design. T. Wong, Engineers Australia.

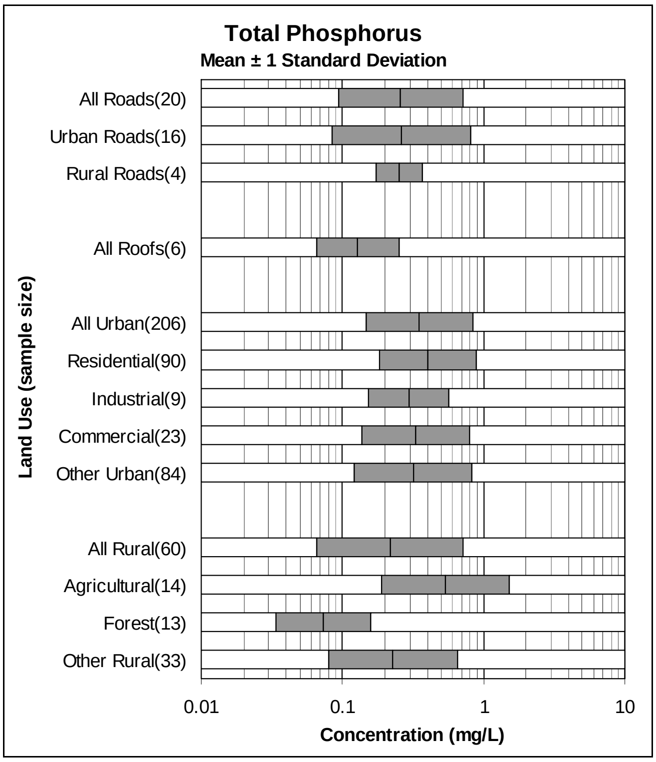
O'Loughlin, G. G. (2007). Drains Investigation Workshop Notes. University of South Australia. Adelaide.

