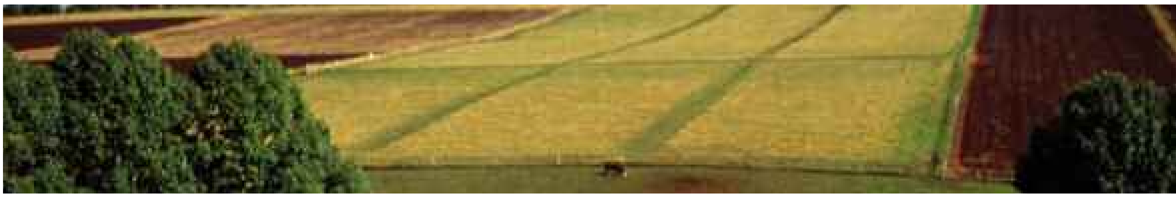
COOPERATIVE RESEARCH CENTRE FOR **CATCHMENT HYDROLOGY**

INTEGRATED STORMWATER TREATMENT AND RE-USE SYSTEMS - INVENTORY OF AUSTRALIAN PRACTICE

TECHNICAL REPORT
Report 04/1

June 2004

Belinda Hatt / Ana Deletic / Tim Fletcher



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Hatt, Belinda, 1978-

Integrated Stormwater Treatment and Re-use Systems: Inventory of Australian Practice

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ISBN 1 920813 07 1

1. Urban runoff - Australia. 2. Storm sewers - Australia. 3. Water reuse - Australia. 4. Water quality management. I. Deletic, Ana, 1965- . II. Fletcher, Tim, 1969- . III. Cooperative Research Centre for Catchment Hydrology. IV. Title. (Series : Report (Cooperative Research Centre for Catchment Hydrology); 04/1)

628.21

Keywords

Urban areas
Water supply
Stormwater
Runoff
Water treatment
Water reuse
Inventories
Recycling
Guidelines
Water quality
Integrated systems
Storage
Cost benefit analysis
Design

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Preface

The current drought in much of Australia has highlighted the need for improved management of the urban water cycle. In particular, there is now recognition that stormwater provides a potential resource, that could help to reduce demand for potable water supplies.

Clearly, utilisation of stormwater for water supply purposes depends on the quality of that stormwater, and the integration of treatment and utilisation systems is therefore critical. Monash University has embarked on a major project to develop new technologies for the collection, treatment, storage and distribution of stormwater for water supply.

In order to underpin this research, a review of existing practice in Australia was conducted. The review considers the design, construction, operation and maintenance of integrated stormwater treatment and re-use systems. It also provides information on regulations supporting (or impeding) adoption of such systems. Costs and benefits are examined, along with implementation issues, and performance. Most importantly, current gaps are examined to set priorities for future research.

There are many case studies presented in the review, and the authors would like to thank the numerous people who provided the information necessary to describe these case studies.

Funding for this project was provided by the NSW Environment Protection Authority (through its Stormwater Trust), whilst Melbourne Water, CSIRO Urban Water, Brisbane City Council and the Victorian EPA (through the Victorian Stormwater Action Program) provided in-kind support.

Tim Fletcher
Director, Institute for Sustainable Water Resources
Program Leader, Urban Stormwater Quality
CRC for Catchment Hydrology

Acknowledgements

The authors would like to thank the NSW Environment Protection Authority for funding this research project, in particular Mike Sharpin. We would also like to acknowledge in kind contributions from Brisbane City Council, Melbourne Water, CSIRO Land and Water, and the Victorian Environment Protection Authority.

This review was also made possible by the assistance of people associated with the studied stormwater re-use schemes.

The authors would like to thank Sandy Booth (University of Western Sydney), Andrzej Listowski (Sydney Olympic Park Authority) and Keith Furniss (HNJ Holdings P/L) for conducting site visits, for providing information and valuable discussion.

The following people are also thanked for providing information and discussions:

Leanne Dallmer Roach (Storm Consulting)

Peter Donley (South Sydney City Council)

Jake Matuzic (City of Canada Bay Council)

Joel Stewart (University of Western Sydney)

Christina Roman (Boyden and Partners P/L)

Daryl Edwards (Taronga Zoo)

Joanne Scarsbrick

Paul Smith (Manly Council)

Kaye Power (NSW Department of Health)

Peter Smith (Kogarah Council)

Greg Jackson (Queensland EPA)

David Mitchell (Charles Sturt University)

Anne Simi (City Design)

Lucy Peljo (Brisbane City Council)

Peter Scott (SA EPA)

Neil Kerby (Winkfield P/L)

Bill Mole (HNJ Holdings P/L)

Gary Spivak (City of Port Phillip Council)

Garry Kerans (Integrated Ecovillages)

Rebecca Brown (Hume City Council)

Ian Brown (Hobsons Bay City Council)

Sam Sampanthar (Hobsons Bay City Council)

Steering Group

Matt Francey, Melbourne Water

Tonia Giobbi, Brisbane City Council

Christine Grundy, GHD

Grace Mitchell, CSIRO Land and Water

Sean Moran, Victoria Environment Protection Authority

Graham Rooney, Melbourne Water

Mike Sharpin, NSW Environment Protection Authority

Matt Thwaites, Victoria Environment Protection Authority

Executive Summary

The use of water resources in many parts of Australia is approaching the limits of sustainability. Better integrated management of urban water (supply, wastewater and stormwater) is needed if the water needs of the expected population are to be met without further deterioration of the environment. A focal point for proposed national water conservation programmes is the use of both treated wastewater and urban stormwater.

The aim of this research was to develop an inventory of technologies for the collection, treatment, storage, and distribution of urban stormwater runoff and, where current knowledge allows, provide interim guidance on stormwater re-use implementation. General urban runoff is defined as runoff generated from all urban surfaces. Schemes that collect and re-use runoff from roofs only are not considered in this study since there is already a good deal of knowledge about this, whereas knowledge about harvesting and re-using general runoff is lacking.

This survey of existing stormwater re-use systems focussed primarily on non-potable water use (e.g. irrigation, non-potable in-house). An extensive review of existing national (focussing on the Eastern seaboard and South Australia) and international stormwater re-use systems was carried out and lessons learned from the selected case studies with respect to sizing, performance, operation, and integration into the total water cycle of re-use systems. Issues regarding optimisation of their overall performance and key factors in their successes (or failures) were also examined.

Regulation

The use of recycled water is governed by States and Territories and regulatory stakeholders. While there are specific statutory obligations under State health, environmental, agricultural or food legislation for re-use of wastewater, stormwater re-use is not regulated. It is generally recommended that guidelines for wastewater re-use be used to operate and evaluate stormwater re-use schemes. However, both the supply and quality of wastewater and stormwater are very different, therefore applying wastewater guidelines to a stormwater recycling scheme is somewhat inadequate. New National Water Recycling Guidelines are currently being developed as part of the Federal government's National Water Initiative and will address stormwater recycling, but not as a first priority.

System Components

At this stage, re-use of stormwater is largely restricted to smaller scale sites, and is mainly used for purposes with low potential for human contact (low risks), such as irrigation. Collection and storage are still based on conventional methods. Treatment is mainly based on Water Sensitive Urban Design (WSUD) techniques (swales, buffers and bio-filters, infiltration systems, wetland ponds and basins and lakes), however advanced techniques along with disinfection are utilised if there is a higher health risk.

Design

Stormwater re-use system design should satisfy end-use requirements and address the multiple objectives these systems often have. Information was readily available with respect to sizes and features of the various components incorporated into the studied re-use systems but very rarely on methods used for their determination. However, it appears that the same design methods are used for re-use schemes as for stormwater pollution control alone (e.g. Australian Rainfall and Runoff, 2003). This may cause some problems since the WSUD systems are not currently designed to deliver high water quality; in particular the reliability of treatment may be an issue. Design of surface stores (such as ponds and urban lakes) is not well defined which may present safety problems (large water level variations, or deterioration of water quality during long dry weather spells).

Construction, Maintenance and Operation

Construction tolerances in integrated stormwater treatment and re-use systems are generally finer than in conventional systems. Further, maintenance is

especially important for re-use systems in order to guarantee reliability of treated water quality. However, a number of studied sites appear to have been neglected since completion of construction. Clear specification of an operation and maintenance program should be prepared during the design process. Without this, it is likely that the integrity of a number of the systems studied is at risk, potentially impacting on public health and amenity.

Implementation Issues

Some of the most frequently encountered issues were lengthy and resource intensive negotiation, assessment and approval processes. This is largely due to a lack of pertinent experience and policies on the part of the water industry and relevant authorities. Many of the re-use schemes were the result of a partnership approach, often between the various levels of government and a private developer. This was found to be successful, since it enabled all parties' skills, roles and experience to be combined. Involving other parties, such as the design team and researchers, in the partnership was also found to be beneficial. There is significant public acceptance of domestic use of rainwater. Government grants assist with project costs, however managing grants takes a lot of time and ongoing effort. Reliable provisions and monitoring plans are fundamental elements of re-use projects, particularly given their experimental nature at this stage.

Costs and Benefits

Stormwater re-use systems offer multiple benefits, including reduced demand for potable water supply, and delay or removal of the need for stormwater drainage infrastructure expansion. Other benefits are reduced stormwater flows, pollution control, habitat creation, and protection/enhancement of downstream waterways. It has been accepted for a number of years that, to correctly assess the worth of a water servicing option, the cost of implementing a re-use scheme must be compared to the true costs of current supply and disposal practices, however little progress has been made in developing such means of comparison.

Performance

Performance results were somewhat limited, partly because most projects are still very new and there is not a lot of feedback available. In general though, developers, operators and regulators appear to be satisfied with the schemes' initial performances, and the public response has been positive.

Critique of Current Practices - Knowledge Gaps and Research Needs

Regulations and guidelines specific to stormwater recycling need to be developed to allow re-use systems to be designed effectively. There is a clear need for the development of innovative techniques for the collection, treatment and storage of stormwater. Performance modelling for evaluation purposes also needs further research. Traditional cost benefits fail to adequately assess non-monetary benefits, therefore a novel approach with well structured methodology should be developed. If the costs and benefits of re-use systems can be shown to compare favourably with the costs and benefits of conventional practices, this will provide a good deal of incentive to overcome other obstacles to widespread adoption of stormwater recycling.

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1. Introduction

1.1 Background

In recent years signs of environmental degradation, manifesting through declining quality of surface and ground water, have been observed in many parts of Australia. For example, the rivers of the Murray-Darling Basin and Hawkesbury-Nepean Basin have deteriorated in part because of urban water demands and polluted stormwater discharges (Anderson, 1996). The use of water resources in many parts of Australia is approaching, and in some urban centres exceeding, the limits of sustainability. Better integrated management of urban water (supply, wastewater and stormwater) is needed if the water needs of the expected population are to be satisfied without further deterioration of the environment.

A focal point for proposed national water conservation programmes is the re-use of both treated wastewater and urban stormwater (Anderson, 1996; Thomas *et al*., 1997; Coombes *et al*., 2002) A number of authors (Thomas *et al*., 1997; Newton *et al*., 2001; Coombes *et al*., 2002; Mitchell *et al*., 2002) have stated that there is potential for stormwater re-use schemes to expand limited primary water sources, prevent excessive diversion of water from other uses, eliminate discharges of untreated urban stormwater runoff, and minimise urban water infrastructure costs. However, this is still not widely practised in Australia, with stormwater being particularly neglected (only 8% of rainwater is used, while 14% of wastewater is reclaimed, (CSIRO, 2003)). The average annual volume of urban stormwater runoff in Australian cities is almost equal to the average annual urban water usage, of which at least 50% is for non-potable use (Mitchell *et al*., 1999). Stormwater is usually of better quality than untreated sewage or industrial discharge, and has better public acceptance for utilisation. All these factors make it a potentially valuable resource for water supply substitution (particularly for non-potable water applications).

The majority of stormwater re-use is practised as roof rainwater harvesting (Coombes *et al*., 2002), or stormwater runoff harvesting for groundwater recharging (Dillon *et al*., 1999). There are only a few examples of stormwater re-use systems that rely on general urban runoff as a source and deliver water for a variety of uses (e.g. systems in Singapore and Canberra, (WBM Oceanics Australia, 1999)). One of the main reasons for this is a lack of clear design guidance for integrated systems that could effectively collect, treat, store, and distribute stormwater runoff for general use (Thomas *et al*., 1997; WBM Oceanics Australia, 1999; Burkhard *et al*., 2000) In their nation-wide survey of water re-use, (Thomas *et al*., 1997) argued that stormwater runoff is neglected because initial infrastructure for its treatment (that could be built upon to provide re-use) is not in place (in contrast to wastewater treatment systems which are widely present). This is changing rapidly, and sustainable systems for stormwater treatment are becoming common features in Australian urban areas (they are an important part of Water Sensitive Urban Design – WSUD). Whether they are constructed wetlands, ponds, swales, or bio-filters, they all act as effective flood control measures, provide treatment of polluted runoff, and many have significant amenity potential (e.g. wetlands, swales and ponds). However, their design could be improved further to allow effective re-use of treated runoff. It is important to achieve this integration between stormwater treatment and re-use now, since WSUD technologies are being installed at a rapid rate around Australian cities. In other words, if the proper technologies are developed and adapted for the integrated stormwater treatment and re-use now, considerable environmental and economic benefits to Australia will be assured.

1.1.1 Recent Progress in the Field

Although practised separately, stormwater treatment and water re-use technologies have improved significantly in recent years. Stormwater ponds, wetlands, bio-filters, and swales (to name some of the WSUD systems) have been installed at a rapid rate around Australia. They have proven to be very effective in the removal of key stormwater pollutants, flood protection and landscape enhancement (Argue, 1998). Design manuals for these systems are now widely available (WEF and ASCE, 1997 in the USA, CIRIA, 2000 in the UK, and Victorian Stormwater Committee, 1999, and IEAust, *in prep* in Australia). The CRC for Catchment Hydrology recently launched software for conceptual design and performance evaluation of the WSUD systems for stormwater pollution control, (named MUSIC, (CRCCH, 2002)).

Current design practice of the WSUD systems does not always guarantee reliable stormwater treatment to required quality standards. Such treatment even stretches the capabilities of most traditional clarification technologies used in treatment of potable water. This paucity of technology for integrated urban stormwater treatment and re-use is one of the main challenges in efficient stormwater use. Existing practice is far ahead of research, which may pose a great danger to the future adoption of such measures. Just one high profile case of public health or environmental failure of a re-use project (conducted without sound scientific backing) could undermine public confidence in re-use nationally, costing our society time and money in the much-needed adoption of future re-use technologies.

If integrated systems are to be successful, they should become a part of the sustainable management of the total urban water cycle. The CSIRO Urban Water research team has recently completed several studies that considered both the total urban water system and the alternative technologies that can be employed to deliver sustainable solutions (Mitchell *et al*., 2002). Tools such as PURRS (Coombes, 2002), Aquacycle (Mitchell, 2000) and UVQ (Farley, 2000) have been developed to aid the assessment of total water cycle options.

It could be concluded that there are rapid developments in the areas of stormwater treatment, water re-use, and management of the total urban water cycle. These areas are developing separately, although there is a huge demand for their integration into a reliable design of systems for collection, treatment, storage, flood protection and re-use of general stormwater runoff.

1.2 Objectives and Scope of Study

The aim of this project was to develop an inventory of technologies for collection, treatment, storage, and distribution of general stormwater runoff and, where current knowledge allows, provide interim guidance on stormwater re-use implementation. General stormwater runoff is defined as runoff generated from all urban surfaces. The research focussed on general runoff and excluded schemes that collected and re-used roof runoff only, since much is already known about re-use of roof runoff, whereas there is a paucity of knowledge about general stormwater runoff re-use. The objectives of this research were to:

- Study Australian and international practices of re-use of general urban stormwater runoff;
- Identify the main components of integrated stormwater treatment and re-use systems with potential for their application in Australia;
- Identify the components' key design parameters, performance, current knowledge gaps, and obstacles to their implementation;
- Where possible, provide interim guidance on how to implement stormwater re-use (based on analysis of success factors and lessons learnt from the case studies); and
- Prioritise the key research needs to overcome the gaps and impediments.

The required performance of the integrated stormwater systems was determined in relation to water user demands. The research focused primarily on **non-potable water use (e.g. irrigation, non-potable in-house use)**. The water quality standards, volume and dynamics of water users, health issues/risks and other issues associated with community acceptance were also considered.

An extensive review of existing national and international stormwater re-use system was carried out and lessons learned from the selected case studies with respect to sizing, performance, operation, and integration into the total water cycle of re-use systems. Issues regarding optimisation of their overall performance and key factors in their successes (or failures) were also examined.

Use was made of both national and international case studies and literature. An attempt was made to contact the developer, operators and regulators of the existing systems and learn from their successes and failures. Where appropriate, this also included an examination of current practice in wastewater re-use and rainwater harvesting, and traditional wastewater treatment techniques.

From the work described above, key learnings have been drawn for sizing, performance, operation and integration into the total water cycle of re-use systems. However, the requirements to achieve successful integration of stormwater treatment and re-use are not being met by existing technologies at their present level of development. Therefore, this review identifies key design issues which require detailed investigation via laboratory, modelling or field techniques.

1.3 Study Sites

The review focuses on re-use schemes along the eastern seaboard of Australia, and South Australia. Stormwater re-use schemes from New South Wales, Queensland, Victoria and South Australia were identified and studied. Tasmania was considered, however no operational stormwater re-use schemes could be found.

Appendix A.1 briefly summarises the stormwater re-use schemes that were studied in this review. Each of these sites was studied in detail by gathering as much information as possible on their characteristics, design, construction, operation, maintenance, costs and benefits, performance, and any other relevant issues. Appendix A.2 presents all the relevant details about the stormwater re-use scheme at Figtree Place, Newcastle as an example[1]. Detailed tables of information for all sites were compiled and are presented in Appendix B.

Appendix A.3 summarises other water recycling schemes that were identified during the course of this review but not studied in detail. Reasons for not studying these sites varied:

- Not yet operational i.e. at design or construction stage;
- Recycled roof runoff only;
- Not well documented; or
- Timely information could not be gathered.

Much of the information gathered was not found in published literature. Rather, we were heavily reliant on communicating with the developer, operators and regulators of the systems for information. This presented some difficulties, although overall most were willing to contribute information. The major obstacle to gathering information seemed to be a lack of documentation of the systems. **Frequently, there seemed to be a lack of knowledge about the system and the existence of relevant reports.**

[1] This table was used to make the report writing process efficient. The required information was able to be quickly sourced for each section of the final report.

2. Current Regulatory Environment Framework

2.1 Introduction

In order to understand the current regulatory environment it is necessary to appreciate that there are considerable differences in both the quality and quantity of different water streams. It can be seen in Table 2.1 that the quality of urban stormwater is very different to the quality of wastewater. Nutrient concentrations tend to be lower in stormwater compared with greywater and wastewater, while stormwater concentrations of metals and suspended solids are generally higher. Stormwater is also very different to wastewater in terms of quantity. While wastewater supplies are relatively constant, stormwater is a highly inconsistent water source.

A recent review of the National Plumbing and Drainage Code and State plumbing regulations with respect to urban water recycling (Workman *et al.*, 2003) identified the following inconsistencies between the different regulations:

- Definition of Class A quality recycled water, domestic use and rainwater;
- Treatment of sewage and rainwater, and how the two systems are managed;
- Non-return values where multiple sources of water are used (backflow prevention);
- Marking of pipes containing waters of different quality;
- Provision in new house construction or extensions to separate water supply and sewage pipes from waters uses within the house at least to the outside of the house;
- Harnessing of rainwater tank supplies to houses; and
- Provision of multiple sources of water for the same use and how these will be interchanged (e.g. supply of laundry from tank with mains supply as a backup) (Workman *et al.*, 2003).

2.2 New South Wales

New South Wales has a policy specific to the re-use of roof runoff (NEHF, 1998) and specific guidelines for urban dual reticulation systems (Table 2.2).

State government is reviewing the guidelines available for water re-use, however re-use of general storm runoff is currently not covered in any State guidelines. A reason given for the lack of guidelines and regulations for stormwater re-use is that there has been no call to address this issue until recently (K Power, *pers. comm.*). This is somewhat surprising given that New South Wales appears to have the highest number of stormwater re-use schemes, either already operational or being planned, in Australia (perhaps with the exception of South Australia), and certainly the most prominent example of water recycling in Australia at the site of the 2000 Olympic Games in Homebush Bay.

The Department of Health and the NSW Environment Protection Agency recommend that the National Water Quality Management Strategy (NWQMS) Guidelines for Sewerage Systems: Use of Reclaimed Water be used as a guide for stormwater re-use schemes based on the final use of the water (ARMCANZ *et al.*, 2000), presented in Table 2.3.

2.3 Victoria

Permits or authorisations for stormwater re-use schemes are not required from the Victorian Environment Protection Authority (VicEPA). However, the general requirement that water re-use must not result in pollution applies. If stormwater is being supplied for re-use by a person or agency the Trade Practices Act may apply. VicEPA recommends (but does not require) that their Guidelines for Environmental Management: Use of Reclaimed Water (2002), which are specific to treated effluent, be used as a guide to evaluate and operate stormwater re-use schemes (Table 2.4).