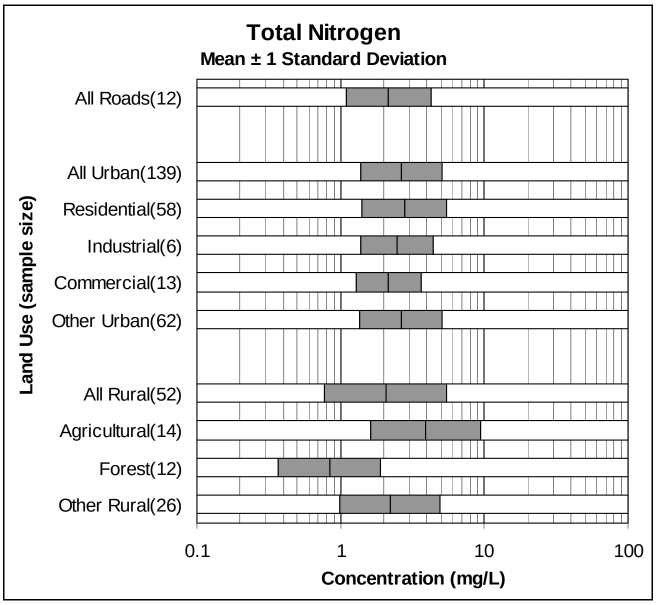
Appendix A
Baseline Water Quality Data

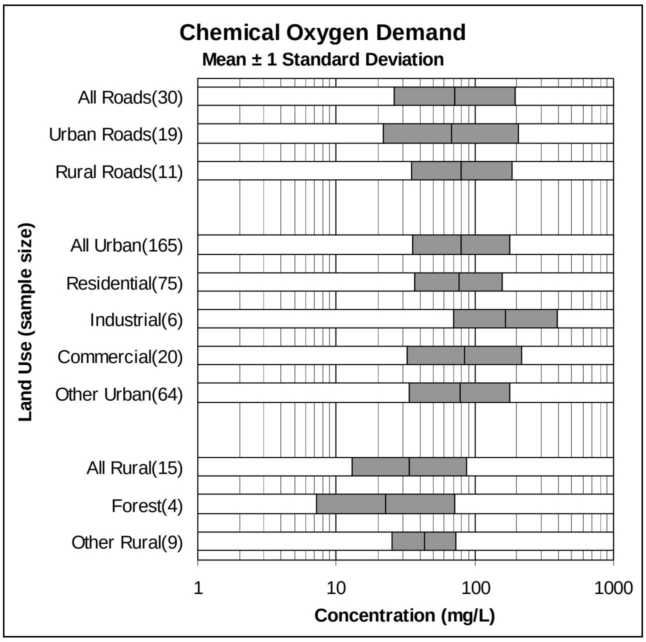
Baseline Water Quality Data

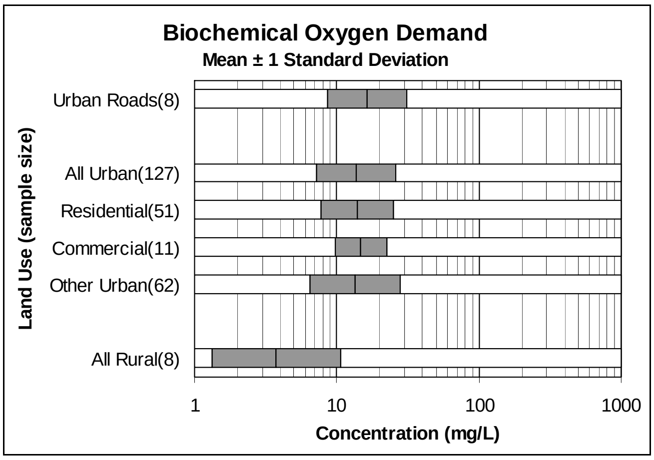
Adapted from Duncan (2005).

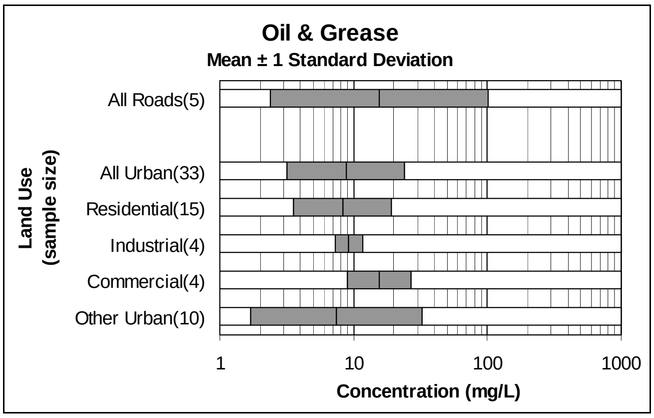


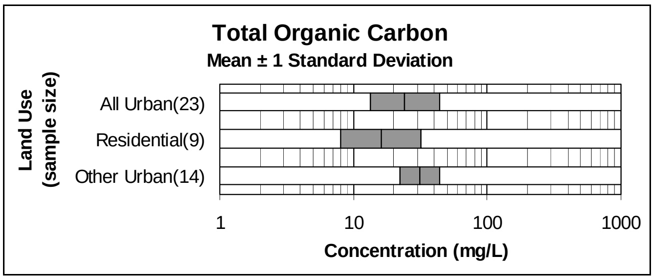

Total Phosphorus
Mean ± 1 Standard Deviation
All Roads(20)
Urban Roads(16)
Rural Roads(4)
All Roofs(6)
All Urban(206)
Residential(90)
Industrial(9)
Commercial(23)
Other Urban(84)
All Rural(60)
Agricultural(14)
Forest(13)
Other Rural(33)
Land Use (sample size)
0.01
0.1
1
10
Concentration (mg/L)