In addition to water quality requirements, the guidelines inform about the statutory framework for re-use schemes, risk identification and risk assessment, obligations of the suppliers and users,

Table 2.1 The Quality of Different Classes of Urban Stormwater and Wastewater and the Requirements of Selected Urban Water Demands (Mitchell *et al.*, 2002)

	Class of Stormwater and Wastewater							
Quality Parameter	**Roof Runoff**	**Rain Tank**	**Stormwater**	**Untreated Greywater**	**Untreated Wastewater**	**Treated Wastewater**	**Potable Supply**	**Urban Garden Watering, Toilet Flushing, Car Washing**
Thermotolerant coliforms, cfu/100 ML	<1–124	0-10	0–6 x 10^5	6–8 x 10^6	8 x 10^6		0	<10
Viruses, org/50L								<2
Parasites, org/50L								<1
BOD5, mg/L			3–73	90–290	100–500	8–80		
pH	5.35-5.99	4.9-6.1	6.7–8.5	6.6–8.7	6.5–8	6.9–8.7	6.5–8.5	6.5–8.0
Total dissolved solids, mg/L	78-102	4-168	44–208	284–1700	250–850	520–4940	500	
Suspended solids, mg/L	0.75–204	0.4-178	13–1622	45–330	100–500	11–250		<5
Turbidity, NTU	0.75–6.5		12–34	20–>200			5	<2
Cadmium, mg/L	0.1–4	<2	0.2–46	<10		0–2	2	
Copper, mg/L	0.002–0.32		0.005–0.56	0.018–0.39	0.001–0.2	0.001–0.12	1	0.2
Iron, mg/L	<0.01	<0.01-0.1	2.4–7.3	0.094–4.37	0.3	0.03–1.6	0.3	1.0
Lead, mg/L	0.002–0.32	<0.01	0.007–2.04	<0.05–0.15	0.05	0–0.03	0.01	0.2
Manganese, mg/L			0.04–0.11	0.014-0.075	0.0003	0.02–0.08	0.1	0.2
Sodium, mg/L	4.4-12.9	3.17-16.5	12–116	29–230	70–300	41–1540	180	
Zinc, mg/L	0.02–1.1	0.4-5.3	0.026–2.4	<0.01–0.44	0.055	0.0–0.26	3	3
Total phosphorus, mg/L	0.034–0.49		0.049–2.14	0.6–27.3	4–30			
Total nitrogen, mg/L	0.65–2.84	0.3-3.6	0.50–12.6	2.1–31.5 (TKN)	20–85 (TKN)	6.1–44.2		
Nitrate, mg/L	0.1–0.87	<0.05-0.05	0.1–6.2	<0.1	5–30	0.1–19.5	50	

cfu: colony forming units
NTU: Nephelometric Turbidity Units
TKN: Total Kjeldahl Nitrogen

Table 2.2 Water Quality Criteria for Non-potable Uses Through a Dual Reticulation System (NSW Recycled Water Coordination Committee, 1993) - Non-potable In-house Use

Water Quality Objectives	**Suitable End-uses**
Tertiary Treatment	
• Faecal coliforms <1/100 ML • Coliforms <10/100 ML (in 95% of samples) • Virus <2/50 L • Parasites <1/50 L • Turbidity <2 NTU • pH 6.5-8.0 • colour <15 TCU • <0.5 mg/L Cl_2 residual	• Open access urban and residential re-use e.g. - irrigation - toilet flushing - car washing and similar outdoor uses - firefighting - water bodies for passive recreation (not involving water contact) - ornamental water bodies
Secondary Treatment	
• BOD <20 mg/L • NFR <30 mg/L	• Municipal landscape watering • Construction purposes e.g. dust suppression and sewer flushing • Aquifer recharge

Table 2.3 NWQMS Guidelines for Sewerage Systems: Use of Reclaimed Water (ARMCANZ *et al*., 2000) for Urban Non-Potable Re-use

Re-use Type	Level of Treatment	Water Quality Criteria	Monitoring	Controls
Residential • irrigation • toilet flushing • car washing • path/wall washing	Tertiary pathogen reduction	pH 6.5-8.5 ≤2 NTU 1 mg/L Cl2 residual thermotolerant coliforms <10 cfu/100 ML	pH weekly BOD weekly turbidity continuous disinfection systems daily thermotolerant coliforms daily	Plumbing controls
Toilet Flushing Closed Systems[1]	Tertiary pathogen reduction	1 mg/L Cl2 residual or equivalent level of disinfection	disinfection systems daily thermotolerant coliforms daily	Plumbing controls For non residential usage, Legionella controls and biocide dosing may be required
Municipal with Uncontrolled Public Access • irrigation open spaces, parks, sportsgrounds • dust suppression • construction sites • ornamental waterbodies	Tertiary pathogen reduction	pH 6.5-8.5 ≤2 NTU 1 mg/L Cl2 residual or equivalent level of pathogen reduction thermotolerant coliforms <10 cfu/100 ML	pH weekly BOD weekly turbidity continuous disinfection systems daily thermotolerant coliforms monthly	Colour reduction may be necessary for ornamental uses Application rates limited to protect groundwater quality Salinity should be considered for irrigation
Municipal with Controlled Public Access • irrigation open spaces, parks, sportsgrounds • dust suppression • construction sites • mines	Secondary pathogen reduction	thermotolerant coliforms <1000 cfu/100 ML	pH monthly SS monthly disinfection systems daily thermotolerant coliforms monthly	Application rates limited to protect groundwater quality Salinity should be considered for irrigation Irrigation during times of no public access Withholding period nominally 4 hours or until irrigated area is dry

treatment and distribution reliability, site selection and site management practices, monitoring, reporting and auditing programs, and environment improvement plans, all of which are relevant to stormwater re-use schemes.

2.4 Queensland

Queensland Environmental Protection Agency (QEPA) takes a similar stance to Victoria with respect to stormwater recycling. In December 2003 the QEPA released a technical review draft of the Queensland Guidelines for Water Recycling. These guidelines explicitly support re-use of stormwater but do not contain any detailed advice. Instead, proponents will be encouraged to carry out a risk assessment and prepare a Recycled Water Safety Plan for risk management. Queensland EPA is proposing to develop more detailed guidelines in the future working with industry partners.

Table 2.4 Water Quality Criteria for Non-potable Use (Vic EPA, 2002)

Class	Water Quality Objectives	Suitable End-uses
A	Indicative objectives • <10 E.coli org/100 ML • Turbidity <2 NTU • <10/5 mg/L BOD/SS • pH 6-9 • 1 mg/L Cl2 residual (or equivalent disinfection)	• Residential e.g. irrigation, toilet flushing, third pipe system • Municipal with uncontrolled public access e.g. irrigation of open spaces, water for contained wetlands or ornamental ponds • Fire protection systems
B	• <100 E.coli org/100 ML • pH 6-9 • <20/30 mg/L BOD /SS	• Municipal with controlled public access
C	• <1000 E.coli org/100 ML • pH 6-9 • <20/30 mg/L BOD /SS	• Municipal with controlled public access

2.5 South Australia

The Guidelines for Urban Stormwater Management (2002), prepared by the Patawalonga Catchment Management Board, the Torrens Catchment Management Board and Planning SA, does address stormwater re-use to a certain extent, although it does not outline specific water quality requirements. Rather it maintains that water quality must be fit for purpose. The guidelines also contain more specific requirements for particular end-uses; subject to the proposed use, origin and characteristics of the reclaimed water.

2.6 Key Learnings

Currently there are no legal requirements in Australia for reclaimed water to be substituted for fresh water. However there is a generally agreed principle that high quality water should not be used for purposes that can tolerate a lower grade (ARMCANZ *et al*., 2000).

Water re-use is governed by States and Territories and regulatory stakeholders include water authorities, water retailers, local government municipalities, environment protection authorities and health departments (Workman *et al*., 2003). At this stage stormwater re-use does not appear to be regulated, in that particular permits or authorisations are not required. In addition, there are no guidelines specific to stormwater re-use, however there does seem to be a few general rules that apply nationwide:

- re-use of stormwater must not result in pollution of the environment in any way;
- quality and quantity must be fit for purpose;
- it is unclear whether re-use of general storm runoff for potable purposes is permitted in urban areas (in some cases roof runoff is, reclaimed wastewater is not); however it is envisaged that it would not be acceptable for potable re-use unless approved by the authority.

It must be noted that, whilst the first general requirement appears perfectly reasonable, the analysis should really consider the net pollutant load (and its temporal distribution) under alternative management scenarios, with the aim of achieving best achievable outcome. For example, to preclude stormwater re-use in the situation where there was a small residual

Table 2.5 Water Quality Criteria for Non-potable Uses (PCWMB *et al*., 2002)

Class	Water Quality Criteria	Suitable End-uses
A	• < 10 *E.coli*/100 ML • Turbidity < 2 NTU • < 20 mg/L BOD	• Primary contact recreation • Residential non-potable e.g. irrigation, toilet flushing, car washing, path/wall washing • Municipal use with public access/adjoining premises • Dust repression with unrestricted access
B	• <100 *E.coli* org/100 ML • < 20 mg/L BOD • < 30 mg/L SS	• Secondary contact recreation • Ornamental ponds with public access • Municipal use with restricted access • Dust suppression with restricted access • Fire fighting
C	• <1000 *E.coli* org/100 ML • < 20 mg/L BOD • < 30 mg/L SS	• Passive recreation • Municipal use with restricted access

pollutant load to receiving waters, when the alternative of not re-using stormwater would result in a larger pollutant load being discharged, seems non-sensical.

There are specific statutory obligations under health, environmental, agricultural or food legislation for re-use of wastewater (this varies from state to state). The suite of documents that comprise the NWQMS include guidelines for use of reclaimed water, specific to effluent arising from municipal wastewater plants (ARMCANZ *et al*., 2000), and most States either refer to this for guidance on stormwater re-use or appear to have based their own State guidelines on this document. The NWQMS provides guidance for specific reclaimed water applications in terms of type of re-use, level of treatment, reclaimed water quality, reclaimed water monitoring, and controls. New National Water Recycling Guidelines are currently being developed as part of the Federal Government's National Water Initiative and will address stormwater recycling but not as a first priority (G. Jackson, *pers. comm.*).

3. Integrated System Components

3.1 Introduction

There are a multitude of methods for stormwater re-use. In general, an integrated urban stormwater system must provide four core ***functions:***

(a) collect stormwater runoff,

(b) treat runoff water,

(c) store the treated water,

(d) distribute water to the end-user.

In Figure 3.1, these functions are presented alongside lists of possible techniques that could be utilised for their accomplishment. These techniques are defined as ***components*** of the integrated stormwater system. Wherever possible, each component of the system should perform more than one function (e.g. a large wetland could perform treatment, storage and flood control, as well as provide amenity to the community).

In a similar way more than one component should be used for each function (e.g. treatment could be performed by a sequence of a bio-filter, wetland, fine polishing filter, and disinfection unit).

The system should deliver water to the end-users according to their needs, taking into account the pattern of the supply (spatial and temporal distribution of stormwater runoff) and flood protection requirements. The system should be fully integrated into the urban water cycle and the surrounding environment (adding to the amenity value of the area), and operated to protect urban waterways. Wherever possible, it should use 'natural' processes for water treatment and minimise utilisation of resources and energy.

It is important to note that treatment measures are really a 'continuum', and that hybrids and adaptations of all the known treatments often occur. ***Treatment trains*** should be based on principles of WSUD, starting from the current practices (Wong, 2003).

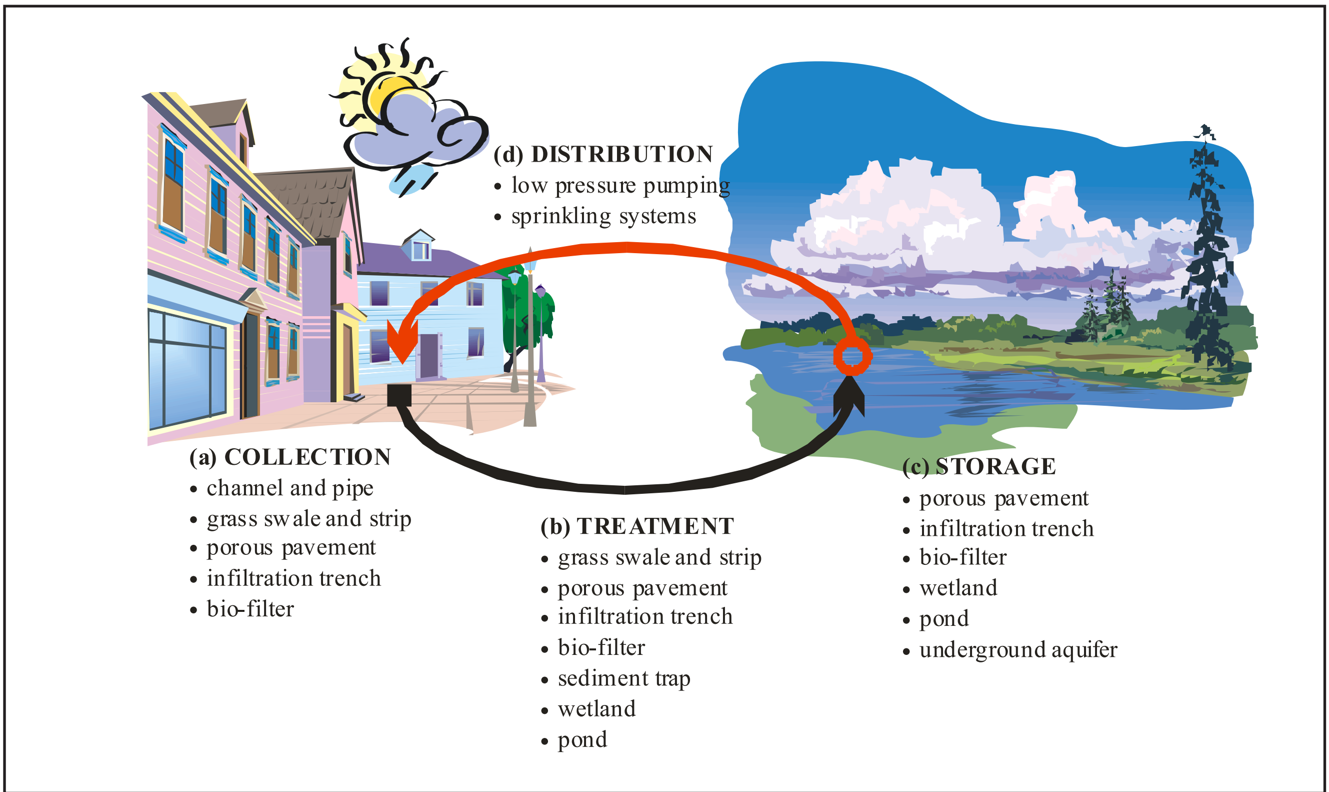

Figure 3.1 The Main Functions of Integrated Stormwater Treatment and Re-use Systems (components that could be used for performing each function are listed)

Stormwater can be a highly inconsistent source of water. Storage is essential for smoothing the temporal variability in availability of stormwater. Therefore, the 'easiest' or most efficient end-uses are those that involve regular (e.g. daily) demand, such as toilet flushing. In general, the potential for re-use depends on end-uses that can accept stormwater as a substitute for mains water.

The ***components*** (mainly based on WSUD principles) that are usually employed in stormwater recycling systems are listed below.

1. Traps

Gross pollutant traps (GPTs) range from simple screens to structures that straddle channels. GPTs remove gross pollutants using various combinations of screening, stalling flow, settlement, flotation and flow separation, and are generally most effective for mid-range rainfall events. GPTs are generally not effective in the removal of fine or dissolved pollutants.

Sediment traps prevent coarse sediment from discharging to downstream treatment measures. They range from simple earthen or concrete basin designs to complex structures using vortices and secondary flows. Sediment traps are generally not effective in the removal of fine or dissolved pollutants.

2. Swales, Buffers and Bio-filters

Swales are open, vegetated channels, basically a long shallow linear depression with low sloping sides and a broad width-to-depth ratio. Swales are used to reduce runoff velocity and retain coarse sediments. Their effectiveness in the removal of fine sediments and dissolved pollutants is variable. When used for stormwater collection for re-use they should not promote infiltration, rather they should minimise infiltration, conveying inflows to downstream receiving waters and thereby maximising the volume of water collected for re-use.

Buffer strips are grassed surfaces that reduce velocity of flow, infiltrate water and therefore remove sediment and associated pollutants. Grass can also remove some soluble pollutants.

Bio-filters are vegetated buffers on top of a filtration medium (e.g. sandy loam, sand and/or gravel). They may also incorporate sub-soil drainage pipes, geotextile layer separation and biologically engineered soils targeted to local pollution characteristics. Bio-filters facilitate flow attenuation, sediment and pollutant removal. As above, the ex-filtration should be subdued.

3. Infiltration and Filtration Systems

Porous pavement systems consist of a porous surface overlaying a filter layer (a bedding material), that is placed on top of a sub-base (usually divided by geotextile). The porous surface can be modular (unbound individual and non-porous blocks, laid down with gaps in between), or monolithic (asphalt or concrete without fine aggregate - the entire surface is porous). Some porous pavement includes a modular lattice arrangement, in which infiltration media is placed, and grass then seeded. The sub-base should contain a collection pipe for drainage. As above the ex-filtration should be subdued if used for collection of stormwater for re-use.

Sand filters are effective in removal of sediment and adsorbed pollutants. They comprise collection chambers, part filled with sand, through which stormwater passes. A variety of different types of filter medium may be employed to target specific pollutants. Sand filters require periodic maintenance through removal of the top layer of sand where oils and sediments are retained.

Biologically engineered soils are soils containing naturally occurring and/or bio-engineered micro-organisms that degrade toxic pollutants (e.g. PCBs, hydrocarbons, organophosphates, herbicides and pesticides), and organic materials that remove nutrients as stormwater infiltrates through the soil.

Infiltration basins (trenches) are detention basins that incorporate seepage through the floor of the basin. They provide flood protection and reduce storm flow velocities, and can retain pollutants including suspended solids, oxygen-demanding materials and nutrients. They represent a combination of infiltration and retention systems. As in the case of other infiltration systems, ex-filtration should be suppressed.

4. Wetlands

Wetlands, whether natural or constructed, offer water quality improvement, landscape amenity, recreational opportunities, habitat provision and flood retention. They may be either free water surface or subsurface flow wetlands. Free water surface wetlands are essentially basins or channels with a subsurface barrier to minimise seepage, and emergent vegetation to treat water. The role of vegetation in wetland performance is critical, and they can be quite effective in the removal of fine sediment and dissolved pollutants. Subsurface flow wetlands are channels or basins that contain gravel or sand media that supports emergent vegetation growth. Water flows through the root zone of the wetland plants beneath the gravel surface.

5. Stormwater Ponds

Ponds and basins (settling ponds, detention/retention ponds) are constructed ponds utilised to intercept and treat runoff. They are largely open water bodies of several metres depth. Treatment is achieved by a combination of sedimentation, biological uptake, and exposure to ultra-violet (UV) light.

Urban lakes, dams and reservoirs are also placed in this category. They are typically artificial and are constructed for the storage and treatment of stormwater. They may also contribute local amenity benefits e.g. aesthetic appreciation, habitat provision. Treatment is achieved, as in ponds, by a combination of sedimentation, biological uptake, and exposure to UV light.

6. Other

Conventional drainage systems are traditional gutter/channel/pipe systems. They are very commonly used for collecting and conveying stormwater runoff into the WSUD systems listed above. A channel may be a concrete or non-lined channel, or a main trunk drain.

Natural drains are natural depressions in the terrain that convey runoff. They may include small creeks and burns.

Advanced treatment includes microfiltration, reverse osmosis, dissolved air flotation, electrolysis, aeration and biological treatment. In general, where advanced treatment is utilised, a number of methods are incorporated in the treatment train.

Disinfection methods utilised by the case study sites include chlorine and UV light disinfection.

Conventional water tanks are simple structures used to store water (usually rain and roof runoff).

Aquifer storage and recovery (ASR) involves artificial recharge of suitable unconfined or confined aquifers through surface spreading basins, infiltration trenches, infiltration wells or direct injection wells. The water is subsequently recovered for re-use. ASR assists in reducing groundwater salinity, flood mitigation and increasing potential for larger water allocations from the aquifer.

3.2 Survey of the Components and End-Use Types

A survey was carried out to determine which components listed were used for the main functions of the stormwater re-use systems (i.e. collection, treatment, storage, and distribution), and how often. Similarly, end-use types and the frequency of their occurrence were determined. Table 3.1 presents the results of the survey.

In this analysis **other outdoor use** is defined as car washing, window washing, and use in water features, ornamental ponds etc. **Other use** includes industrial re-use, backup supply, bus washing and groundwater recharge (without recovery).

The basic statistical analysis of the results presented in Table 3.1 is discussed in the following five sections. The effect of catchment size on the frequency of the components is also discussed. Four different catchment sizes were analysed: <5 ha (nine sites), 5-200 ha (four sites), 200-500 ha (two sites), and >500 ha (two sites).

Table 3.1 Summary of Components against Functions (the number indicates how many structures have been implemented for each function e.g. at Manly there are two different types of infiltration systems used for treatment)

	Bobbin Head Road	Figtree Place	Kogarah Town Square	Manly STAR	Powells Creek	Taronga Zoo	Bowies Flat	Parfitt Square	Altona Green Park	Inkerman Oasis	CSU Thurgoona	Solander Park	Oaklands Park	Santa Monica	Hawkesbury	Homebush Bay	Parafield	Total
End-Use																		
Irrigation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
Firefighting	1												1			1		3
Environmental Flows					1						1				1	1		4
Other		1			1										1		1	4
Toilet Flushing			1			1				1			1	1		1		6
Other Outdoor Use		1	1			1							1			1		5
Collection																		
Gutter	1	1		1	1	1	1	1	1	1		1		1	1	1	1	14
Pipe			1		1	1	1		1	1		1		1	1	1	1	11
Natural Drainage	1								1	1	1	1	1					6
Channel							1					1		1	1		1	5
Swales and Buffers											1		1			1		3
Infiltration Systems				1	1											1		3
Treatment																		
Litter and Sediment Traps	1			2		1	1	1		1		1		1		1		10
Swales and Buffers								1	1		1		1			1		5
Wetlands	1							1		1	1				1	1	1	7
Ponds, Basins Lakes							1								1			2
Infiltration Systems	1	1	1	2	1			1		1		1				1		10
Advanced Treatment						4				1		1		3		2		11
Disinfection						1				1				1		1		4
Storage																		
Tank	1		1	1	1	1			1	1		1		1		1		10
Ponds, Basins and Lakes						1	1				1		1		1	1	1	7
Aquifer		1						1									1	3
Wetlands																1		1
Distribution																		
Irrigation System	1		1	1	1		1	1	1	1		1		1				10
Pumping											1				1		1	3
Dual Reticulation		1	1			1				1			1	1		1		7

3.3 End-Use

Various end-uses for harvested stormwater were identified, each having particular quality and quantity requirements, as discussed below.