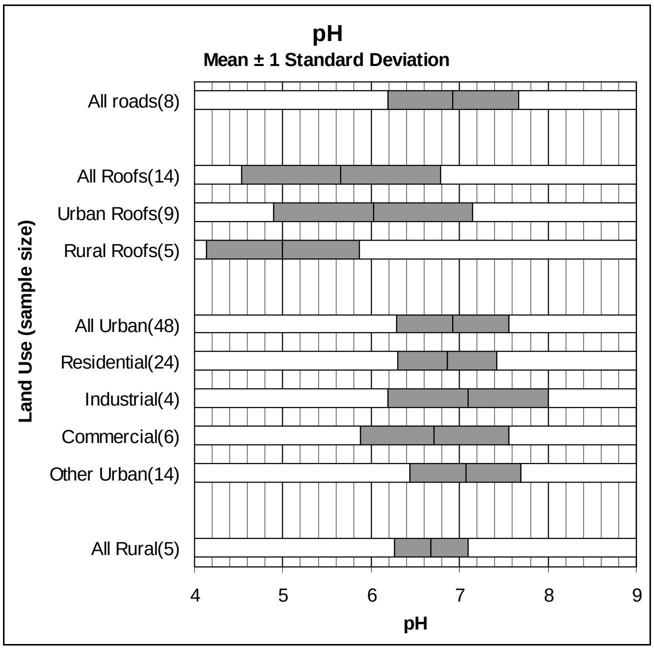

Total Nitrogen
Mean ± 1 Standard Deviation
All Roads(12)
All Urban(139)
Residential(58)
Industrial(6)
Commercial(13)
Other Urban(62)
All Rural(52)
Agricultural(14)
Forest(12)
Other Rural(26)
Land Use (sample size)
0.1
1
10
100
Concentration (mg/L)

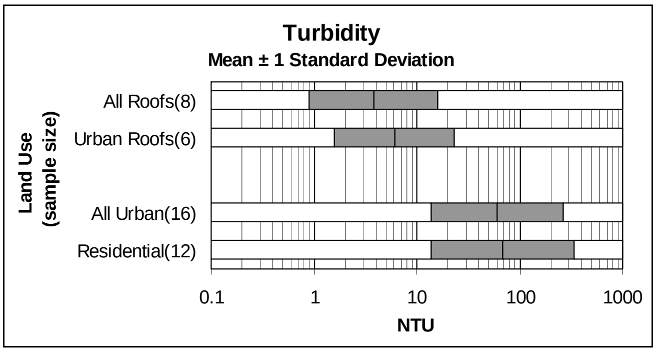

Chemical Oxygen Demand
Mean ± 1 Standard Deviation
All Roads(30)
Urban Roads(19)
Rural Roads(11)
All Urban(165)
Residential(75)
Industrial(6)
Commercial(20)
Other Urban(64)
All Rural(15)
Forest(4)
Other Rural(9)
Land Use (sample size)
1
10
100
1000
Concentration (mg/L)

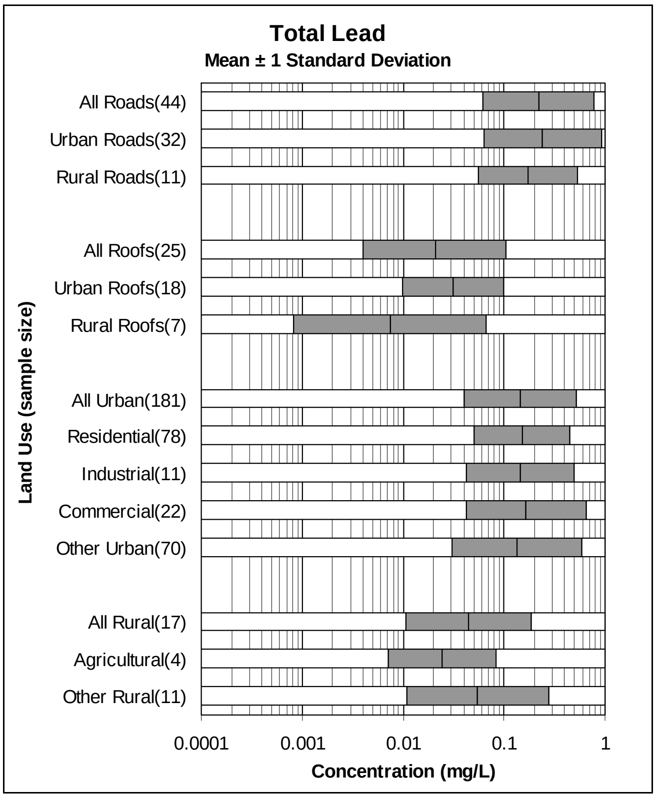

Biochemical Oxygen Demand
Mean ± 1 Standard Deviation
Urban Roads(8)
All Urban(127)
Residential(51)
Commercial(11)
Other Urban(62)
All Rural(8)
Land Use (sample size)
1
10
100
1000
Concentration (mg/L)

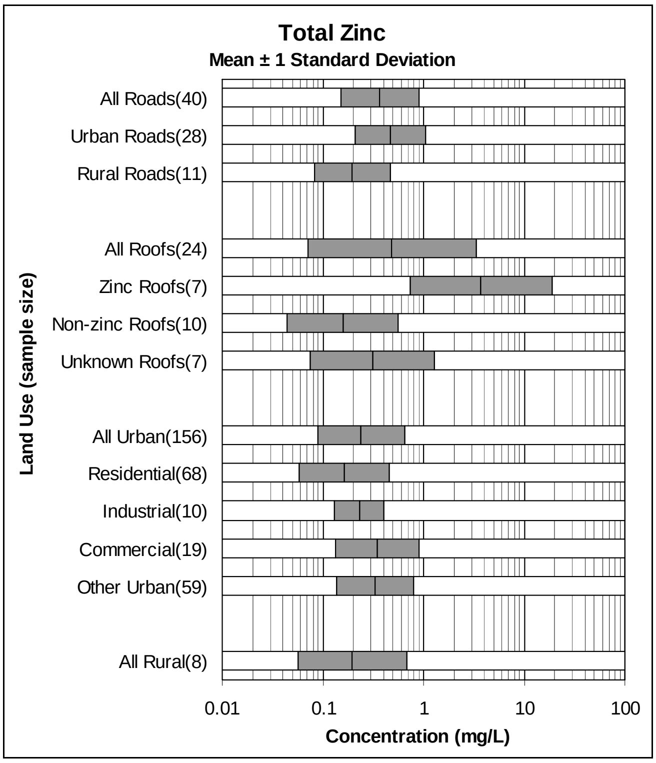

Oil & Grease
Mean ± 1 Standard Deviation
All Roads(5)
All Urban(33)
Residential(15)
Industrial(4)
Commercial(4)
Other Urban(10)
Land Use (sample size)
1
10
100
1000
Concentration (mg/L)

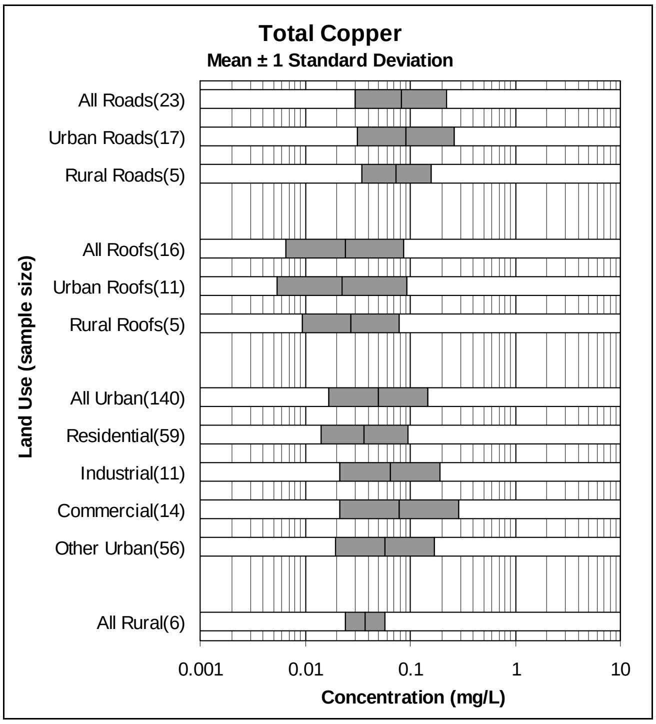

Total Organic Carbon
Mean ± 1 Standard Deviation
Land Use (sample size)
All Urban(23)
Residential(9)
Other Urban(14)
1
10
100
1000
Concentration (mg/L)