Re-use for irrigation includes watering of residential gardens, public open space, parks and sportsgrounds. Irrigation of private gardens will require water of a higher quality than for irrigation of areas with controlled public access since primary contact is more likely. A fundamental water quality consideration for all irrigation is salinity. Quantity requirements and the distribution method employed will depend on factors such as scale, climate, vegetation type and provision of a backup supply. Toilet flushing and other outdoor end-uses would require similar considerations as for residential irrigation with respect to both quality and quantity.

The quality of stormwater re-used for firefighting would not need to be as high as for residential non-potable use since the likelihood of primary contact occurring is less. The most important concern for firefighting end-uses is reliability of supply and sufficient water pressure.

Stormwater re-used for environmental flows would need to be of a quality that would not cause detriment to either the quality or the ecology of the water body to which the stormwater is discharged. Re-use for groundwater would require similar water quality considerations. Required quantity is probably more flexible for environmental flows than for other end-uses, in that many urban waterways are already stressed, especially in terms of flow and therefore any water released to them as environmental flows is likely to be beneficial.

The required quality and quantity of stormwater re-used in industrial processes will be largely dictated by the particular process. A requirement common to all industrial re-use would be water of a sufficient quality to ensure machinery is not damaged or its lifespan shortened. Reliability of supply would be necessary to maintain productivity unless a backup supply is incorporated into the system.

Figure 3.2 presents the frequency of a particular end-use type. It is clear that irrigation is the most common type of end-use (44%), followed by toilet flushing (15%) and other outdoor uses (13%). Re-use for

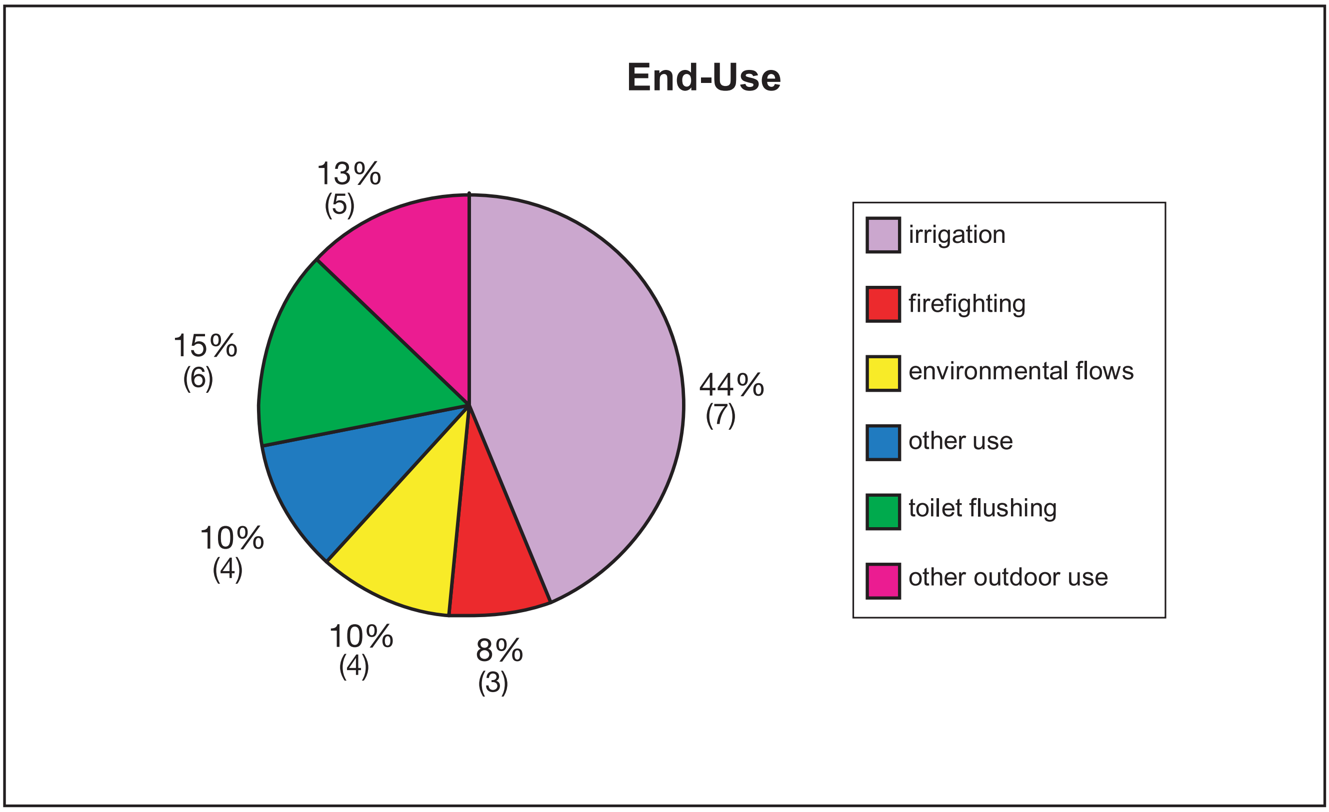

Figure 3.2 Frequency of End-Use Types

environmental flows (10%) and other uses (10%) are next, with re-use for firefighting least common (8%). All these end-uses would require pathogen removal to some extent, perhaps with the exception of environmental flows. The level of pathogen reduction required is determined by the degree to which public access is controlled and thus the likelihood of primary contact occurring.

Figure 3.3 displays the influence of catchment size on the occurrence of the various re-use types. Although the entire range of re-use types is largely employed across all size classes (i.e. size does not seem to restrict re-use types), it appears that re-use for irrigation purposes is more present in smaller catchments than at larger sites.

3.4 Collection

Figure 3.4 presents the frequency of application of particular components for collection. The most common method of collection utilised by the study sites were conventional methods (70% of cases) i.e. gutters, pipes and channels. Natural drainage (14%) and elements of WSUD (14%) were not widely utilised for collection purposes. This may be because conventional pipes and gutters are well developed. Further, they are hydraulically efficient and thus deliver the maximum proportion of runoff to the storage.

Figure 3.5 presents the distribution of components according to their respective catchment sizes. Both conventional drainage systems and WSUD elements

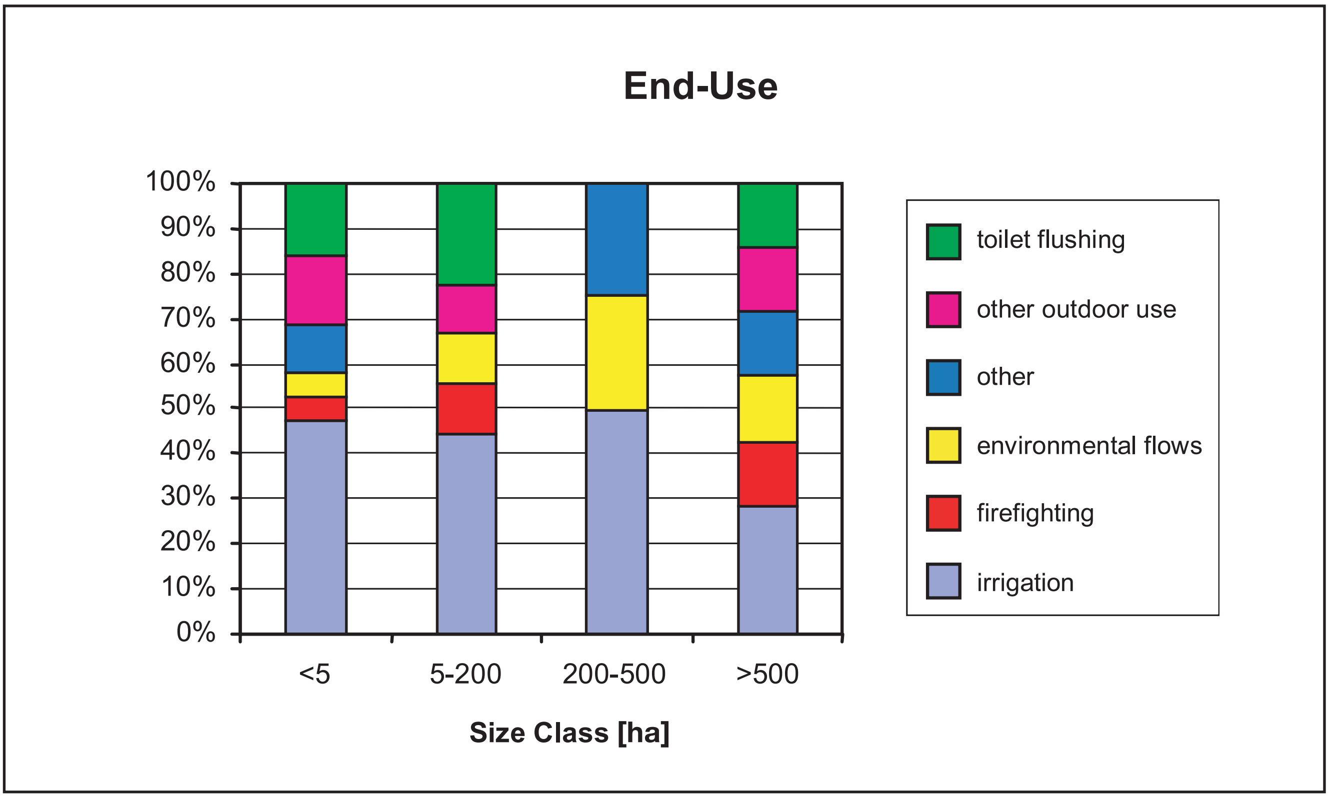

Figure 3.3 Influence of Catchment Size on the Frequency of End-Use Type

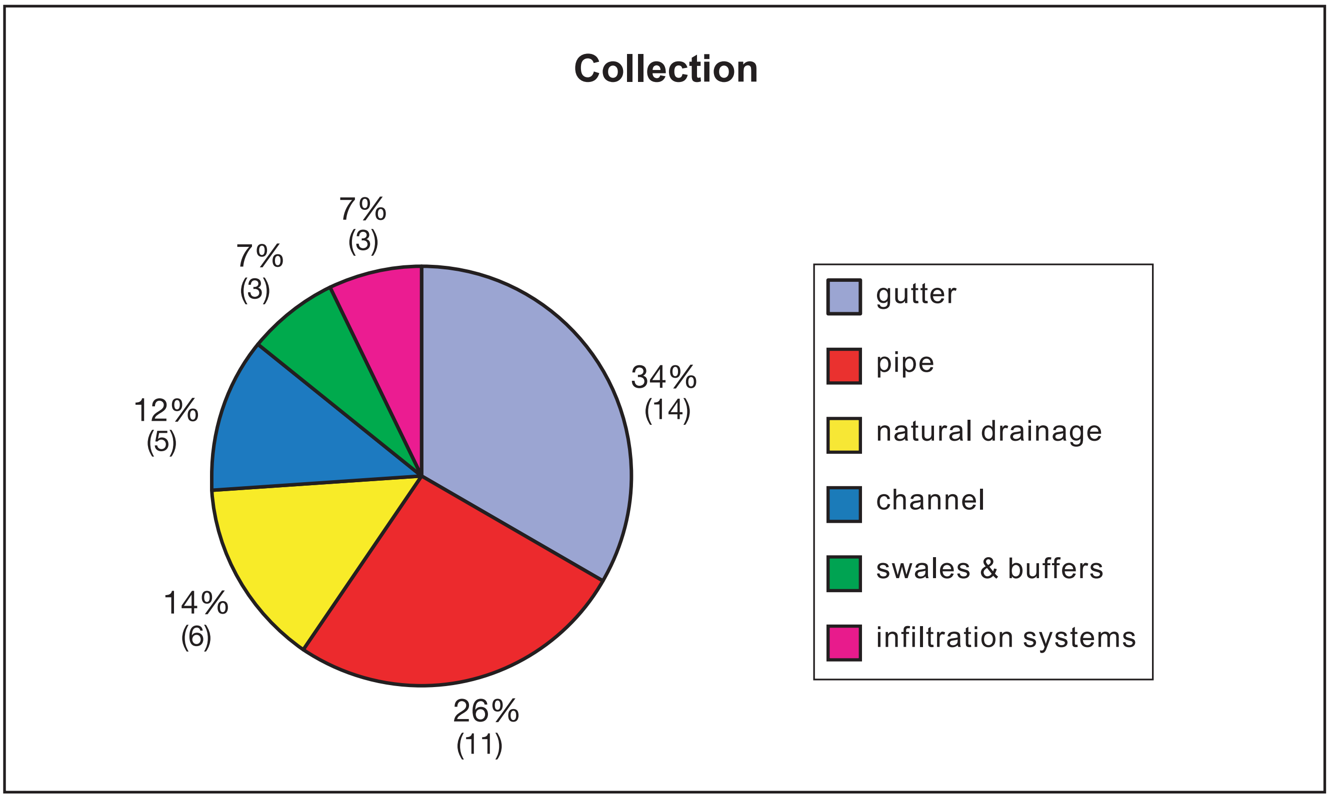

Figure 3.4 Frequency of Components Used for Collection Purposes

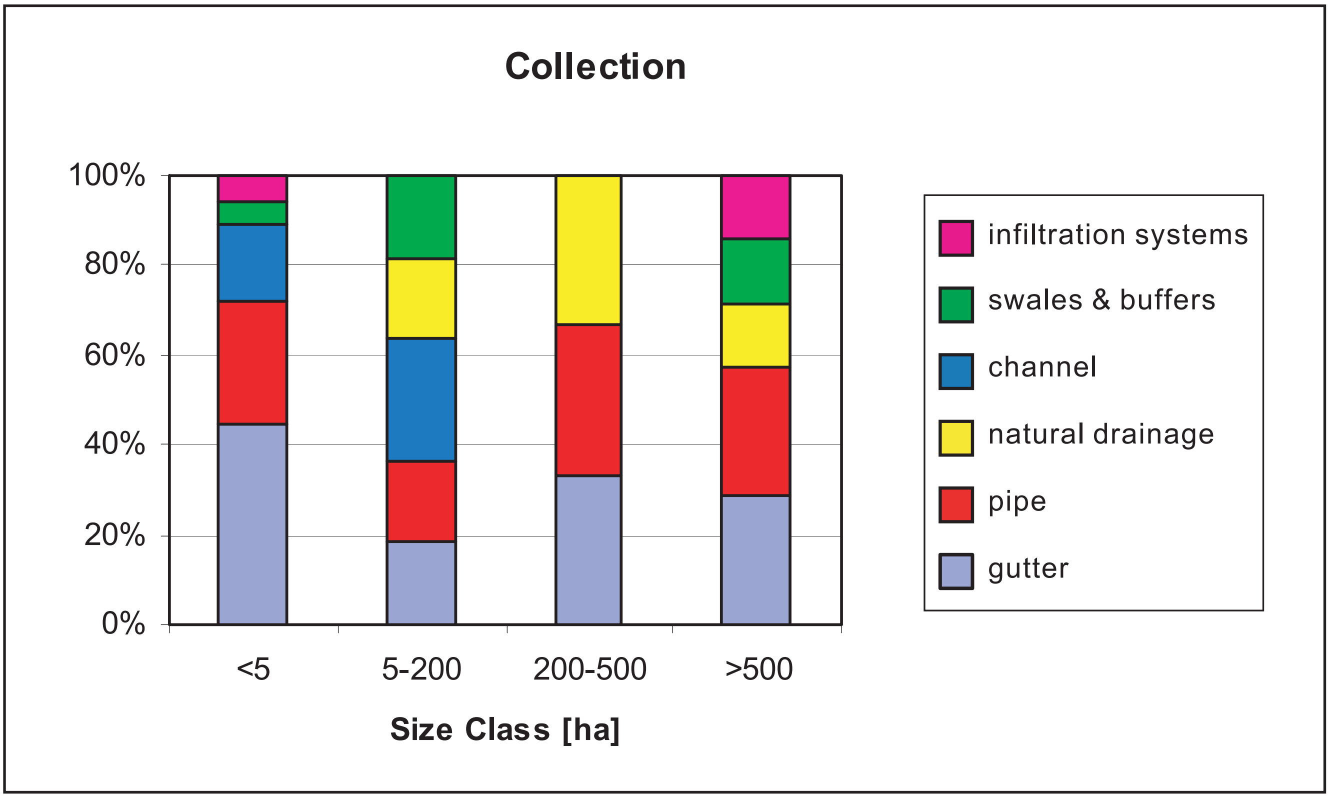

Figure 3.5 Influence of Catchment Size on Collection Component Frequency

were employed across all size classes. Natural drainage tended to be utilised by systems with a catchment area less than 200 ha.

3.5 Treatment

Figure 3.6 illustrates how frequently a particular component was utilised for stormwater treatment, while Figure 3.7 demonstrates the influence of catchment size. Finally, Figure 3.8 presents the distribution of components used for treatment according to end-use type.

In general, all treatment methods were used to some extent across all size classes. WSUD treatment methods (litter and sediment traps, swales and buffers, wetlands, ponds and basins, and infiltration systems) were most common.

The use of wetland systems for treatment purposes was more common among the larger scale systems. This is not surprising given that, although wetlands are scaleable, their maintenance costs as a percentage of capital costs increase as size decreases. Wetlands may therefore be a less feasible option for small sites. Similarly, infiltration systems were more common at smaller sites, since these systems are multifunctional and therefore an efficient use of space.

The high occurrence of advanced methods of treatment (20% of cases) is somewhat misleading, in that where advanced treatment was utilised there were usually several methods combined to form a treatment train. For example, there are four methods of advanced treatment in the 5-200 ha size class, however three of these are part of the treatment train at the Santa Monica site. Further, the relatively large proportion of sites where advanced treatment was employed to treat stormwater for irrigation purposes may seem surprising, however, in such systems stormwater was also re-used for toilet flushing. Disinfection is more common if water is to be used for purposes where human contact is more likely (Figure 3.8).