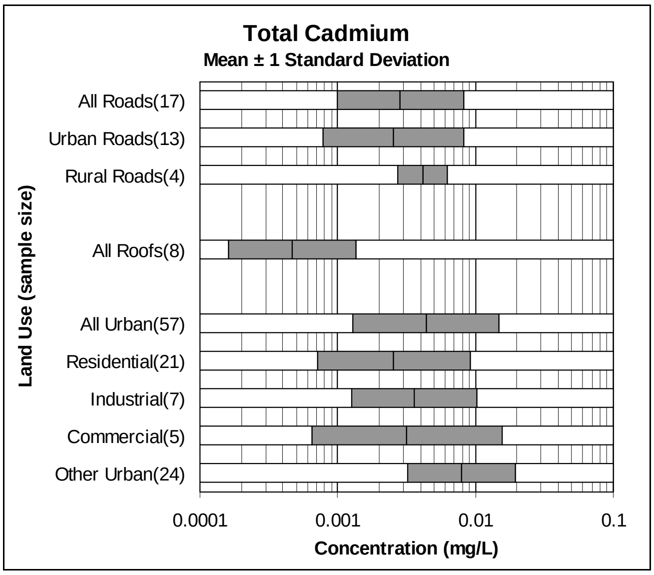

pH
Mean ± 1 Standard Deviation
Land Use (sample size)
All roads(8)
All Roofs(14)
Urban Roofs(9)
Rural Roofs(5)
All Urban(48)
Residential(24)
Industrial(4)
Commercial(6)
Other Urban(14)
All Rural(5)
4
5
6
7
8
9
pH

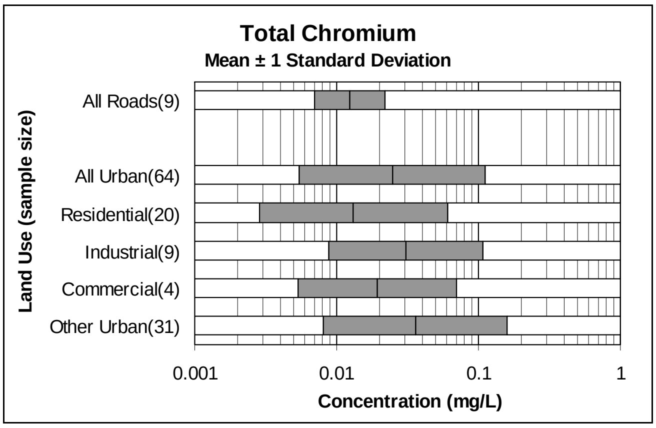

Turbidity
Mean ± 1 Standard Deviation
Land Use (sample size)
All Roofs(8)
Urban Roofs(6)
All Urban(16)
Residential(12)
0.1
1
10
100
1000
NTU

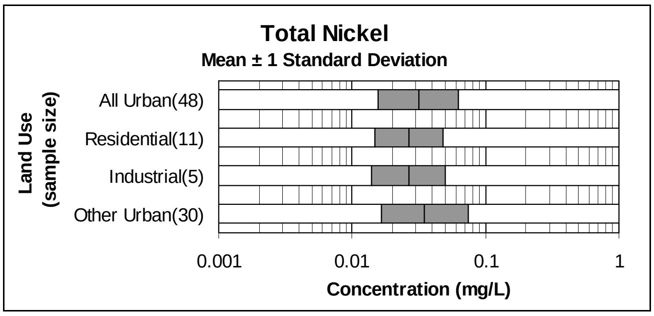

Total Lead
Mean ± 1 Standard Deviation
All Roads(44)
Urban Roads(32)
Rural Roads(11)
All Roofs(25)
Urban Roofs(18)
Rural Roofs(7)
All Urban(181)
Residential(78)
Industrial(11)
Commercial(22)
Other Urban(70)
All Rural(17)
Agricultural(4)
Other Rural(11)
Land Use (sample size)
0.0001
0.001
0.01
0.1
1
Concentration (mg/L)