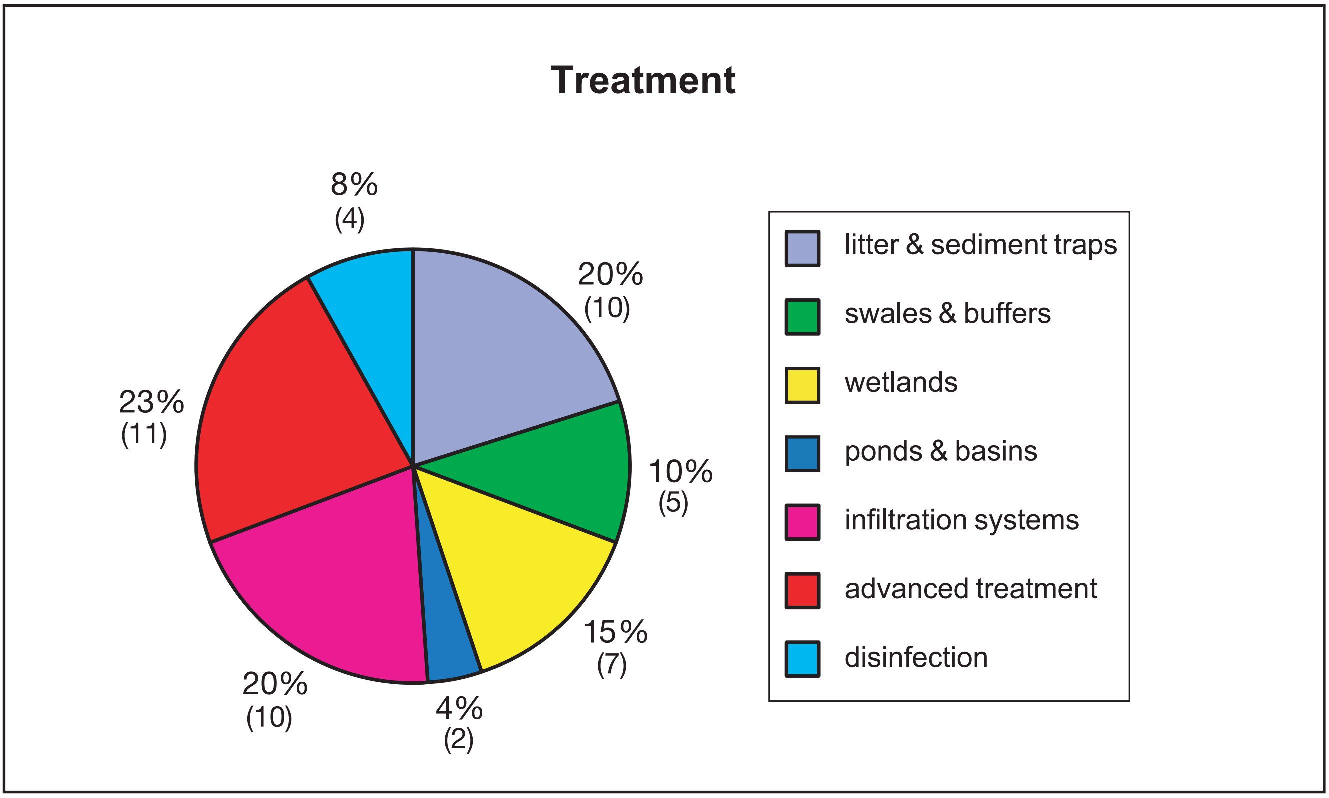

Figure 3.6 Frequency of Components Used for Treatment

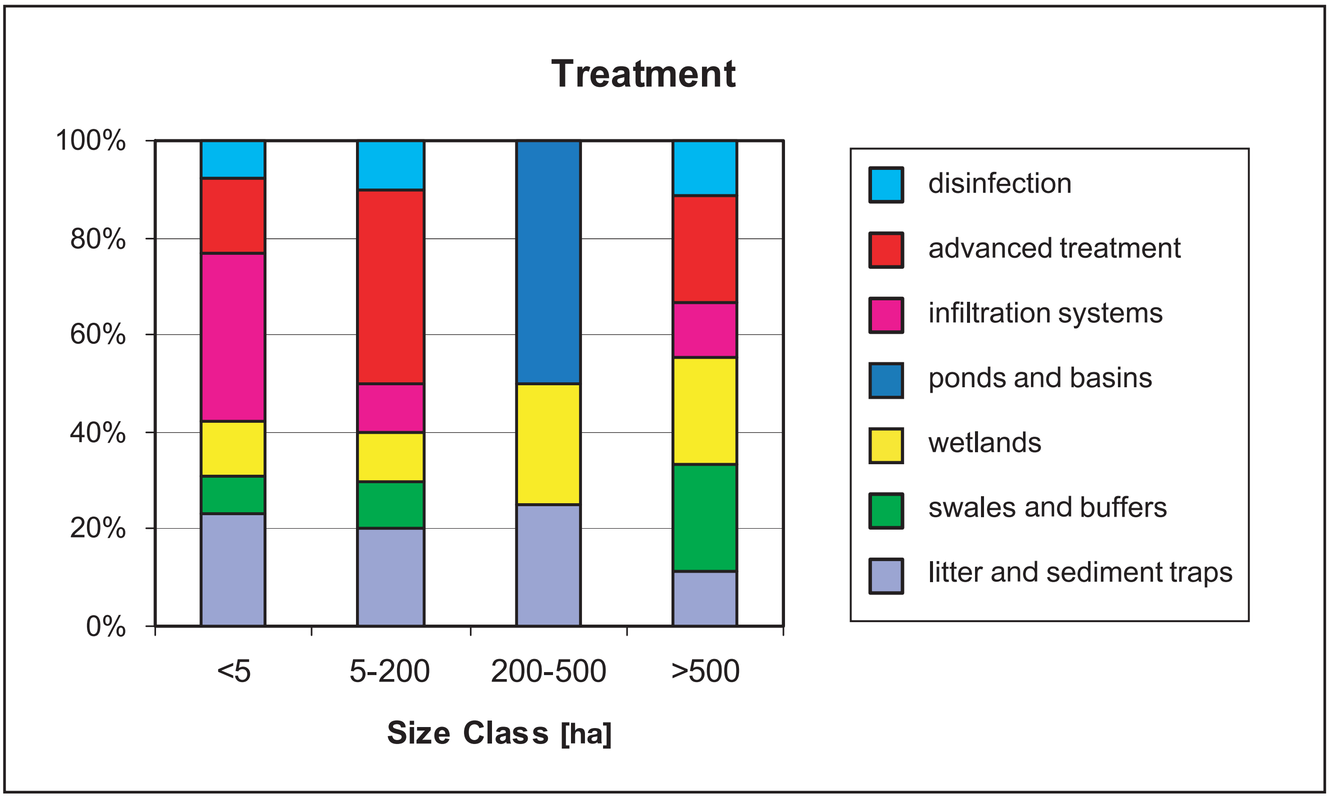

Figure 3.7 Influence of Catchment Size on Treatment Component Frequency

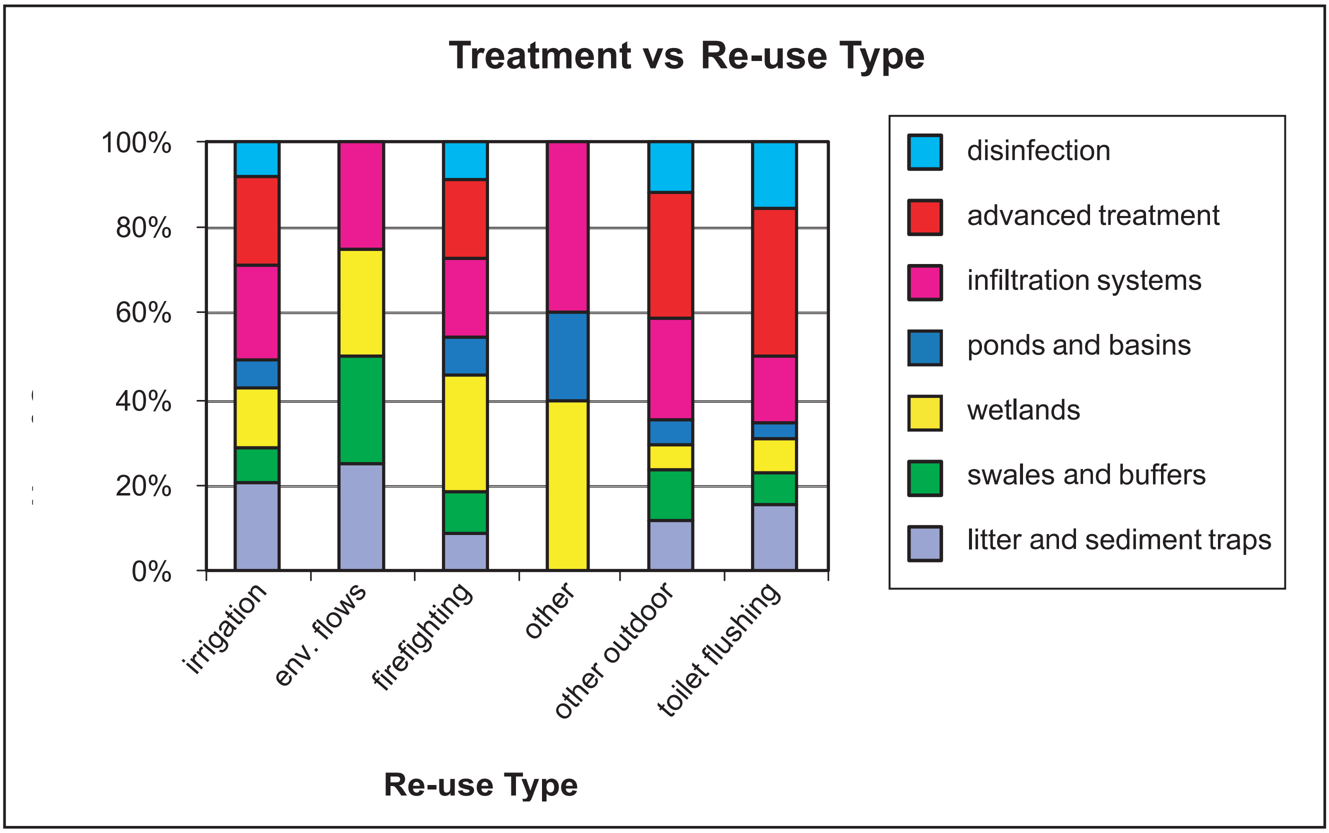

Figure 3.8 Influence of Re-use Type on Treatment Component Frequency

3.6 Storage

As shown in Figure 3.9, tanks were the most widely utilised method of storage (45% of cases). Where ponds and basins were used for storage purposes (32% of cases), it was mostly in the form of larger dams and reservoirs rather than smaller ponds. The use of wetlands and aquifers for storage was infrequent and, in the case of aquifers, restricted to South Australia and New South Wales. The use of aquifers for storage is likely to be constrained to areas with soils of high permeability and easily accessible aquifers.

The use of tanks for storage decreases as the catchment area increases (Figure 3.10). In the same way, the use of ponds, basins, and lakes increases with the catchment size. However, the scale of the stormwater re-use scheme does not appear to preclude the use of other storage methods.

With the exception of aquifer storage, all storage methods are used for all re-use types, as shown in Figure 3.11. However, it appears that aquifer storage is only utilised where the end-use has the lowest exposure potential to humans i.e. irrigation, other outdoor use, and other use. This may be because the interaction with another water source, namely, the groundwater increases the potential for pollution problems, particularly if the groundwater is polluted.

On the other hand the use of ASR for recycled water is relatively new and adoption of this technique may become more widespread with both further development and increased awareness.

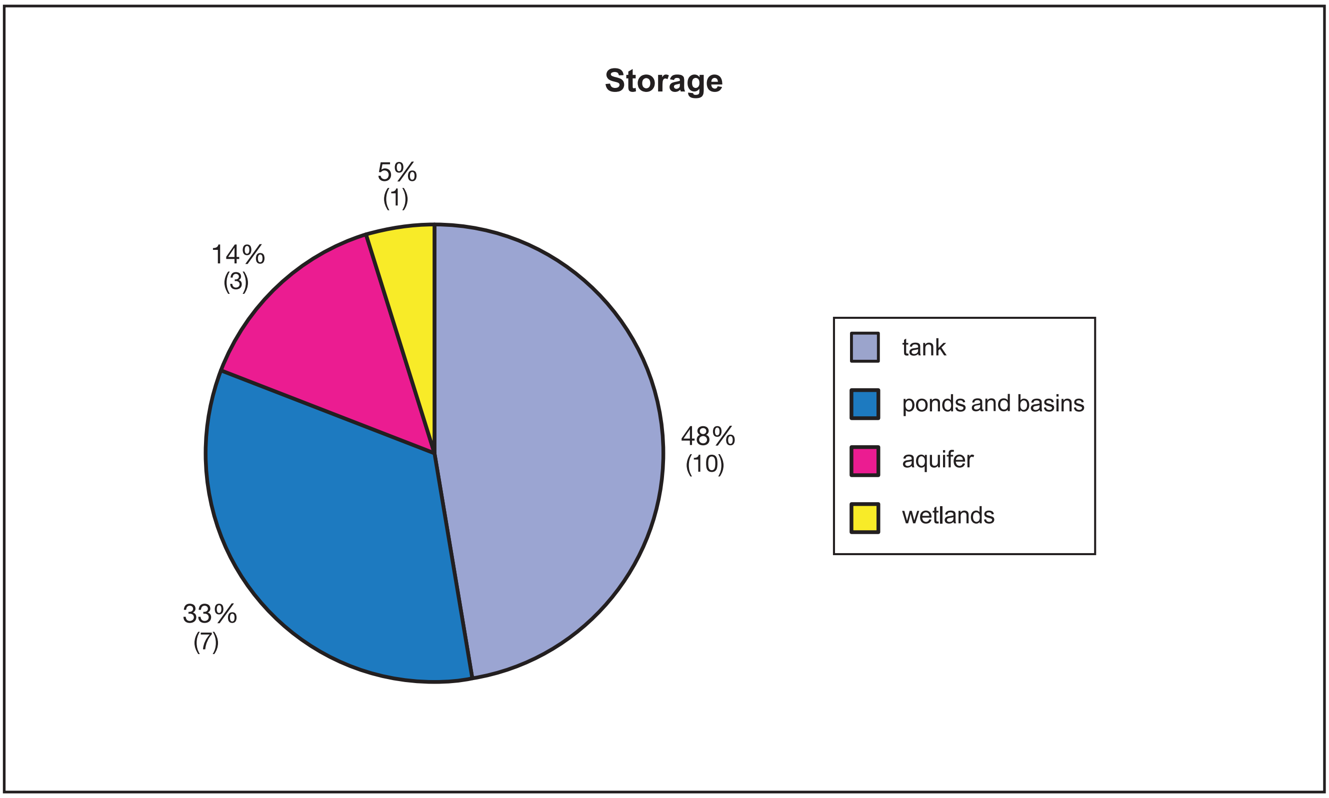

Figure 3.9 Frequency of Components Used for Storage Purposes

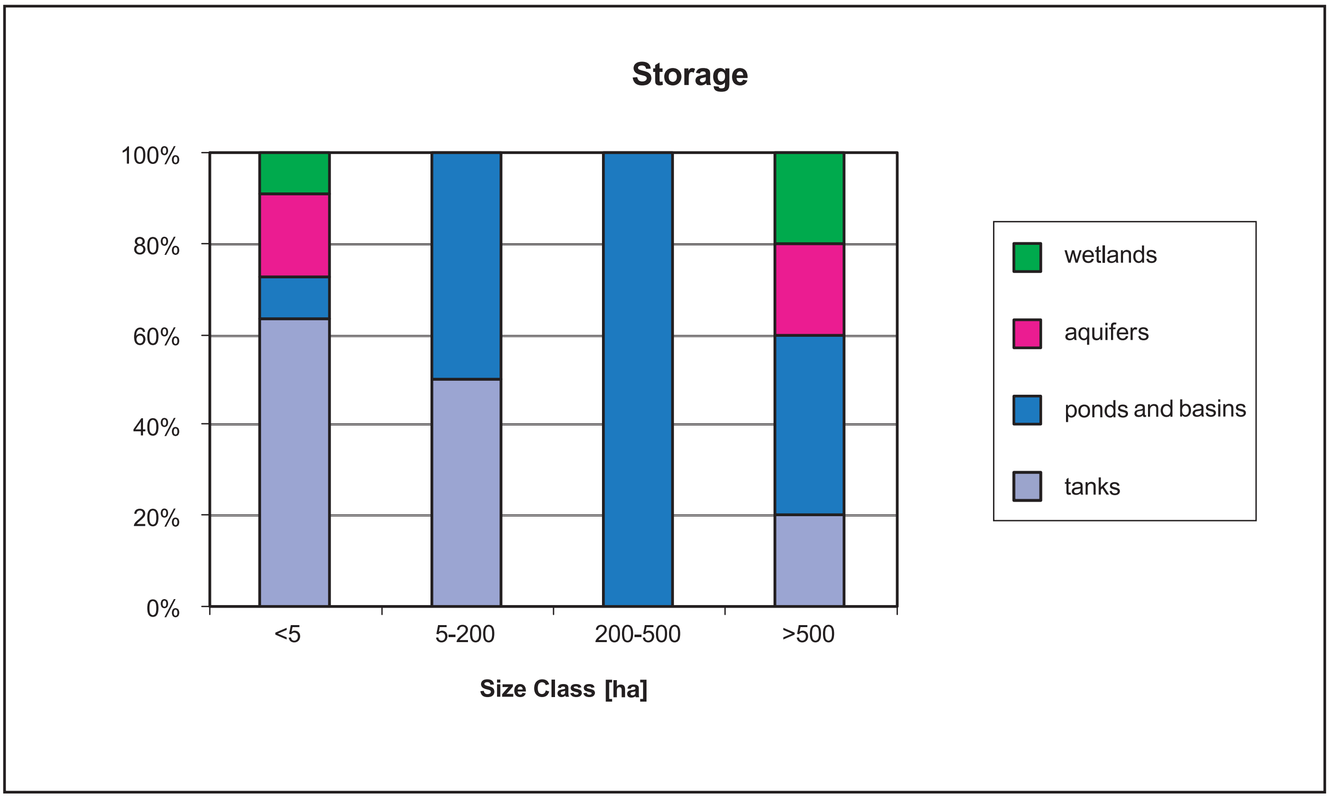

Figure 3.10 Influence of Catchment Size on Storage Component Frequency

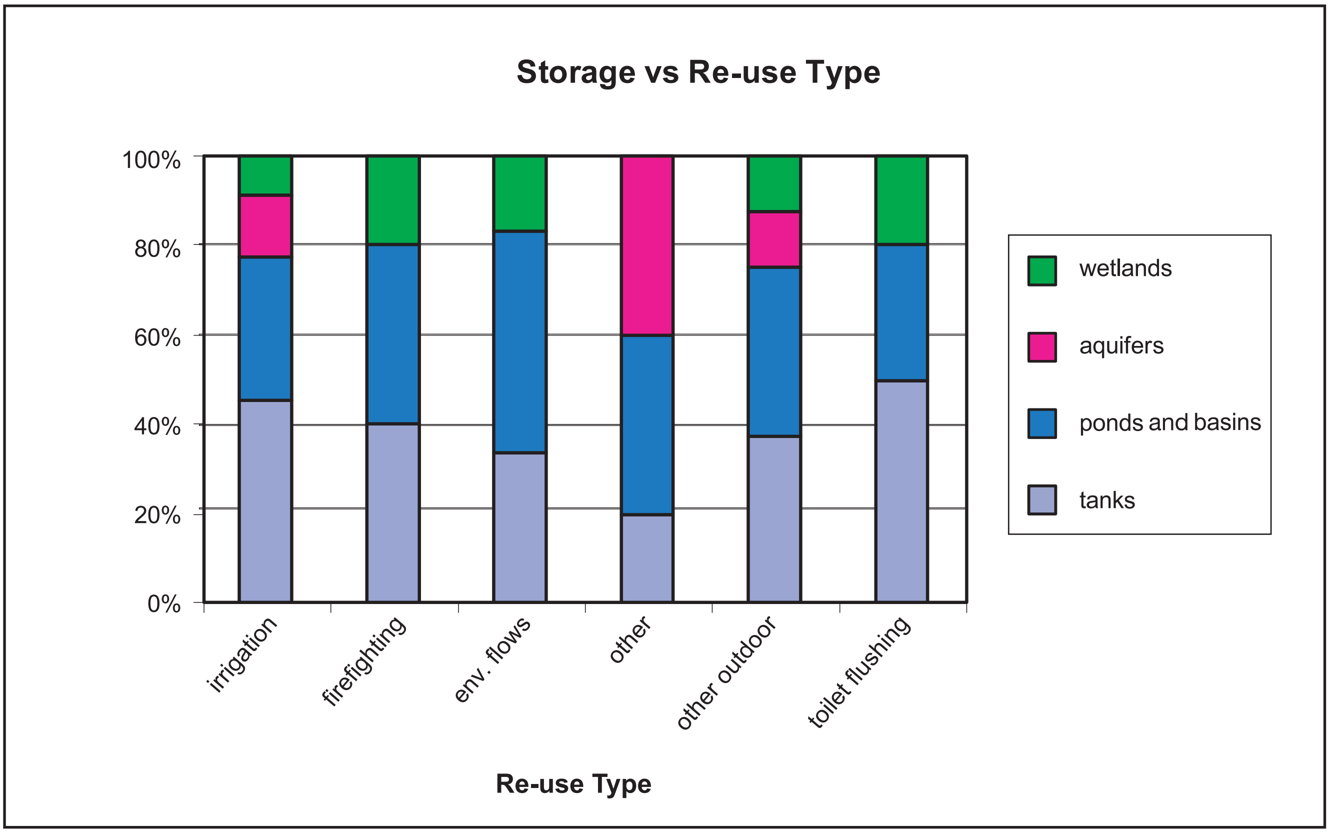

Figure 3.11 Influence of Re-use Type on Storage Component Frequency

3.7 Distribution

Figure 3.12 shows that irrigation systems are the most common method employed for stormwater distribution (50% of cases), followed by dual reticulation (35% of cases). The use of irrigation systems was restricted to the smaller scale re-use schemes (<200 ha). Dual reticulation, where potable water is piped through the usual mains and recycled water is distributed via a separate pipe (lilac), is a viable distribution option for re-use schemes from the neighbourhood scale and upwards.

At present, irrigation systems are mainly used in small scale schemes (Figure 3.13), while the use of dual reticulation is more common for larger catchments.

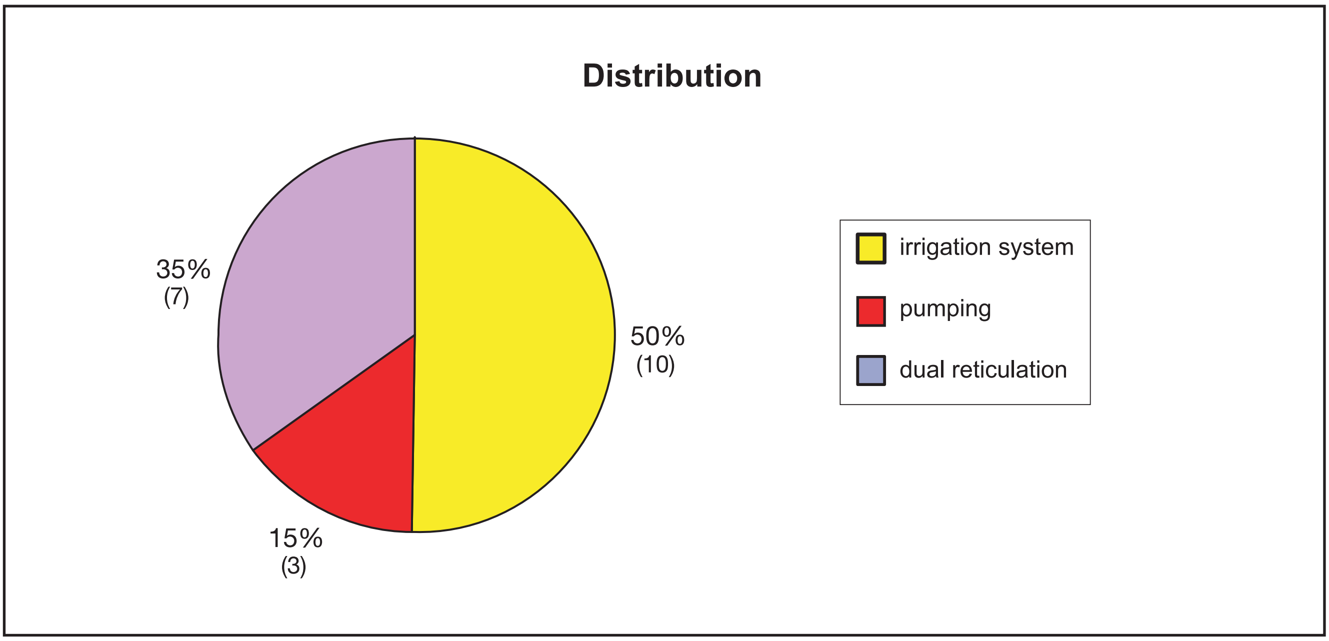

Figure 3.12 Frequency of Distribution Methods

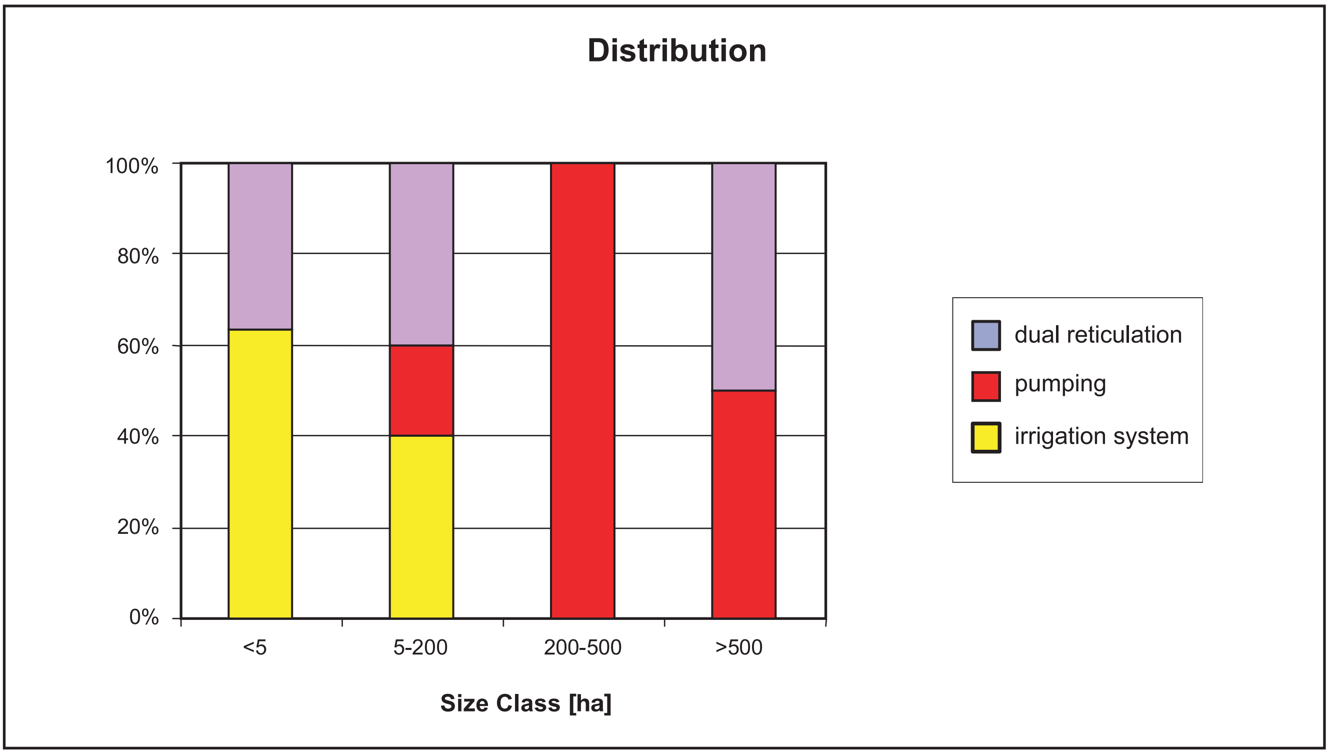

Figure 3.13 Influence of Catchment Size on Distribution Methods

3.8 Key Learnings

Table 3.2 presents possible components of re-use systems and the particular functions that these components perform.

From the survey results the following can be concluded:

- At this stage, re-use of stormwater is largely restricted to smaller scale sites;
- Stormwater is mainly used for purposes with low potential for human contact (low risks), such as irrigation;
- Collection is largely based on traditional methods, such as gutter/channel/pipe systems;
- Treatment is mainly based on WSUD techniques, however advanced techniques alongside with disinfection are utilised if there is higher health risk;
- Storage methods are still conventional, with water tanks being predominant; and
- The frequency of components presented is not necessarily a reflection of the suitability of the method, but in some cases may simply reflect the limited awareness (and guidance) of the range of applicable techniques.

Table 3.2 Identified Components of Stormwater Re-use Systems and their Functionality

Component	Function			
	Collection	Treatment	Storage	Distribution
Gutter	✓			
Pipe	✓			
Channel	✓			
Natural Drainage	✓			
Litter and Sediment Traps		✓		
Swales, Buffers and Bio-filters	✓	✓		
Infiltration Systems	✓	✓		
Wetlands		✓	✓	
Ponds and Basins and Lakes		✓	✓	
Advanced Treatment		✓		
Disinfection		✓		
Tank			✓	
Aquifer			✓	
Irrigation System				✓
Pumping				✓
Dual Reticulation				✓

4. Design

4.1 Introduction

There are few examples of stormwater re-use systems that rely solely on general urban runoff as a source and deliver water for a variety of uses (e.g. systems in Singapore and Canberra, WBM Oceanics Australia, 1999). One of the main reasons for this is a lack of clear design guidance for integrated systems that could effectively collect, treat, store, and distribute stormwater runoff for general use (Thomas *et al*., 1997; WBM Oceanics Australia, 1999; Burkhard *et al*., 2000).

Stormwater treatment and water re-use technologies have improved significantly in recent years. Stormwater ponds, wetlands, bio-filters and swales have been installed at a rapid rate around Australia. They have proven to be very effective in removal of key stormwater pollutants, flood protection and landscape enhancement (Argue, 1998). Design manuals for these systems are now widely available (WEF and ASCE, 1997 in the USA, CIRIA, 2000 in the UK, and Victoria Stormwater Committee, 1999, and Australian Rainfall and Runoff, 2003 in Australia). The Cooperative Resource Centre (CRC) for Catchment Hydrology has recently launched software for conceptual design and performance evaluation of the WSUD systems (named MUSIC, (CRCCH, 2002)), and others have developed a deterministic models of swale performance (e.g. Deletic, 2001).

In general, it was found that WSUD elements incorporated in stormwater re-use systems were not designed differently compared with those designed exclusively for pollution control. The following describes the design of components utilised for re-use that differed from those for pollution control. Other details of the designs of particular systems can be found in Appendix C. Information was readily available with respect to sizes and features of the systems but very rarely on methods used for their design.

4.2 Treatment

4.2.1 Swales, Buffers and Bio-filters

From the limited information available, it may be concluded that standard methods suggested for the design of swales, buffers and bio-filters for pollution control were utilised (Australian Runoff Quality, Wong, 2003). In order to collect as much water as possible modifications may be made to limit ex-filtration from the systems. No specific mention of such modifications was made in any of the documentation gathered on the relevant sites. However, it is understood that for the sites where swales and bio-filters have been utilised, the underlying soils have low permeability, hence it is likely that such modifications were not required.

Hybrids of swales and infiltration trenches are also possible. Infiltration trenches are briefly discussed in the following section and more detailed information can be found in Appendix C.

4.2.2 Infiltration and Filtration Systems

From the evidence gathered, systems incorporating porous pavements and infiltration basins/trenches are designed similarly for re-use or for stormwater pollution control (see Appendix C.1-4). The use of sand filters and biologically engineered soils is new and discussed in more detail below.

Sand Filters

- **Bobbin Head Road – Appendix B.2**

The system at Bobbin Head Road was designed to pre-treat runoff from the roadway through a sand filter prior to it entering the wetland system. The area of the filter media bed required to treat flow rates characteristic of this particular catchment was determined using Darcy's law. While the sand filter is designed to allow for clogging (the top 50 mm layer of sand requires periodic replacing), a trash basket and sedimentation chamber offer pre-treatment to delay clogging. Weep holes prevent stagnant water sitting in pits. In designing the filter the water quality volume was considered rather than peak flow, since the system was designed primarily to treat any first flush that may be present for the site.

- **Inkerman Oasis – Appendix B.8**

Following treatment in the constructed wetland, stormwater flows through a 100 m^2 dosed aerobic sand filter.

Medium to coarse sand should be used for sand filters since fine sand tends to remobilise. The use of angular sand granules is also successful in encouraging biofilm growth. Other learnings relevant to sand filters highlight the need for pre-treatment to delay clogging of the sand bed. This may be achieved by incorporating a litter basket and a sedimentation chamber. Wrapping the sand filter in geotextile further protects the pore spaces of the filter (Roman, 2003).

Biologically engineered soils

- **Manly STAR – Appendix B.10 and Powells Creek – Appendix B.14**

Both the Manly STAR and Powells Creek systems incorporate Atlantis Ecosoils® into their treatment trains. These soils are comprised of expanded polymer made from recycled plastics with sufficient strength to carry normal pavement loadings, have a high cation exchange capacity and biofilm to remove bacteria. They act to degrade and remediate toxic pollutants and remove nutrients. At both sites runoff is treated prior to infiltration through the biologically engineered soils; through porous pavement at Manly and turf cells at Powells Creek.

- **Kogarah Town Square – Appendix B.9**

Garden beds at the Kogarah Town Square contain biologically engineered soils to filter first flush general runoff. The stormwater is collected in a detention tank, filtered through the biologically engineered soils, and then stored in another tank for re-use.

4.2.3 Wetlands

From the information gathered it appears that wetlands are designed similarly, be they for re-use or for pollution control purposes. Table 4.1 summarises the main characteristics of the studied wetlands. It can be seen that they are very different in their design. Further details about the particular systems may be found in Appendix C.5.

Table 4.1 Summary of Wetland Components

Study Site	Catchment Area (ha)	Surface Area (ha)	SA/CA*	Detention Time (h)	Annual Rainfall (mm)	Macrophyte Zone	Deep Oxidation Pond	Settling Pond	Sub-surface Flow	Aeration
Inkerman Oasis	1.223	0.04	0.033		657.3	✓			✓	
Parfitt Square	1.3	0.03	0.023		558.4	✓				
Bobbin Head Road	2	0.02	0.010		1068	✓				
CSU Thurgoona	87				715.2	✓		✓		✓
Hawkesbury	415	5.5	0.013	14	807.1	✓	✓	✓		
Homebush Bay	760	8	0.010		921.3	✓		✓		
Parafield	1600	2	0.001	7-10	460.5	✓				

*SA/CA – Surface Area / Catchment Area

Of all the wetland systems studied, only one site (Homebush Bay) specifically incorporated storage of treated stormwater into the design. To avoid public safety issues, disruption to wetland processes and unattractive edges, ponds were built for either draw down or habitat provision/ornamental purposes. **Wetlands/ponds built for draw down are neither visible to nor accessible by the public.**

4.2.4 Ponds, Basins and Lakes

Table 4.2 summarises the main characteristics of the ponds, basins and lakes studied. Further information can be found in Appendix C.6.

Evaporation can be a storage issue in a period of drought, hence the Surface Area / Volume ratio is important in a pond designed for storage. At Oaklands Park during times of low rainfall water is preferentially stored in the dam with the lowest SA/Volume ratio.

It is apparent that in most situations, ponds are used for storage only. They are not relied on to achieve the required water quality treatment; other treatment measures are generally used to deliver water of an acceptable quality to the pond for storage.

4.2.5 Litter and Sediment Traps

A range of GPTs and sediment traps have been utilised by the stormwater re-use schemes surveyed. In quite a few cases, not enough detail was obtained to describe their design; however it is supposed that in most cases "off the shelf" products would have been installed. Examples of the litter and sediment traps utilised can be found in Appendix C.7.

GPTs and sediment traps can only ever provide primary treatment (i.e. be the first stage in the treatment train). They will not deliver the required water quality for re-use without further treatment.

4.2.6 Advanced Treatment

The types of advanced treatment techniques (microfiltration, reverse osmosis, dissolved air flotation, electrolytic flocculation, aeration and biological treatment) found in the stormwater re-use schemes studied were typical of those utilised by potable water and wastewater treatment plants.

Table 4.2 Summary of Pond Functions and Capacities

	Catchment Area (ha)	Capacity (ML)	Capacity/ CA#	Annual Rainfall (mm)	Detention	Treatment	Storage
Bowies Flat	377	2.3	0.006	1146.6	✓	✓	✓
Hawkesbury	415	175	0.422	807.1	✓	✓	✓
CSU Thurgoona	87	56.5	0.649	715.2			✓
Oaklands Park	174	49	0.282	547.8			✓
Homebush Bay	760	490	0.645	921.3			✓
Parafield	1600	100	0.062	460.5	✓		✓

#CA – Catchment Area

4.3 Storage

Figure 4.1 indicates that the selection of the storage type for each re-use scheme is influenced to some extent by evapotranspiration. For example, ponds and basins are not used for storage in areas with higher evapotranspiration. On the other hand, in areas with the lowest evapotranspiration, ponds and basins are the most frequently used storage method.

4.3.1 Tanks

Table 4.3 summarises the main characteristics of the storage tanks studied. Further information can be found in Appendix C.8.

4.3.2 Aquifer Storage and Recovery

Although the use of aquifers for water storage with subsequent recovery is not exclusive to stormwater re-use, it is a relatively new technique and therefore warrants some discussion. The following outlines the particular details of each ASR system identified.

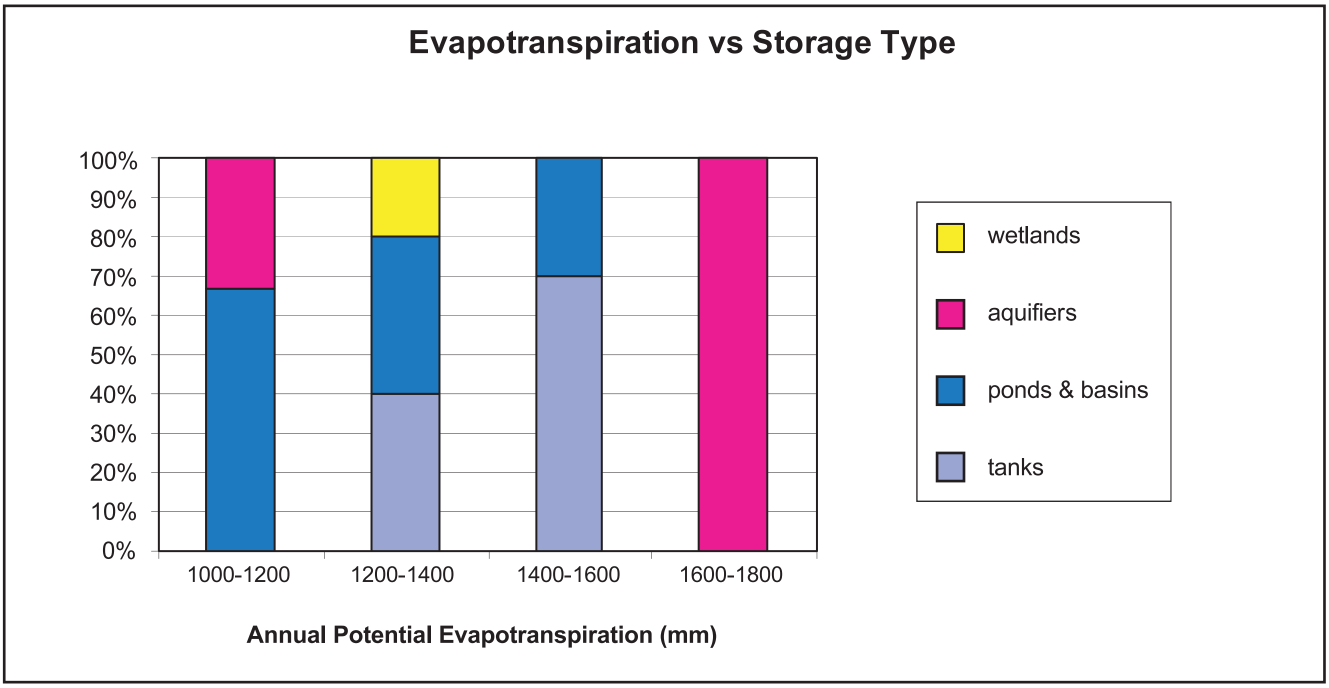

Figure 4.1 Influence of Evapotranspiration on Storage Type

Table 4.3 Summary of Tank Storages

	Flood Capacity	Catchment Area (ha)	Capacity (kL)	Annual Rainfall (mm)	Capacity/CA*
Powells Creek		0.66	1.75	921.3	0.003
Taronga Zoo	first flush	0.83	500	1219.8	0.602
Kogarah	1:3 month storm	1	511	1102.3	0.511
Inkerman Oasis	first flush	1.223	45	657.3	0.037
Bobbin Head Road	1:50 yr storm	2	500	1068	0.265
Manly		3	400	1220.6	0.133
Altona Green		4	400	557.3	0.100
Santa Monica	dry weather	42			
Solander Park	1:20 yr storm	65	255	1102.4	0.004

* CA – Catchment Area

- **Figtree Place – Appendix B.5**

At Figtree Place general runoff collects in the central dry detention basin and then infiltrates through the underlying sandy soil for storage in the aquifer. Geotechnical testing prior to site development confirmed that groundwater at a depth of 3-4 m was of a quality satisfactory for irrigation, however it showed dark discolouration due to the presence of iron and manganese salts. A flownet model of the aquifer was used to explore possible groundwater impacts. There is a submerged pump within the recharge basin at a depth of 10 m. Water stored in the aquifer is pumped as required for re-use for irrigation and other outdoor uses. There is a net excess recharge to the aquifer as a result of high local rainfall. Recharged water excess to the demands of on-site residents is extracted, treated with activated carbon to remove colour and distributed to the adjacent bus station for bus washing.

- **Parfitt Square – Appendix B.13**

At Parfitt Square four recharge wells are situated in the ponding area at the end of the bio-filter. These bores are designed to inject up to 20 L/s of clean stormwater to the Quaternary 1 saline aquifer that underlies most of the Adelaide metropolitan area. The bore headworks include a geotextile layer for final filtering. The design annual recharge is approximately 1.7 ML; the aquifer is estimated to have a storage capacity of 50,000 ML. The annual groundwater movement of the underlying aquifer is approximately 12 m, hence the discharge bore and pump is located 10 m downstream of the nearest recharge bore. This allows the plug of stormwater injected in winter to be centred around the production bore in summer when extraction is required. It is anticipated that the aquifer will show a gradual reduction in salinity over time.

- **Parafield – Appendix B.12**

Clean stormwater, excess to the needs of local industry is injected into the underlying saline limestone aquifer at Parafield for recovery at times of low rainfall. There are two wells in the well field, each around 190 m deep and capable of injecting up to 35 L/s of water. The design annual injection volume is approximately 650 ML. An initial buffer of 2,000 ML was incorporated as a balancing storage to overcome yearly variations in rainfall and hence recharge. Annually, 500 ML is extracted from the aquifer for re-use.

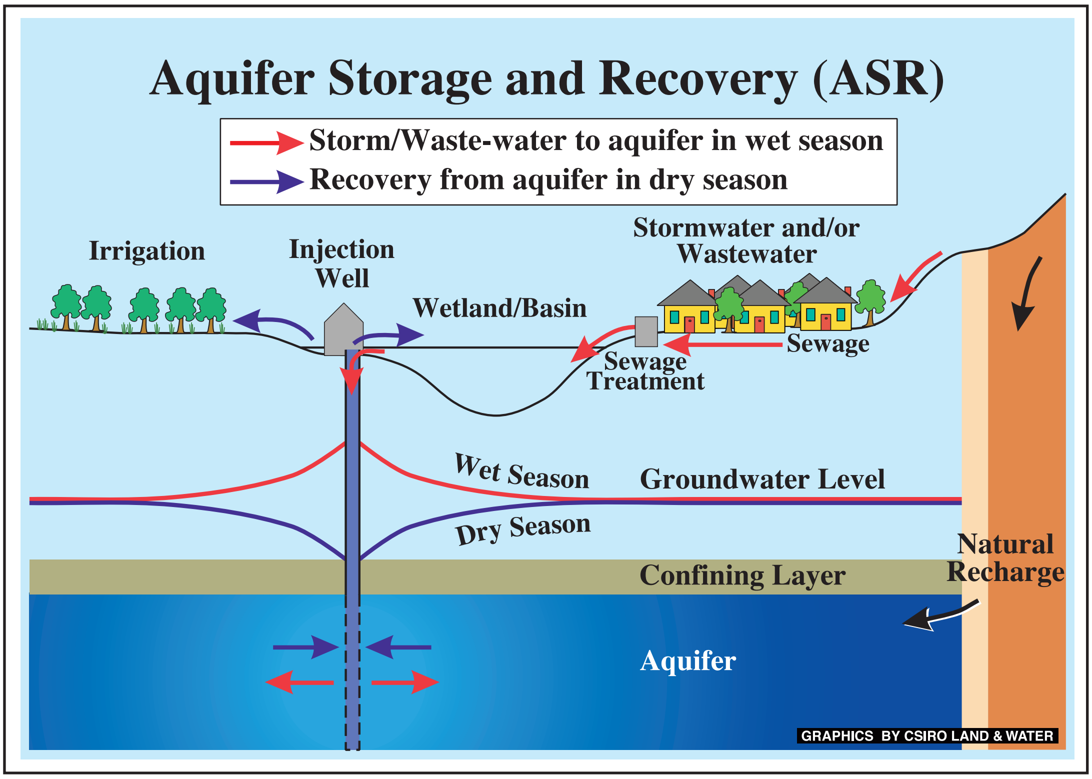

Figure 4.2 Diagram of the Aquifer Storage and Recovery System at Parafield (source: CSIRO)

Although used infrequently in the three Eastern states (but often present in South Australia), this method can provide a means of cheap and reliable storage. Key issues are availability of a natural aquifer for safe storage and groundwater quality.

4.4 Key Learnings

Current design practice of WSUD systems does not always guarantee reliable stormwater treatment to required quality standards, since the design approach has focussed on protection of aquatic ecosystems, requiring less stringent design standards than required for re-use. Such treatment of stormwater, whose characteristics vary greatly, in quite short periods, even stretches the capabilities of the most traditional clarification technologies used in treatment of potable water.

Storage of treated stormwater is another key issue. Water has to be safely stored over long periods of drought. It appears that the ratio of the volume of permanent water body to available storage volume is not clearly specified in any of the systems studied.

It can be concluded that one of the main challenges in efficient stormwater use is a paucity of technology for integrated urban stormwater treatment and re-use. Existing practice is far ahead of research, which may pose a danger to the future adoption of such measures. Just one high profile case of public health or environmental failure of a re-use project (conducted without sound scientific backing) could undermine public confidence in re-use nationally, costing our society time and money in the much needed adoption of future water re-use technologies.