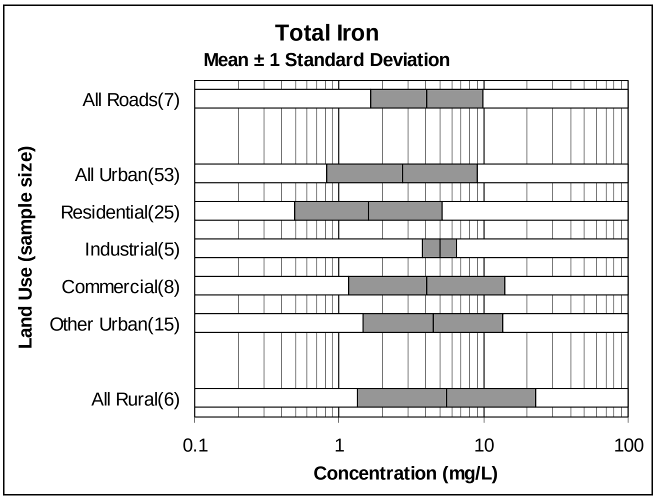

Total Zinc
Mean ± 1 Standard Deviation
All Roads(40)
Urban Roads(28)
Rural Roads(11)
All Roofs(24)
Zinc Roofs(7)
Non-zinc Roofs(10)
Unknown Roofs(7)
All Urban(156)
Residential(68)
Industrial(10)
Commercial(19)
Other Urban(59)
All Rural(8)
Land Use (sample size)
0.01
0.1
1
10
100
Concentration (mg/L)

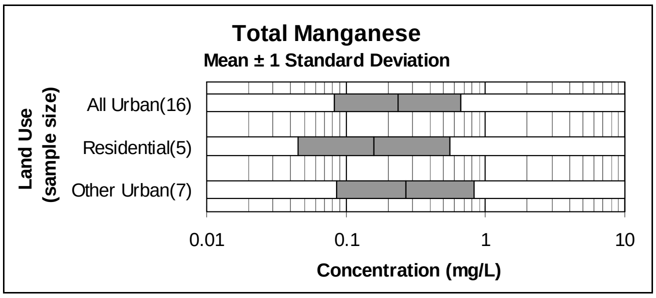

Total Copper
Mean ± 1 Standard Deviation
Land Use (sample size)
All Roads(23)
Urban Roads(17)
Rural Roads(5)
All Roofs(16)
Urban Roofs(11)
Rural Roofs(5)
All Urban(140)
Residential(59)
Industrial(11)
Commercial(14)
Other Urban(56)
All Rural(6)
0.001
0.01
0.1
1
10
Concentration (mg/L)

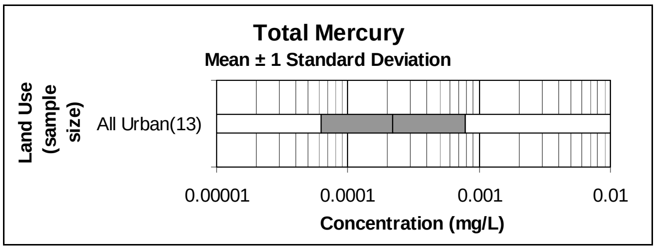

Total Cadmium
Mean ± 1 Standard Deviation
Land Use (sample size)
All Roads(17)
Urban Roads(13)
Rural Roads(4)
All Roofs(8)
All Urban(57)
Residential(21)
Industrial(7)
Commercial(5)
Other Urban(24)
0.0001
0.001
0.01
0.1
Concentration (mg/L)

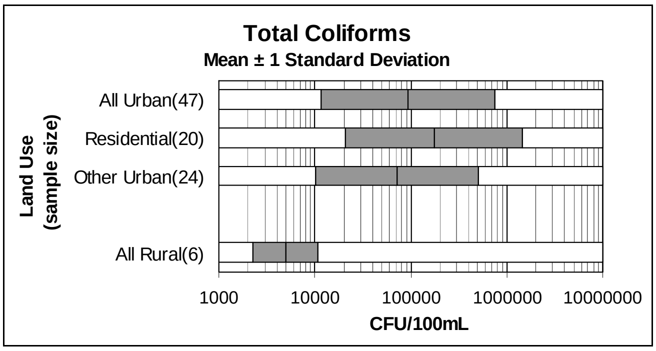

Total Chromium
Mean ± 1 Standard Deviation
Land Use (sample size)
All Roads(9)
All Urban(64)
Residential(20)
Industrial(9)
Commercial(4)
Other Urban(31)
0.001
0.01
0.1
1
Concentration (mg/L)