5. Construction, Operation and Maintenance

5.1 Introduction

There was limited information pertaining to construction, operation and maintenance procedures and issues for the cases studies. Perhaps this is not surprising, given the previously reported (Taylor and Fletcher, 2004) lack of information on construction, operation and maintenance of WSUD. Information that was available is summarised in this chapter, and key learnings drawn.

5.2 Construction

5.2.1 Current Practice

From the limited information gathered regarding the construction of stormwater re-use systems, it appears that:

- Construction must comply with the relevant State agency requirements that apply to all construction sites. For example, part of the planning process for the constructed wetlands at Bowies Flat in Brisbane involved preparation of an Environmental Management Plan, including the construction phase. In addition, specific documents such as Brisbane City Council's Guidelines on Sediment Basin Design, Construction and Maintenance also applied. At Oaklands Park in Melbourne, the requirements of Vic EPA's "Construction Techniques for Sediment Pollution Control" applied.
- Construction procedures for re-use are essentially the same as those for WSUD construction (e.g. Wong, 2003), although these too are not yet particularly well documented. Production of technical manuals (Melbourne Water, in prep) will go some way towards addressing this lack of information.
- A number of the problems encountered were the result of poor construction practices. For example, at Figtree Place the post-construction site inspection found that underground rain tanks had not been cleaned following construction, water in recharge trenches flowed to the raintanks, first flush pits were not constructed, covers had not been sealed allowing entry of debris into the stored water, and ponding in the roof and gutter system was occurring (Coombes *et al*., 2000). Water in the raintanks was subsequently of poor quality.

5.2.2 Key Learnings

During construction of Bowies Flat official environmental audits were conducted weekly. As a result, this process could alleviate only major problems and it was found that, without an environmental auditor permanently on-site to ensure controls were well-maintained and implemented, there were times when the environmental controls were not sufficient (BCC, 2003).

Diverting water around a construction site is a successful way to meet water quality targets. Another option, relevant to sites with ponds or wetlands is to stabilise a pond early in the construction phase for use as a sediment/treatment pond.

Sediment control during construction is critical; without it, the integrity and operation of the systems installed can be threatened. This is particularly the case for infiltration systems and filters, which are susceptible to clogging during the construction period.

Construction tolerances in integrated stormwater treatment and re-use systems are generally finer than in conventional systems. It is important, therefore, to ensure that contractors are well-briefed, and fully understand the design intent of the system.

5.3 Operation and Maintenance

It is understood that operation and maintenance manuals were developed for most of the studied re-use schemes, at the very least for the larger scale schemes or those with more complex treatment trains. Operation and maintenance requirements for re-use schemes do not appear to differ from requirements for typical water supply nor other types of WSUD. For example, regular inspection and maintenance of filters, GPTs, pumps and pipes is required, but this is also a requirement of both conventional water supply and WSUD schemes. The major difference would be more stringent monitoring schedules to ensure water quality is adequate for the intended re-use purpose. The respective monitoring programs will be discussed in Chapter 8.

The following briefly describes examples of the operation and maintenance practices of the re-use schemes that are specific to water re-use.

5.3.1 Collection

The scheme at Inkerman Oasis combines re-use of greywater with first flush stormwater. Since the capacity of the collection, treatment and storage system is relatively small, when rainfall is detected greywater is diverted to the conventional sewerage system. Once all the collected and treated stormwater has been re-used into the toilets, the system reverts to collecting greywater.

5.3.2 Treatment

Constructed wetlands and ponds are designed to be low maintenance, self-sustaining systems (over relatively long-time periods, of at least 20 years). The type of maintenance required for these systems is not exclusive to wetlands and ponds incorporated into re-use schemes e.g. weed control and silt removal. However it is more likely that this maintenance will actually be carried out since it determines the health and thus the performance of the system – and it is critical that these systems function satisfactorily to ensure water quality is adequate for safe re-use (as opposed to wetlands and ponds constructed specifically to provide environmental flows of improved quality – maintenance of these systems may tend to be neglected, with less direct human impacts).

The advanced treatment tank at Inkerman Oasis is duplicated to permit maintenance on each individual membrane module. This avoids the need for the system to revert to the conventional system (where greywater goes to the sewerage system and all stormwater to the drainage system) during maintenance periods.

5.3.3 Storage

Storage tanks, particularly those with provision for mains supply as a backup, tend to be constantly drawn down to ensure tanks regularly have the storage capacity available to accept runoff. This is also important if the system is going to have any flow-attenuation, or flood-mitigation function.

At Oaklands Park there is provision to pump between the three storage dams. This has a number of benefits; a) it enables water levels in each dam to be maintained above the minimum level required for water quality, b) two of the dams have larger catchments and higher impervious areas and therefore fill faster (water from these dams is pumped to the third dam to allow maximum collection), and c) in times of low rainfall (when evaporation may be an issue) water can be stored in the dam with the lowest surface area: volume ratio (and thus lowest potential evaporation).

In the case of ASR schemes, consideration of potential groundwater impacts is essential. For example, at Parfitt Square, recharge and retrieval volumes are kept approximately in balance to avoid adverse pressure fluctuations. Operation of the ASR scheme at Figtree Place includes monitoring of the watertable to ensure that neither significant drawdown nor the formation of a groundwater mound, which could lead to structural problems, occurs.

5.3.4 Distribution

The initial design of the re-use scheme at Santa Monica required the injection of a background level of chlorine within the distribution line. However, it has been found that algae grows almost everywhere within the advanced treatment facility, particularly in the storage tank. As a result, the City is considering adding chlorine earlier in the treatment train to reduce algal growth.

5.3.5 Flood Protection

Most neighbourhood scale sites have provision for overflow to traditional stormwater drainage systems or nearby waterways when their design flood capacity is exceeded. For example, at Altona Green Park, if the storage tank is at full capacity, runoff discharges along a swale (hence some treatment may occur) before overflowing into the conventional drainage system. Wetland systems generally have bypass channels to lower the risk of flood damage to macrophyte zones and reduce the potential for export of pollutants caused by re-suspension of sediment during high flows (well known from the operation of wetlands used only for pollution control).

5.3.6 Key Learnings

The larger scale schemes or those with complex treatment systems tend to be controlled centrally. For example, the Parafield scheme is controlled by a System Control and Data Acquisition (SCADA) system linked to a central control scheme at the City of Salisbury offices. The advanced treatment plant at Taronga Zoo is also controlled centrally.

There are a number of sites studied that appear to have been neglected since completion of construction. Further the subsequent planned stages of at least one project appear not to have been completed, potentially jeopardising the integrity of the original design intent. It appears that a lack of adequate monitoring and maintenance is particularly a problem for the smaller-scale sites, where there are inadequate resources and/or expertise to undertake the required maintenance. This definitely needs to be taken into account when planning, designing and regulating stormwater re-use systems.

Some sites do not have defined operation and maintenance programs as such; rather it is a "wait and see" situation. For example, at Kogarah Town Square it is expected that screen filters on the pumps will need to be cleaned once a year and the storage and header tanks approximately every 5-6 years. In another case, an operation and maintenance schedule for the Manly STAR project was meant to be developed, however this seems to have been considered a low priority since, at this stage, it has not occurred. Currently, the extent of the operation and maintenance is regular street sweeping to reduce pollution, maintenance of pumps as required and, according to manufacturer specifications, once every 10 years the biologically engineered soils should be harvested and accumulated pollutants extracted (although there is currently no defined feedback mechanism to determine whether this frequency is adequate).

The operation and maintenance of a stormwater re-use system may be contracted out e.g. maintenance of pumps and the ring main at Taronga Zoo is carried out by a contractor, and the maintenance of the re-use scheme at Homebush Bay is contracted to the construction company for 25 years. In the case of subdivision type developments, the body corporate is generally responsible for the operation and maintenance of the re-use scheme.

The principal lesson is that clear specification of an operation and maintenance program should be prepared during the design process. This specification should include clear identification of the responsible entity, and a realistic assessment of whether that entity is capable of taking on the operation and maintenance responsibly. Without this, it is likely that the integrity of a number of the systems studied is at risk, potentially impacting on public health and amenity.

Operation and maintenance of stormwater re-use schemes must be controlled centrally and managed strictly, at the authority level rather than privately.

6. Implementation Issues

6.1 Introduction

Essential considerations for implementation of stormwater re-use systems, other than costs and pricing, include ecological responses, environmental impacts, social consequences, technical feasibility and flexibility (Mitchell *et al*., 1999).

This chapter provides a discussion of implementation issues and how the re-use schemes address these concerns.

6.2 Integration into the Total Urban Water Cycle

The urban water cycle is typically defined by the three urban water streams i.e. potable water, wastewater and stormwater. Traditionally the approach has been to manage each water stream separately. However, if integrated systems are to be successful, they should become a part of the sustainable management of the total urban water cycle. The following is a discussion of how this has been addressed at a number of sites.

Two of the study sites also incorporated greywater re-use into their water recycling schemes. At CSU Thurgoona, greywater is treated in intermittent-flow constructed wetlands (separate from the stormwater wetlands) and is then mixed with the treated stormwater in the storage reservoirs for subsequent re-use. Greywater is also collected from about half of the units at Inkerman Oasis. It is passed through a different primary treatment method before joining the stormwater for treatment in the wetlands and tertiary tank.

A number of sites collect, treat and recycle wastewater in addition to stormwater. Reclaimed wastewater is the primary source of recycled water at Hawkesbury and Homebush Bay. At Hawkesbury, wastewater undergoes advanced treatment at the Richmond Sewerage Treatment Plant, polishing in a different wetland system and storage in a separate dam from the stormwater. At Homebush Bay, wastewater from Newington, the sporting venues and showgrounds is reclaimed and passed through an advanced treatment plant. Clean stormwater from the brickpit storage is used to supplement this supply prior to distribution around the site. Excess treated wastewater is stored in a 7 ML buffer underground storage tank at the treatment plant as well as in the brickpit storage. At Oaklands Park each individual lot has a wastewater treatment system to produce water suitable for irrigation. Wastewater from animal cage hose-downs at Taronga Zoo is mixed with stormwater at the inflow to the treatment plant.

Six sites collect, treat and re-use roof runoff separately from general runoff. These sites tend to use the roof runoff, which is generally cleaner than general runoff (particularly lower in sediment concentration), for purposes where the risk of human contact is higher. For example, roof runoff at Figtree Place is passed through first flush devices, stored in five central underground tanks, and re-used for toilet flushing and hot water systems. Re-use of the general runoff, on the other hand, is restricted to irrigation and other outdoor uses. At CSU Thurgoona, it is a similar situation, with raintanks incorporated into the walls of the buildings storing roof runoff for re-use for laundry, cooling and insulation purposes. The stadiums and showgrounds at Homebush Bay collect their own roof runoff, store it in underground tanks and re-use it to irrigate the playing fields etc. Oaklands Park differs from all other studied sites in that roof runoff from individual lots is collected, passed through first flush devices, undergoes natural sedimentation processes in individual storage tanks and is re-used for potable and other in-house uses. Interestingly, at Oaklands Park, there is no clearly defined charge for the use of collected general stormwater runoff for garden irrigation. Instead it is included in body corporate fees, potentially giving little incentive for saving water resources.

The incorporation of additional supplies as backup during periods of low rainfall was almost universal. In most cases, this was in the form of connection of the mains supply to the storage. This also provides a water supply of reliable quality should the stormwater quality fall below accepted levels. Oaklands Park does not have access to mains water, however it has provisions for pumping from nearby Deep Creek to supplement storage. This will also more than compensate for any future loss of catchment area (some is external to the site). In addition, there is a minimum house size to ensure adequate collection for potable re-use.

Other initiatives that have been adopted by various schemes to integrate the system into the total urban water cycle include the use of water efficient fittings and appliances, incorporation into an integrated environmental precinct, and the promotion of maintenance of good water quality.

6.3 Public Safety

There are various issues to consider in terms of ensuring public safety and a range of techniques have been implemented to address these.

To some extent, most schemes carried out risk assessment as part of their design process. Part of the planning of the re-use scheme at Hawkesbury was the development of an Environmental Management Plan (based upon ISO 14000 processes), including a preliminary risk assessment and an ongoing program to develop effective risk communication and management strategies.

With respect to minimising risks associated with irrigation with recycled water, various approaches were taken. At Figtree Place irrigation occurs only during night hours (thus minimising the risk of human contact), while at Hawkesbury shelterbelts have been planted along the edges of pastures to prevent the public from coming into contact with spray drift. At Manly the mains supply is also linked to an irrigation system and is mixed with the treated stormwater as a risk management precaution (and to supplement the supply in extended dry periods).

A survey of residents at Figtree Place found that 48% of the respondents use water from the hot tap for cooking. As a result, the rainwater used in hot water systems must be compliant with drinking water guidelines.

All re-use schemes must also provide flood protection. Most systems divert to conventional drainage systems once the design flood capacity of the collection system is exceeded. There is also usually some means of flow control for the treatment system. For example, at Kogarah Town Square surge tanks regulate water flow in periods of high stormwater flow. Storages also generally have provision for overflow.

Figure 6.1 Signs at Homebush Bay Inform the Public About the Use of Recycled Water

Other public safety issues:

- Schemes utilising ponds and wetlands as part of their re-use system must address mosquito management;
- The use of signage informing the public about the use of recycled water is also widely used (Figure 6.1);
- A number of sites had contaminated soils as a result of previous land use (e.g. Homebush Bay and Figtree Place); this was required to be remediated during the initial construction stages.
- Storage tanks and ASR headworks are either underground or have restricted access to ensure public safety. If ponds and basins are utilised for storage purposes only, access is restricted. However, it is generally not known what, if any, safety precautions have been incorporated into the design of ponds that are open to the public i.e. barriers, maximum gradings, shelving margins.

6.4 Landscape Requirements

Landscape requirements for stormwater re-use systems include:

- Consideration of the need for soil treatment to prevent groundwater accessions and to aid in plant establishment in constructed wetlands;
- Community expectations for provision of open space for active and passive recreation;
- Other needs of the surrounding community;
- Irrigation requirements of vegetation (most sites encourage the use of locally native plant species; Powells Creek also incorporated specific vegetation types with high evapotranspiration rates into the re-use scheme);
- If the site is a major tourist destination (e.g. Manly), it should be taken into account that intensive developments with high transient populations give rise to greater than normal amounts of vehicles and litter;
- Changes in topography, and hence wind shear control was a landscape issue for the Parafield scheme;

6.5 Site Amenity

Major amenity issues that have been found at the studied sites include:

- Interaction with major public infrastructure. For example, issues that needed to be resolved in the development of the Parafield re-use scheme included possible disruption to airport activities and ensuring access to the re-use system (since airports are secure areas). In addition, an Emergency Response Plan was developed for the project in order to ensure effective and efficient responses to incidents that may threaten to adversely impact the project.
- Limited space, as at Powells Creek. In these cases, the utilisation of subsurface systems can free up space.
- Improvement of visual amenity. For example the redevelopment of Solander Park improved the visual amenity. All elements of the re-use system were integrated into a total management approach and do not obstruct the aesthetics or useability of the park.
- A couple of re-use schemes with multifunctional ponds and lakes allowed recreation on and around the water storage, however this was restricted to passive recreation (i.e. non-contact activities such as boating).

6.6 Institutional and Other Issues

During the development phase of the re-use scheme at CSU Thurgoona, the option of potable re-use was explored, however, following risk consideration, the University required water for human consumption, personal hygiene and some other domestic uses to be provided by an authorised supplier (Mitchell *et al.*, 2001).

Significant delays, caused by approval agencies, were experienced during the development stage of Figtree

Place. This was largely due to the lack of institutional frameworks regarding WSUD design principles, maintenance requirements and costs (Coombes *et al*., 1998). To avoid these problems, a detailed technical and legal assessment of the Parafield project was undertaken to ensure that regulatory approvals were received in time to keep to schedule.

The development of Inkerman Oasis required rezoning of the land and Council acceptance of building heights and unit density. This was a straightforward process since Council was a project partner. However, the relevant water authority would not agree to any reduction in infrastructure charges and an alternative means of reducing costs could not be agreed upon.

The development at Bobbin Head Road did not make it past the design stage. While the application was supported by Council, it could not be approved because the State government declared that the type of development (SEPP5) was no longer allowed in the area. In a similar way Oaklands Park reportedly had little support or involvement from relevant institutions.

The initial motivation for the Manly STAR project was a call from the community in regard to removal of stormwater pipes from the beachfront (Figure 6.2). Relocating these outlet pipes would have been an expensive exercise and would not have offered any improvement in stormwater quality, hence it was decided to implement the treatment and re-use scheme. However, the community still wants the stormwater pipes removed, indicating they are more concerned with visual pollution than water quality issues. This is supported by the strong public acceptance of permeable pavers, despite initial hesitation by the community, which have visual appeal as well as reducing surface flows.

It appears that the key lesson is that all organisations with regulatory responsibility should be brought in as key stakeholders early on in a project's development. There is a need to identify a 'champion' for the project, within each organisation, to "smooth its path" through regulatory requirements. Until regulations have 'caught up' with stormwater re-use, this type of case-by-case facilitation approach will be needed.

Figure 6.2 (a) Stormwater Outlet Pipe at Ocean Beach in Manly and (b) Pollution Warning Sign

Other issues included:

- Minimisation of avifauna at the two sites that are on or near airports (Hawkesbury and Parafield) to reduce the risk of bird strike; and
- Indigenous heritage issues e.g. at Parafield

6.7 Key Learnings

Many learnings and recommendations with respect to implementation issues have arisen from the development and operation of the stormwater re-use schemes surveyed.

One of the most frequently encountered issues were lengthy and resource intensive negotiation, assessment and approval processes. This is largely due to a lack of pertinent experience and policies on the part of the water industry and relevant authorities. In many instances, regulatory and legal reforms were tested. The overwhelming recommendation with respect to gaining project approval is to involve the relevant approval agencies at an early stage.

A key learning identified by the Kogarah Council is that, while it is worthwhile incorporating both waste and stormwater recycling initiatives in planning controls and especially public projects, it is essential that the objectives are clearly identified and that there is flexibility with respect to the outcome. Further, the standard of design documentation for innovative practices must be above average (Coombes *et al*., 1998). Evaluation of the whole process (from design all the way through) is also essential.

Many of the re-use schemes were the result of a partnership approach, often between the various levels of government and a private developer. This was found to be successful, since it enabled all parties' skills, roles and experience to be combined. Involving other parties, such the design team and researchers, in the partnership was also found to be beneficial. It is crucial that all stakeholders are kept informed.

Kogarah Council found that some developers can see the long term benefit of learning how to apply and demonstrate best practice design as part of a long-term business strategy to be seen as "green". Further, the tenderers and the design teams all responded well to the environmental objectives of this project. Coombes also advocated involving a constructing contractor who is supportive of the project innovations early in the development stage (Coombes *et al*., 1998).

Communicating the innovations to the buyers and wider community is important. Two examples of communication to the general public are shown in Figure 6.3. Kogarah Council reflected that consulting with the community early in the development stage would have reduced costs and greatly reduced timeframes associated with the implementation of the Kogarah Town Square water re-use project. Some

Figure 6.3 Information Boards (at Manly Beach and Solander Park) are Effective Ways to Communicate Water Recycling Innovations to the General Public

schemes have also incorporated artwork into the facility (Figure 6.4). Many re-use schemes have found that community consultation and interpretive artwork has resulted in interest and ownership of the scheme by both the local and wider community.

Other learnings to have arisen from the implementation of the re-use schemes studied include:

- There is significant public acceptance of domestic use of rainwater;
- Stormwater re-use systems should be developed within a broader landscape management plan and landscape architects should be part of the design process;
- Government grants assist with project costs, however managing grants takes a lot of time and ongoing effort (for which funding is often not available); and
- Reliable provisions and monitoring plans are fundamental elements of re-use projects, particularly given the experimental nature of them at this stage (Coombes *et al*., 1998).

Figure 6.4 Art Work at Solander Park (source: (SSCC, 2002))

7. Costs and Benefits

7.1 Introduction

One of the main attributes of every stormwater re-use scheme is their multiple objectives. Stormwater re-use reduces demand for traditional potable water supply while diminishing environmental problems caused by elevated and polluted stormwater runoff arising from urbanization. However, it can be very costly.

Assessing the costs and benefits of any water recycling project is a complex process. The traditional cost/benefit approach uses the discounted cash flow method to compare the cost of a development against the benefits realised (Wong, 2003). However, this method is inadequate since water re-use schemes also offer non-monetary social and environmental benefits and disadvantages. Methods for objectively and consistently assessing these are not yet well developed.

The following sections describe the types of costs associated with implementing a stormwater re-use scheme, the potential benefits that may be achieved and new key learnings.

7.2 Costs

Costs involved in developing a stormwater re-use system are:

- Capital costs: the cost of design, approval, and construction (often called total acquisition costs);
- Operating costs: including maintenance and energy requirements;
- Actual total cost is the sum of capital and operating costs;
- A user price may apply where recycled stormwater is provided by a central agency; this may be higher or lower than the actual cost.

7.3 Benefits

The potential benefits of stormwater re-use schemes are:

- Provision of water supply (a potable water substitute) where water resources are constrained or non-existent;
- Reduced demand for potable water (particularly peak flows), which offers savings through the reduced need to develop other water resources (and therefore helps in their conservation) or expand water supply infrastructure (therefore delay or remove the need for enhanced water supply reticulation and stormwater drainage infrastructure);
- Reduction in volume and peak of stormwater flows, protecting downstream waterways, and reducing the need for downstream stormwater infrastructure;
- Reduction in stormwater pollution, which may lead to protection/enhancement of downstream waterways as well as savings resulting from the reduced need for downstream pollution mitigation measures;
- Multi-functionality of waterways for recreation, environmental enhancement and stormwater storage and recycling purposes, which generally manifests itself in greater property values.

7.4 Collected Data

Table 7.1 summarises the known costs and **qualitative** benefits of each re-use scheme studied.

In interpreting these costs, some important issues must be taken into account:

- It can be seen that only limited information about operating costs and user prices was available. This is not due to reluctance on the part of the developers/operators to divulge this information. Rather it seems that, in most cases at least, these costs have not been formally considered as part of the project design process. Future projects should have a disciplined costing analysis undertaken.