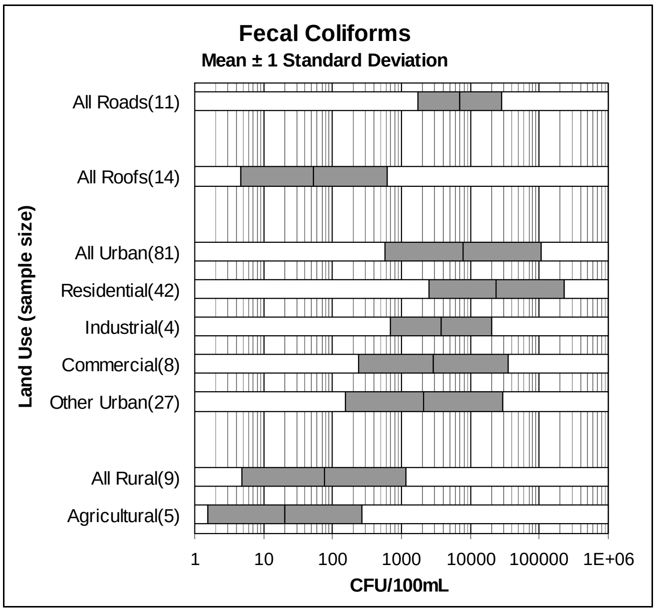

Total Nickel
Mean ± 1 Standard Deviation
Land Use (sample size)
All Urban(48)
Residential(11)
Industrial(5)
Other Urban(30)
0.001
0.01
0.1
1
Concentration (mg/L)

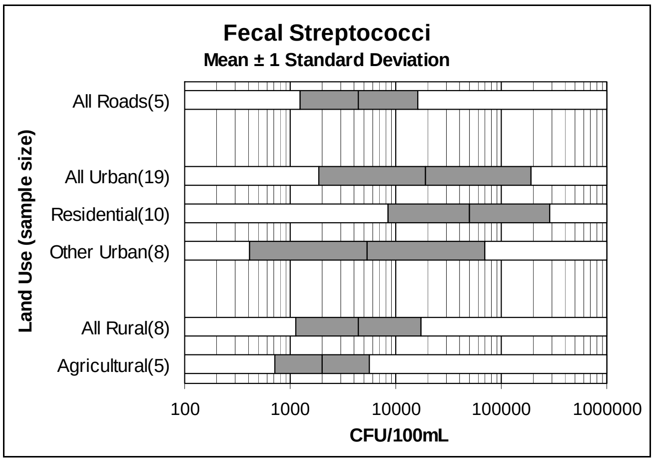

Total Iron
Mean ± 1 Standard Deviation
Land Use (sample size)
All Roads(7)
All Urban(53)
Residential(25)
Industrial(5)
Commercial(8)
Other Urban(15)
All Rural(6)
0.1
1
10
100
Concentration (mg/L)

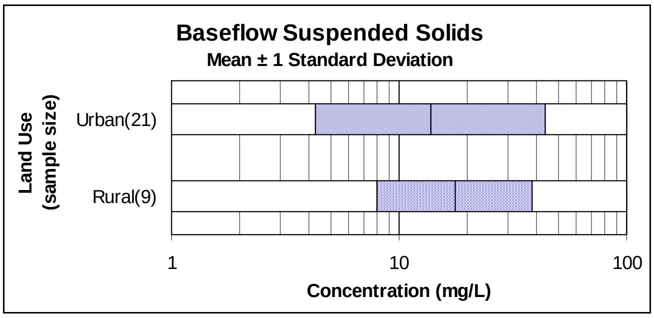

Total Manganese
Mean ± 1 Standard Deviation
Land Use (sample size)
All Urban(16)
Residential(5)
Other Urban(7)
0.01
0.1
1
10
Concentration (mg/L)

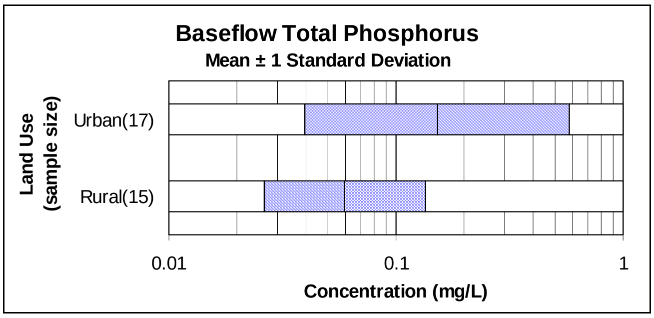

Total Mercury
Mean ± 1 Standard Deviation
Land Use (sample size)
All Urban(13)
0.00001
0.0001
0.001
0.01
Concentration (mg/L)