- Public grants have been used to help the implementation of many of the systems, which reduced the user price e.g. approximately 60% of the costs for WSUD elements at Inkerman Oasis were funded by a Commonwealth *Urban Stormwater Initiative* grant.

In interpreting the qualitative benefits, there are also a number of important considerations:

- Where it was deemed appropriate, benefits have been assessed relative to other schemes and rated accordingly e.g. for reduced demand of potable supply, the schemes that provide the largest relative reduction have been given three ticks, while those that offer the smallest relative reductions in demand have one tick.
- Categories have only been ticked if reports/conversations have specifically stated that this is a benefit. For example, even though only three schemes have listed habitat provision as a benefit, this may very well be an incidental benefit of other schemes.

Table 7.1 Summary of Costs and Benefits Associated with Surveyed Stormwater Re-use Schemes

		Costs			Benefits									
	Year	Capital Cost ($)'000s	Operating (c/kL)	User Price (c/kL)	Reduced Demand for Potable Supply	Reduced Discharge to Waterways/ocean	Reduced Discharge to Sewage System	Delays need for Drainage Infrastructure Upgrade	Pollution Control	Environmental Flow of Improved Quality	Abatement of Former Flooding Problem	Nturient Recycling	Habitat Provision	Other[3]
Altona Green	2003	250		n/a	✓	✓		✓	✓					
Bowies Flat	2002	2400[1]		n/a	✓	✓			✓	✓	✓		✓	
CSU Thurgoona	1999			n/a	✓✓	✓✓✓	✓✓✓		✓	✓			✓	✓
Figtree Place	1998	109.9			✓✓✓	✓✓		✓	✓					
Hawkesbury	2003	3900[2]			✓✓✓	✓✓✓	✓✓	✓	✓	✓		✓		
Homebush Bay	2000	15800[2]	180	77.5	✓✓✓	✓✓✓	✓✓	✓	✓	✓			✓	
Inkerman Oasis	2003	434[2]			✓✓✓	✓	✓	✓	✓			✓		
Kogarah	2003	629			✓✓	✓		✓	✓					
Manly STAR	2001	1300		n/a	✓	✓			✓					
Oaklands Park	1997	73			✓✓✓	✓✓✓	✓✓✓		✓					
Parafield	2003	4500	30		✓✓✓	✓	✓✓	✓	✓	✓	✓			✓
Parfitt Square	1997			n/a	✓	✓✓		✓	✓					✓
Powells Creek	1998	400		n/a	✓	✓		✓	✓	✓				
Santa Monica	2001	16600	212		✓✓	n/a			✓					
Solander Park	2001	615		n/a	✓	✓✓		✓	✓		✓			
Taronga Zoo	1996	2200[2]		n/a	✓✓	✓✓	✓		✓					

[1] Capital cost of total redevelopment i.e. not just re-use component
[2] Includes capital costs for both stormwater and wastewater recycling
[3] Other benefits: CSU Thurgoona – part of the campus is unsewered; Parafield – provides local job opportunities and economic stability (cost of potable water in South Australia high enough that industry was considering relocation); Parfitt Square – aquifer recharge

It can be seen in Figure 7.1 that capital cost is only partly determined by the size of the catchment (and therefore usually the system size). Other factors that influence capital cost would include treatment method (type and complexity), storage type, and physical characteristics of the land (e.g. slope, which would have a large influence on the type of collection and distribution methods selected). Capital cost may also be influenced by the degree of external benefits (e.g. public amenity facilities) which are integrated into the systems.

Table 7.2 lists selected quantitative benefits of stormwater re-use schemes as reported. Note that although pollution control was a specifically stated benefit of all re-use systems (Table 7.1) it was quantified in only two instances. This further highlights the need for data collection to be undertaken as part of stormwater re-use projects.

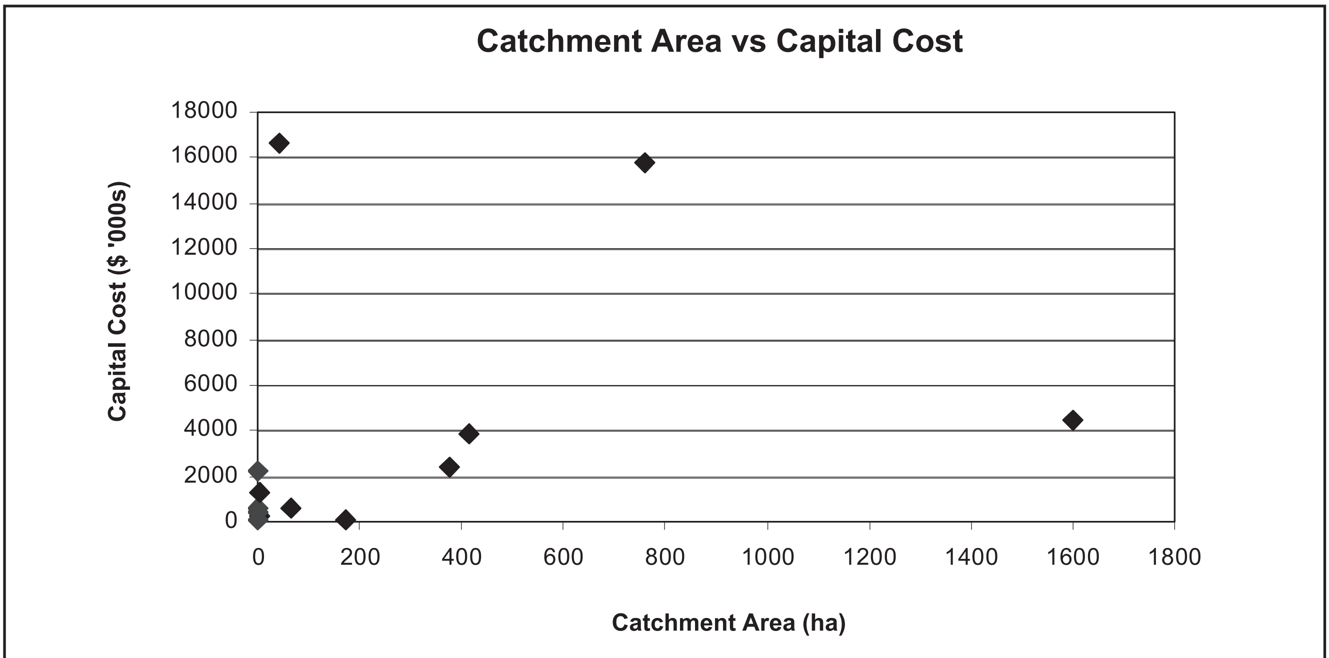

Figure 7.1 Relationship Between Catchment Area and Capital Cost

Table 7.2 Quantified Benefits Associated with Selected Stormwater Re-use Schemes

	Reduced Potable Demand	**Pollution Control**	**Reduced Runoff Volume**
Figtree Place	40-45%		83% of runoff up to 1:50 year ARI storm event
Hawkesbury	28%		50% of annual runoff (400 ML)
Homebush Bay	50%		all runoff up to 1:100 year ARI storm event (with some release as environmental flows)
Inkerman Oasis	30%	~14 tonnes P and N removed year[1]	first flush (until wetland is full)
Kogarah	17%		6375 kL year
Oaklands Park	6.9 ML year		75 ML year
Parafield	1500 ML year	removes 90% of nutrient and pollutant loads	all runoff up to 1:10 year ARI storm event

[1] Figure is for pollution removal from greywater and stormwater combined

Due to lack of available data, a simple analysis was undertaken to demonstrate the costs and benefits of the studied systems. Table 7.3 demonstrates two possible benefits of selected stormwater re-use schemes; reduced potable water demand and pollution control. All capital costs are taken as reported. Mean annual runoff is calculated from annual rainfall and estimated runoff coefficient. The percentage of collected and used runoff was either taken as reported or estimated from the qualitative data available. Potable water savings are then simply estimated as the volume of the re-use water multiplied by the cost of potable water production, as supplied by Melbourne Water (0.3 $/kL).

The benefits of the pollution control were assessed as the 'equivalent cost' of nitrogen removal only (based on data provided by Melbourne Water). This was done because the resultant benefits, such as environmental protection and nutrient recycling, cannot be reliably costed, particularly given the different (and unknown) conditions at each site, and their downstream environments. The mass of nitrogen removed from stormwater is assessed as the volume of re-used stormwater (that is never to reach streams in its state) multiplied by the concentration of total nitrogen (TN) in stormwater. The calculation is done for lower (TN = 0.7 mg/L) and upper (TN= 6 mg/L) wet weather concentrations (Fletcher *et al*., 2003). Finally, the total cost of nitrogen removal was calculated using the estimated cost of $787 per kg of TN removal (as supplied by Melbourne Water). The costings provided indicate an equivalent cost which would be required to remove this level of nitrogen, using typical stormwater treatment wetlands.

It must be noted that this demonstration is most likely an underestimate of potential benefits because it estimates only the benefits of the portion of stormwater collected for re-use only. For example, the WSUD elements incorporated into the systems offer additional treatment of non-collected stormwater, but inadequate data were available to estimate these.

Table 7.3 Demonstrated Benefits of Selected Stormwater Re-use Schemes. Note: cost of potable water production = 0.3 $/kL (Melbourne Water), lower wet weather TN conc = 0.7 mg/L and upper wet weather TN conc = 6 mg/L (Fletcher *et al*., 2003), cost of nitrogen removal = $787/kg (Melbourne Water)

	Capital Cost ($)[1]	Mean Annual Runoff (ML)	% Collected	Volume of Runoff Collected (ML)	Potable Water Savings ($)	Pollution Control: Quantity TN Removed (kg)[3]	Pollution Control: Cost Range ($)
Inkerman Oasis	434,000	7.6	20[2]	1.52	456	1.1 - 9.1	837 - 7,200
Figtree Place	109,900	6.3	83[1]	5.2	1,569	3.7 - 31	2,900 - 24,700
Kogarah	629,000	9.4	85[1]	8.0	2,397	5.6 - 48	4,400 - 37,700
Oaklands Park	73,000	75	100[2]	75	22,500	53 - 450	41,300 - 354,200
Hawkesbury	3,900,000	800[1]	50[1]	400	120,000	280 - 2,400	220,400 - 1,888,900
Homebush Bay	15,800,000	1,179	100[2]	1,179	353,700	825 - 7,074	649,500 - 5,567,200
Parafield	4,500,000	2,210	100[2]	2,210	663,120	1,547 - 13,262	1,217,700 - 10,437,500

[1] As reported
[2] Conservative estimates based on qualitative data
[3] Quantity removed = concentration x volume collected

7.5 Key Learnings

While it has been accepted for a number of years that, to correctly assess the worth of a water servicing option, the cost of implementing a re-use scheme must be compared to the true costs of current supply and disposal practices, little progress has been made in developing such means of comparison. The difficulties in defining boundaries of potential benefits (externalities) appear to have discouraged attempts to fully quantify costs and benefits of stormwater re-use schemes. The lack of attention to this area is concerning, given the (often) high levels of public funding which has gone into these systems.

An extensive study was conducted at the aluminium smelter at Portland, Victoria, to develop a strategy for retrofitting the plant with improved water management practices. The smelter uses more than 500 ML of mains water annually. This water is supplied by the local council, which is under pressure to expand its supply system to meet the demand of a growing community. The study found that conservation-oriented water management practices have the potential to reduce present mains water use at the plant by 80%. In addition, significant pollution control and subsequent environmental protection was likely to be achieved since the plant collected and discharged stormwater (with process effluents) to sea using a conventional drainage system. As a result of the study's recommendations, steps to improve process efficiencies through increased maintenance (e.g. finding and repairing leakages etc.) were implemented. However, although it was planned to introduce stormwater collection to supplement mains water used in industrial processes, management could not be convinced of the need for what would be an expensive capital outlay, particularly since the price of mains water is so inexpensive.

The developers of Inkerman Oasis identified the lack of developer front-end incentives as the most difficult issue associated with water recycling. The high capital cost for WSUD practices is unable to be recompensed at any time in the project since market demand for WSUD is not compensated by the prices units can sell for.

The lack of attention to collecting lifecycle cost data on most of these projects is also of concern; the lack of data reduces the ability to develop reliable predictions of costs for systems being proposed.

Other key learnings:

- The developers of the Santa Monica recycling facility considered that the additional costs of incorporating art into public works was miniscule compared to the long term public educational benefits and the public acceptance of a treatment facility near a major tourist attraction.
- Some buyer reluctance at Oaklands Park was initially experienced due to concerns about economic viability, however persistence on the part of the developer paid off as all lots have been sold and many developed.
- Of all the re-use schemes surveyed, the Figtree Place development has had the most extensive cost/benefits analysis conducted. Coombes *et al.,* (2000) suggested an alternative way to adequately compare re-use schemes with conventional water supply and disposal practices without having to address the difficulties of costing in social and environmental benefits. A novel approach with well structured methodology should be developed to resolve these issues (that is based on sound science, such as Australian Standard for Lifecycle Cost analysis, Australian Standards, 1999). The CRC for Catchment Hydrology is currently undertaking a project to this end, with results expected towards the end of 2004.

The main key learning is that there is inadequate development of methodology to objectively assess the costs and benefits of water re-use systems, and this lack will hold back both their assessment, and their implementation.

8. Performance

8.1 Introduction

Performance results are somewhat limited at this stage, partly since most of the stormwater re-use schemes studied are still very new and thus there is not a lot of feedback available. In general though, developers, operators and regulators appear to be satisfied with the re-use schemes' initial performances, and the public response has been positive.

The following sections describe the monitoring programs and performance of the various stormwater re-use schemes.

8.2 Monitoring

Tables 8.1 and 8.2 summarise the monitoring schedules developed for various stormwater re-use schemes for which we were able to gather information. This table contains details for only half of the studied sites. Water quality is not currently being monitored as part of the stormwater re-use scheme at Kogarah Town Square. It is planned to monitor water quality to some extent, but this is not considered critical because the end-use type is non-contact (P. Smith, *pers. comm.*). At Bowies Flat, ambient and post-storm event water quality monitoring occurs, however this is part of the monitoring program to evaluate the water quality improvement efficiency of the wetlands and is not specific to re-use. It is understood that long term water quality monitoring is taking place at Parfitt Square, however no further details could be obtained. No details about the monitoring programs for CSU Thurgoona and Oaklands Park were gathered, however it is understood that they do exist.

From Tables 8.1 and 8.2 it is clear that the larger the scale of the scheme, the higher the public profile, or the more personal the re-use type, the more extensive the monitoring program is. Conversely, the simpler the scheme and the less personal the re-use type, the smaller the monitoring schedule is.

It must be noted that in almost all cases the NWQMS and relevant State guidelines for water recycling comprehensively outline monitoring parameters and suggested monitoring frequencies. The fact that these suggestions are not always incorporated into the re-use schemes further highlights the need for regulations (rather than guidelines) specifically targeting stormwater re-use.

8.3 Assessment of Performance

Performance was generally assessed against whether the system met its overall objectives, whether relevant water quality guidelines were achieved and whether the system adequately supplied demand. Unfortunately, only limited data, mostly qualitative assessment, were available (as noted earlier, it was difficult to obtain information regarding performance achievements).

Table 8.3 summarises, where possible, how each scheme is meeting its performance objectives; a tick means that the systems met that particular objective. If a particular criterion is not ticked, it may not be that it hasn't been achieved, rather it may not have been a specific performance goal. Further, it also may be due to lack of a monitoring program that allowed it to be assessed.

The data were gathered for 13 schemes (Table 8.3). Performance of the re-use scheme at Altona Green cannot be assessed yet; the system has been briefly operational but is currently not due to problems with pumps. The system at Bowies Flat is also difficult to assess given that it is not specifically designed for re-use and monitoring is aimed at assessing how the wetland system treats water for flows of improved quality and addresses flood abatement; it does not explicitly target quality of water for re-use.

The scheme at Figtree Place has been successful with respect to both water quality and quantity. There has been no overflow to the conventional system in the first two years of operation, infiltration rates in the dry detention basin have been more than adequate to deal with general runoff and, overall, water quality complies with Australian Drinking Water Guidelines (although some parameters were found to occasionally exceed recommended levels).

Table 8.1 Summary of Water Quality Monitoring Programs for Stormwater Re-use Systems

Parameters		**Altona Green**	**Bowies Flat**	**Figtree Place**	**Hawkesbury**	**Homebush Bay**	**Inkerman Oasis**	**Manly STAR**	**Parafield**	**Powells Creek**	**Santa Monica**	**Solander Park**	**Taronga Zoo**
Components Monitored	storage	✓		✓	✓	✓			✓	✓		✓	
	treatment					✓	✓			✓		✓	✓
	hot water service			✓									
	potable supply			✓									
	runoff/inlet		✓					✓	✓	✓	✓	✓	
	soil				✓		✓		✓				
	other[1]					✓							✓
Water Quality Parameters	quality[2]	✓					✓	✓			✓		
	TSS		✓		✓	✓			✓	✓		✓	✓
	TS			✓					✓				
	VSS		✓										
	turbidity			✓	✓					✓			
	TN		✓		✓	✓				✓		✓	
	NO_x		✓	✓									
	NH_4+		✓										
	TP		✓	✓	✓	✓				✓		✓	
	FRP		✓										
	pH		✓	✓	✓				✓	✓		✓	✓
	DO			✓									
	EC			✓	✓					✓			
	temp		✓	✓	✓								
	BOD			✓	✓								✓
	salinity/TDS			✓	✓							✓	
	chlorides			✓									
	colour			✓									
	bacteria		✓	✓	✓	✓						✓	✓
	viruses					✓							
	chlorophyll *a*				✓								
	chlorine residual				✓								
	heavy metals		✓		✓	✓				✓		✓	
	toxicants				✓					✓			
	other[3]				✓						✓	✓	
Sampling Method	*in situ* sensors	✓							✓				
	autosampler		✓	✓									
	manually		✓	✓					✓				
Monitoring Frequency	continuous					✓			✓				
	6 hourly			✓									
	weekly				✓								
	monthly			✓	✓								✓
	during/after events		✓	✓						✓		✓	
	half yearly				✓								✓
	yearly				✓								

1 Homebush Bay: 20 monitoring points throughout system plus all other significant ponds and wetlands; Taronga Zoo: overflow from the treatment plant's inlet detention tank

2 Know water quality monitoring occurs but don't know specific parameters

3 Hawkesbury: Na, K, Mg, Ca, Cl, SO_{4-}, HCO_3, CO_3; Santa Monica: oil and grease; Taronga Zoo: oil and grease

Table 8.2 Summary of Water Quantity and Other Monitoring Programs for Stormwater Re-use Systems

Parameters		**Altona Green**	**Bowies Flat**	**Figtree Place**	**Hawkesbury**	**Homebush Bay**	**Inkerman Oasis**	**Manly STAR**	**Parafield**	**Solander Park**	**Taronga Zoo**
Components Monitored	quantity[1]						✓			✓	
	storage (volume)	✓	✓	✓	✓						
	water use			✓	✓						✓
	recharge basin			✓							
	infiltration rates			✓				✓			
	inflow/runoff quantity			✓				✓			✓
	watertable			✓					✓		
	outflow										✓
Sampling Method	in situ sensors	✓	✓	✓							
	meter			✓	✓						
Monitoring Frequency	6 hourly			✓							
	weekly				✓						
	monthly				✓						
	during/after events			✓							
Other	maintenance			✓							
	economic viability			✓							
	social acceptance			✓							
	ecological studies					✓			✓		
	groundwater				✓						
	other									✓	

[1] Know water quantity is monitored but don't know specific components

Table 8.3 Summary of Performance

	Against Objectives							Quality			Quantity
	Decrease Potable Water Usage	**Protection of Downstream Waterways (pollution)**	**Decrease Frequency and Severity of Discharges**	**Reduce Sewage Discharge**	**Demonstrate Viable Stormwater Re-use**	**Showcase Best Water Management Practices**	**Other[1]**	**Pollutant Removal**	**Complies with Relevant Standards**	**Groundwater Quality Maintained/Improved**	**Adequate Storage Capacity/Supply**
Figtree Place	65%		✓		✓				✓		
Hawkesbury	✓	✓		✓	✓	✓	✓				
Homebush Bay	50%	✓		>90%		✓	✓	✓	✓		✓
Inkerman Oasis	30%	✓	✓	✓		✓		✓			
Kogarah	17%	✓	✓				✓				
Manly STAR		✓	✓		✓				✓	✓	✓
Oaklands Park					✓				✓		✓
Parafield	✓	✓	✓		✓		✓	90%	✓	✓	✓
Parfitt Square	✓	✓	✓				✓	✓		✓	
Powells Creek		✓				✓	✓	90%			
Santa Monica	4%	✓				✓	✓				
Solander Park	✓	✓			✓		✓	>90%			
Taronga Zoo	✓	✓		✓	✓	✓					

[1] Other objectives:
- develop community awareness (Hawkesbury, Kogarah, Santa Monica, Solander Park),
- provide recreational areas (Hawkesbury, Powells Creek),
- ensure compliance with environmental undertakings committed to as part of bid for Olympic Games (Homebush Bay),
- secure regional economic development (Parafield),
- aquifer replenishment (Parfitt Square), and
- provide wildlife habitat (Powells Creek).

At Homebush Bay approximately 40 tonnes of litter was removed from Haslams Creek in 2000 by floating booms and physical cleaning of banks, and there has been no need to revert to the backup supply in the first three years of operation.

The Manly STAR project collects 70% of surface runoff and, as yet, the storage tank has not been emptied, although monitoring has not confirmed whether the tank has overflowed.

At Oaklands Park, backup pumping from Deep Creek has only been made use of once, to fill the storage dams during the establishment period.

Timely information about performance of the re-use scheme at CSU Thurgoona was not able to be obtained. However, from the information that was gathered, it appears that all is going well.