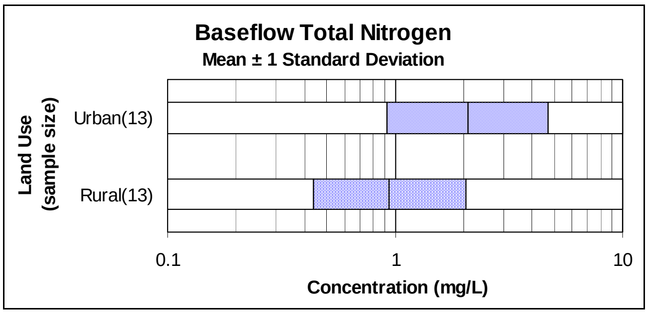

Total Coliforms
Mean ± 1 Standard Deviation
Land Use (sample size)
All Urban(47)
Residential(20)
Other Urban(24)
All Rural(6)
1000
10000
100000
1000000
10000000
CFU/100mL

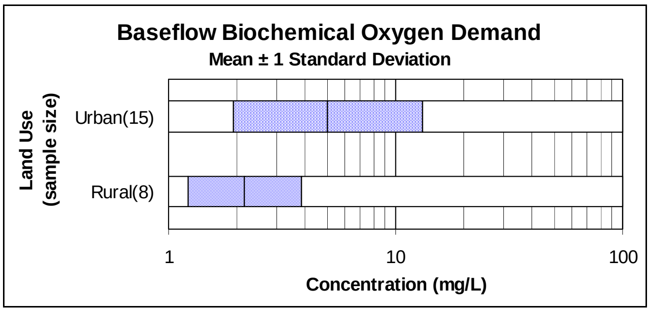

Fecal Coliforms
Mean ± 1 Standard Deviation
Land Use (sample size)
All Roads(11)
All Roofs(14)
All Urban(81)
Residential(42)
Industrial(4)
Commercial(8)
Other Urban(27)
All Rural(9)
Agricultural(5)
1
10
100
1000
10000
100000
1E+06
CFU/100mL

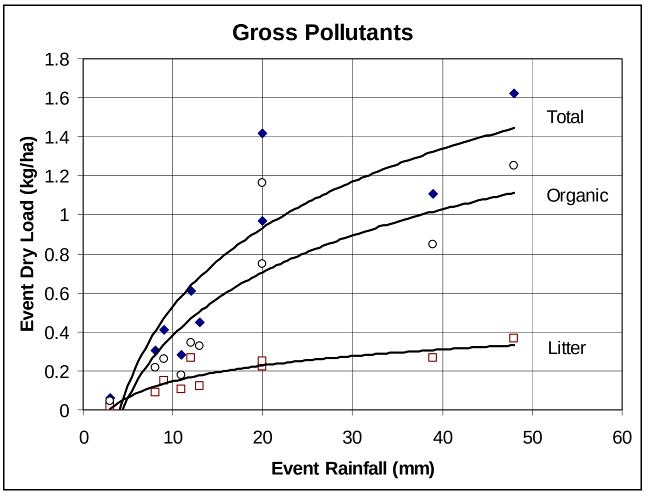

Fecal Streptococci
Mean ± 1 Standard Deviation
Land Use (sample size)
All Roads(5)
All Urban(19)
Residential(10)
Other Urban(8)
All Rural(8)
Agricultural(5)
100
1000
10000
100000
1000000
CFU/100mL


Baseflow Suspended Solids
Mean ± 1 Standard Deviation
Land Use (sample size)
Urban(21)
Rural(9)
1
10
100
Concentration (mg/L)


Baseflow Total Phosphorus
Mean ± 1 Standard Deviation
Land Use (sample size)
Urban(17)
Rural(15)
0.01
0.1
1
Concentration (mg/L)


Baseflow Total Nitrogen
Mean ± 1 Standard Deviation
Land Use (sample size)
Urban(13)
Rural(13)
0.1
1
10
Concentration (mg/L)


Baseflow Biochemical Oxygen Demand
Mean ± 1 Standard Deviation
Land Use (sample size)
Urban(15)
Rural(8)
1
10
100
Concentration (mg/L)


Gross Pollutants
Event Dry Load (kg/ha)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
Event Rainfall (mm)
Total
Organic
Litter