8.4 Key Learnings

Experience gained from the Figtree Place development revealed opportunities for improved design in the form of reduced plumbing, elimination of backflow prevention devices, exclusion of redundant elements and more efficient construction practices (Coombes *et al*., 2000). Some of these options are currently being investigated at an existing housing allotment in a suburb of Newcastle, although re-use at this site is limited to roof runoff.

Although the quality of water for re-use at Homebush Bay is compliant with guidelines, high nutrient levels are present in the brickpit storage and there is visible algal growth. Options for nutrient removal from this storage are currently being investigated.

A key learning resulting from the Inkerman Oasis development is, since stormwater is of a higher quality than greywater, it is intended to keep these two streams separate and use stormwater for hot water supply in future developments.

A second component of the Manly STAR project involved the installation of Rocla Ecoloc® permeable pavers in Smith St North (Figure 8.1). This component of the project aimed to treat and infiltrate runoff from the street surface to the underlying soil; it did not involve direct re-use. This infiltration

Figure 8.1 Interlocking Pavers Installed in Smith St North Create a Permeable Surface to Treat and Infiltrate Runoff from the Street Surface

component has been deemed more successful than the re-use component. The problem with the re-use component is that it concentrates pollutants to one point before passing through the treatment system, resulting in decreased treatable flow rates and increased maintenance requirements (P. Smith, *pers. comm.*). The infiltration component using permeable pavers in Smith St North is regarded as more efficient because it infiltrates water where it lands.

At Oaklands Park the water supply has been more than adequate for non-potable requirements to date; no residents have used their full 150 kL annual allocation. It will be interesting to see whether the water supply continues to be adequate in the future when all allotments have been developed. Finally, GH Michell and Sons Australia, the primary users of the stormwater collected by the Parafield scheme, are very pleased with the quality of the water (250 mg/L salinity (TDS) recycled stormwater is considerably less than the salinity of water from the Murray River (>400 mg/L)).

9. Critique of Current Practices - Knowledge Gaps and Research Needs

Although some progress has been made in the field of stormwater re-use, there are many knowledge gaps that need to be filled before it can be efficiently and safely integrated into the urban water cycle on a widespread scale.

At present, the largest obstacles to implementing stormwater re-use are:

- lack of regulation and design criteria;
- lack of clear design guidelines; and
- lack of a method to adequately assess costs and benefits of re-use systems against conventional practices.

Knowledge gaps and research needs may be arranged into four main categories: regulation, design, costs and benefits, and other. Issues related to performance, construction, operation, maintenance, implementation, etc. are directly related to the existing problems in the four listed categories. The four main categories are themselves also highly interrelated. For example, without clear design criteria re-use systems cannot efficiently perform. Further, without knowledge of performance, benefits cannot be quantified.

9.1 Regulation

9.1.1 Knowledge Gaps

Stormwater recycling is not effectively regulated at this stage. There are only a few general guiding principles that apply:

- re-use of stormwater must not result in pollution of the environment in any way;
- the quality and quantity of the treated stormwater must be fit for the intended purpose;
- it is unclear whether re-use of general storm runoff for potable purposes is permitted (in some cases roof runoff is, reclaimed wastewater is not); however it is envisaged that it would not be acceptable for potable re-use unless approved by the relevant authorities, most likely on a case-by-case basis.

There are specific, State government level statutory obligations under health, environment, agricultural, and food legislation for re-use of wastewater, and it is generally recommended that these be referred to as guides to evaluate and operate stormwater re-use schemes. However, the characteristics of stormwater and wastewater are very different, therefore these guidelines are only adequate to a certain extent.

New National Water Recycling Guidelines are currently being developed as part of the federal government's National Water Initiative and will address stormwater recycling but not as a first priority (G. Jackson, *pers. comm.*).

9.1.2 Research Needs

Given the potential for stormwater re-use in Australia, higher priority should be given to development of specific guidelines to facilitate appropriate implementation and to allow re-use systems to be designed effectively. If stormwater re-use can be implemented via a well defined, step-by-step process which is backed by research (rather than the lengthy, complicated procedures currently experienced) it follows that developers will be more inclined to incorporate stormwater re-use schemes.

9.2 Design

9.2.1 Knowledge Gaps

Re-use of stormwater is currently largely restricted to smaller scale sites. This is not surprising, given that stormwater re-use is still very much at an experimental stage and system complexity increases with size, particularly with respect to collection and distribution methods. Further, stormwater is primarily used for purposes with the lowest risk of human contact (e.g. irrigation) suggesting a lack of confidence in treatment and storage reliability.

While collection and storage are still based on conventional methods, treatment is mainly based on current stormwater treatment techniques. Current design practice for stormwater treatment systems does not always guarantee reliable stormwater treatment to required quality standards, since the design approach focusses on the protection of aquatic ecosystems, which requires less stringent design standards than required for re-use. There doesn't seem to be any difference in design of techniques for re-use compared with for pollution control. This may pose a weakness, in that consistently producing treated stormwater of a quality suitable for re-use may not adequately addressed by such designs.

Designing a stormwater storage for safe and efficient re-use is also a challenge (spatial and temporal variability of runoff is one of the main challenges in sound stormwater re-use). The optimal and economical type and size of the store is unclear, particularly for open surface stores (e.g. ponds/urban lakes). It is well known that water quality in such a system will be affected by its size, detention time, and level variations. Safety and aesthetics will also be highly influenced by the design of its banks and maximum level variations. However, there is little evidence of how these factors are taken into account at present.

When treating stormwater, is it best to direct runoff to one point or treat it where it lands? While directing runoff to one point for treatment concentrates pollutants and therefore increases efficiency, it also decreases treatable flow rates and increases maintenance requirements.

It can be concluded that one of the main challenges in efficient stormwater use is a paucity of technology, and guidance in their design, for integrated urban stormwater treatment and re-use. Existing stormwater re-use practice is far ahead of research, in that there are no technologies designed specifically for stormwater re-use, rather technologies designed for pollution control are frequently utilised. Such technologies are not necessarily applicable to stormwater re-use and may pose a danger to the future adoption of stormwater re-use measures.

9.2.2 Research Needs

There is a clear need for the development of innovative techniques for the collection, treatment and storage of stormwater. Until this knowledge gap is addressed stormwater re-use will most likely be limited to smaller scale, less complex systems. Design standards for stormwater treatment for the purposes of re-use, based on targeted research, are also needed. The design standards should be published as part of an "Integrated Stormwater Treatment and Re-use Design Manual".

Performance modelling for design evaluation purposes also needs further research, to adapt it to the requirements of integrated stormwater treatment and re-use. Reliable models should be developed that are capable of predicting the treatment efficacy of new technologies, or water quality changes in storages. Existing models, such as MUSIC (CRCCH, 2002), Aquacycle (Mitchell, 2000), or PURRS (Mitchell, 2000), could be used as a starting point for their development. Designing efficient systems would then be more readily accessible to the industry.

9.3 Costs and Benefits

9.3.1 Knowledge Gaps

The lack of developer front-end incentives is a difficult issue associated with water recycling. A key learning from the Inkerman Oasis project is that the high capital cost for WSUD practices is unable to be recompensed at any time in the project since market demand for WSUD is not compensated by the prices developments can sell for. At this stage, there is inadequate development of methodology to objectively assess the costs and benefits of re-use systems, and this will hold back both their assessment, and their implementation.

Assessment of benefits which are not easily measured, such as environmental flows, conservation and new habitat creation, is one of the main challenges. However, the scope of this challenge (and the time it may take to solve) means that a simple, more pragmatic approach may be required, undertaking the analysis on readily-obtainable cost and benefit data.

9.3.2 Research Needs

It has been accepted that, to correctly assess the worth of a water servicing option, the cost of implementing a re-use scheme must be compared to the true costs of current supply and disposal practices. However, little progress has been made in developing such means of comparison. The difficulties in defining boundaries of potential benefits (externalities) appear to have discouraged attempts to fully quantify costs and benefits of stormwater re-use schemes. A novel approach with well structured methodology should be developed to resolve these issues (that is based on sound science, such as Australian Standard for Lifecycle Cost Analysis, Australian Standards, 1999). If the costs and benefits of re-use systems can be shown to be compare favourably with the costs and benefits of conventional practices, this will provide a good deal of incentive to overcome other obstacles to widespread adoption of stormwater recycling.

9.4 Other

9.4.1 Knowledge Gaps

Construction, Operation and Maintenance

The fundamental knowledge gap with respect to construction, operation and maintenance is the lack of clear specification of an operation and maintenance program. There are a number of sites studied that appear to have been neglected since completion of construction. It appears that a lack of adequate monitoring and maintenance is particularly a problem for the smaller-scale sites, where there are inadequate resources and/or expertise to undertake the required maintenance. An operation and maintenance program should be prepared during the design process and include clear identification of the responsible entity, and a realistic assessment of whether that entity is capable of taking on the operation and maintenance responsibly. Without this, it is likely that the integrity of a number of the systems studied is at risk, potentially impacting on public health and amenity.

Implementation Issues

One of the most frequently encountered issues during the implementation of the studied re-use schemes was lengthy and resource intensive negotiation, assessment and approval processes. This is largely due to a lack of pertinent experience and policies on the part of the water industry and relevant authorities. Also lacking is a clearly defined process to involve community, developers, and regulators. Informing and involving all relevant parties is instrumental in ensuring the successful adoption of new ideas.

Partitioning of Re-use Sources

When recycling different water streams, is it best to combine or separate them? This question has arisen as a result of performance assessment where different water streams are re-used and is yet to be answered. Greywater and wastewater are more regular with respect to both quality and supply, making collection, treatment and re-use more straightforward than for irregular stormwater. Since stormwater is variable in terms of quality and supply, it may be more useful as a backup supply to supplement other recycled water in times of high demand. However, stormwater is generally of a higher quality than wastewater and therefore is likely to have higher public acceptance for more personal re-use e.g. in hot water systems.

9.4.2 Research Needs

Other issues that require further research to resolve include:

- Development of well defined guidelines with respect to construction, operation and maintenance to ensure adequate information is available to allow successful operation;
- Development of a clear process, supported by regulation, that involves all concerned parties i.e. regulators, developers, design team, community from the initial stages of a project; and
- The previously mentioned development of clear regulations and appropriate design guidelines, based on appropriate research, would also be helpful in overcoming implementation issues.

9.5 Synthesis of Key Learnings

There is a need for a clear framework for developing new water servicing approaches. Veldkamp *et al.*,

(1997) proposed the following decision network for choosing the best combination of techniques for integrated urban water management:

1. Problem definition – key factors include development type, quality and quantity of stormwater, and existing facilities;
2. Technologies – consideration of possibilities of different technologies for treatment and storage of stormwater;
3. Selection procedure – assessing appropriateness of likely alternatives;
4. Combination – development of scenarios by combining potential technologies;
5. Ranking by sustainability – assessment of scenarios according to their sustainability; and
6. Costs – integrated urban water management is far more likely to be implemented on a widespread scale if it is economically feasible (Veldkamp *et al*., 1997).

Veldkamp *et al*., (1997) briefly describes each step of this decision network, with more detailed discussion of the selection procedure and sustainability ranking.

The key learnings from our survey of existing stormwater re-use systems were combined with the above step-by-step approach, resulting in the following decision support framework:

- **Problem definition:** this step should address the multiple objectives of integrated water management i.e. human health, environmental protection (flow management and pollution loads), water demand, economic feasibility, site amenity, and social acceptance (Mitchell, 2002);
- **Selection procedure:** the selection of possible technologies will be influenced by the drivers for stormwater re-use for a particular system i.e. water trading (water shortages), disconnection of impervious surfaces from urban streams (environmental protection), and runoff control with respect to both volume and pollution (drainage infrastructure, environmental protection). Other important factors (that at least partly determine system complexity) are scale (allotment, neighbourhood, catchment) and whether the system is centralised or de-centralised;
- **Combination:** including a risk assessment in the design process offers a way around the current lack of regulation of stormwater re-use i.e. this may simplify the approval process;
- **Ranking by sustainability:** ideally a stormwater re-use system should mimic natural drainage processes. Of particular importance is consideration of environmental flows for overstressed urban rivers. A stormwater re-use system cannot be considered sustainable unless a portion of the water collected is released to waterways as environmental flows; and
- **Costs:** can be reduced if the total water cycle is managed, particularly if the re-use project is at a greenfields site i.e. infrastructure is not initially there.

Interestingly, the use of small-scale solutions (allotment scale) is advocated by Veldkamp *et al*., (1997). It is likely that de-centralising a stormwater re-use system will greatly contribute to improved public understanding of stormwater processes (through increased visibility of the system). De-centralisation will also simplify the re-use system, particularly in terms of collection and distribution processes, thus reducing the risk of cross-connecting different pipelines. However, this must be balanced with economic feasibility and it is suspected that re-use efficiency and thus cost viability improves with scale.

10. Conclusions

Stormwater re-use is not effectively regulated at this stage. Given the potential for stormwater re-use in Australia, higher priority should be given to development of specific guidelines to facilitate appropriate implementation and to allow re-use systems to be designed effectively. If stormwater re-use can be implemented via a well defined, step-by-step process (rather than the lengthy, complicated procedures currently experienced) it follows that developers will be more inclined to incorporate stormwater re-use schemes.

Methods employed for the collection and storage of stormwater intended for re-use are based on conventional methods while treatment methods are mainly based on current stormwater treatment techniques (which are primarily designed for pollution control). There is a paucity of technologies, and guidance in their design, specific to integrated stormwater treatment and re-use. There is a clear need for the development of innovative technologies (or adaptation of existing technologies) for the collection, treatment and storage of stormwater. Until this knowledge gap is addressed stormwater re-use will most likely be limited to smaller scale, less complex systems. Design standards for stormwater treatment for the purposes of re-use are also needed.

Performance modelling for design evaluation purposes also needs further research, to adapt it to the requirements of integrated stormwater treatment and re-use. Reliable models should be developed that are capable of predicting the treatment efficacy of new technologies, or water quality changes in storages. Existing models, such as MUSIC, Aquacycle, or PURRS, could be used as a starting point for their development. Designing efficient systems would then be more readily accessible to the industry.

Currently, there is inadequate methodology to objectively assess the costs and benefits of re-use systems. It has been accepted that, to correctly assess the worth of a water servicing option, the cost of implementing a re-use scheme must be compared to the true costs of current supply and disposal practices. However, little progress has been made in developing such means of comparison, and getting agreement on this method. A novel approach with well structured methodology, based on sound science, should be developed to resolve these issues. If the costs and benefits of re-use systems can be shown to compare favourably with the costs and benefits of conventional practices this will provide a good deal of incentive to overcome other obstacles to widespread adoption of stormwater recycling.

Other key learnings and research needs:

- It appears that a number of studied sites have been neglected since completion of construction. The development of well defined guidelines with respect to construction, operation and maintenance to ensure adequate information is available to allow successful operation is required. Without this, it is likely that the integrity of a number of the systems is at risk, with potential impacts for public health and amenity;
- The involvement of all concerned parties i.e. regulators, developers, the design team and the community, is a key factor in determining the success (or failure) of a re-use project. A clear process, supported by regulation, that facilitates this involvement from the initial stages of a project should be developed; and
- The previously suggested development of clear regulations and appropriate design guidelines would also be helpful in overcoming many of the implementation issues encountered by the proponents of the studied re-use schemes.

Notwithstanding the limitations described above, there is a great potential for the integration of stormwater treatment and re-use in Australia. The combination of climate and relative availability of space, means that re-use of stormwater could provide significant benefits in both protection of receiving waters from pollution, and reduction in potable water demand. Ongoing commitment by the water management industry to this area is warranted.

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APPENDICES

Appendix A

A.1 Summary of Stormwater Re-use Schemes Studied

Site	State	Contact	Size (ha)	Other water?	Treatment method	Re-use type	ARI Event Capacity	Monitored?
Homebush Bay	NSW	**Andrzej Listowski** Sydney Olympic Park Authority	760	y	GPTs swales & buffers wetlands infiltration system advanced disinfection	irrigation firefighting environmental flows toilet flushing other outdoor use	1:100 yr	y
Figtree Place	NSW	**Peter Coombes** University of Newcastle	1.1	n	infiltration system	irrigation other outdoor use other use	1:50 yr	y
Taronga Zoo	NSW	**Daryl Edwards** Taronga Zoo	0.83	y	litter & sediment traps advanced treatment disinfection	irrigation toilet flushing other outdoor		y
Hawkesbury Water Re-use Scheme	NSW	**Sandy Booth** University of Western Sydney	100	y	wetlands ponds & basins	irrigation environmental flows other use		y
Powells Creek East	NSW	**Jake Matuzic** City of Canada Bay	0.66	n	infiltration system	irrigation environmental flows other use		y
Kogorah Town Square	NSW	**Peter Smith** Kogarah Council	1.0	n	infiltration system	irrigation toilet flushing other outdoor use	1: 3 mth	n
Manly Council	NSW	**Joanne Scarsbrick** **Paul Smith** Manly Council	3	n	litter & sediment traps infiltration systems	irrigation		y
Charles Sturt University, Thurgoona	NSW	**David Mitchell** Charles Sturt University	87	y	swales & buffers wetlands	irrigation		y

A.1 Summary of Stormwater Re-use Schemes Studied ...Continued

Site	State	Contact	Size (ha)	Other water?	Treatment method	Re-use type	ARI Event Capacity	Monitored?
Solander Park	NSW	**Leanne Dallmer-Roach** Storm Consulting **Peter Donley** South Sydney City Council	65	n	litter & sediment traps infiltration systems advanced treatment	irrigation	1:20 yr	y
Bobbin Head Road	NSW	**Christina Roman** Boyden and Partners Pty Ltd	2	y	litter & sediment traps infiltration systems wetlands	irrigation fire fighting		n
Bowies Flat Wetland	Qld	**Anne Simi** City Design	377	n	ponds & basins	irrigation	1:2 yr	y
Parafield/Michell Project	SA	**Colin Pitman** City of Salisbury	1600	n	wetlands	irrigation other use	1:10 yr	y
Parfitt Square	SA	**David Pezzaniti** University of South Australia	1.3	n	litter & sediment traps swales & buffers wetlands infiltration systems	irrigation	1:100	y
Altona Green Park	VIC	**Ian Brown** Hobsons Bay City Council	4	n	biofilter	irrigation		y
Inkerman Oasis	VIC	**Gary Spivak** City of Port Phillip	1.223	y	litter & sediment traps wetlands infiltration systems advanced treatment disinfection	irrigation toilet flushing	first flush	y
Oaklands Park	VIC	**Bill Mole** HNJ Holdings Pty Ltd **Neil Kerby** Winkfield Pty Ltd	174	n	swales & buffers	irrigation firefighting toilet flushing other outdoor use	1:100	y
Santa Monica Urban Runoff Recycling Facility	USA		174	n	litter & sediments traps advanced treatment disinfection	irrigation toilet flushing	dry weather	y

A.2 Example of Detailed Table

Site Information		
Site Name		Figtree Place
Contact Name		Peter Coombes
Location		Hamilton, Newcastle, NSW
Project Partners		Newcastle City Council Building Better Cities Program (federal government) NSW Department of Housing
References		(Coombes et al., 1998) (Coombes et al., 1999) (Coombes et al., 2000) (Coombes, 2002) (UWRC, 2003) (Melbourne Water, 2003)
General Site Details:		
Development Type		27 small- and medium-size inner city housing venture
Size		1.1 ha (Hamilton Bus Station site area = 3.0 ha)
Date of commission		April 1995 (concept investigation and design) Redevelopment opened on 21 June 1998
Scale of implementation		Streetscape and allotment
Rainfall	*Rainfall (mm/yr)*	1141.9
	No. rainfall days/yr	133.0
	1 yr intensity	
	Mean daily evaporation (mm)	
Geology		Sand to depth of 10m, substrate of clay, bedrock at 25m
Aquifer	*Watertable*	2-2.5 m, varies seasonally
	Groundwater movement	~4 m/yr
	Other	Prior to remediation, groundwater at 3-4 m depth showed dark discolouration due to presence of iron and manganese salts

A.2 Example of Detailed Table ...continued

Site History		Previously used as a transportation centre since the early 1900s, initial use by trams, more recently buses; resulted in major contamination hot spots of PAH, TPH, heavy metals, pesticides, oil and grease
System Requirements		
Objectives		To retain stormwater on-site and reduce potable water consumption To demonstrate that normal urban living could be pursued with significantly less potable water consumption than used in conventional developments Planning indicated that sufficient water could be harvested on site to meet 50% in-house needs, 100% domestic irrigation needs, 100% bus-washing demand
End-use requirements (regulation)	*Quality* *Quantity* *Operational* *Risk assessment*	
Other		Assessed against Australian Drinking Water Guidelines
System Components:		
Collection	*How*	Runoff from paved areas, lawns and gardens passes to central Detention Basin Recharge Area
	Capacity (ML) *(% mean ann. runoff)*	
	Design methods	Internal kerbed roadways Design flood capacity is 83% of runoff for all events up to and inc 1 in 50 year event High infiltration rates of sandy soil exploited to minimise overflows from the basin
	Key Learnings	
Treatment	*How*	Infiltrated through base of dry detention basin; 250 sq.m grassed depression, overlays 750mm layer of gravel enclosed in geofabric below 300mm topsoil layer
	Capacity (ML) *(% mean ann. runoff)*	
	Design methods	
	Key Learnings	
Storage	*How*	Unconfined aquifer (ASR)
	Capacity (ML) *(% mean ann. runoff)*	
	Design methods	Flownet model of aquifer system used to explore possible groundwater impacts

A.2 Example of Detailed Table ...continued

Storage cont…	*Key Learnings*	No stormwater overflow from site up to 2000 and a maximum depth of ponding in the detention basin of 260mm with a residence time of 6 hours has been experienced
Re-use	*What*	Garden and open space irrigation, bus washing at adjacent depot
	How	Submerged pump within recharge basin at depth of 10 m, pumped as required, dual reticulation, optionally treated (activated carbon) for colour removal
	Capacity (ML)	max 2000 kL/yr supplied to bus depot
	(% mean ann. runoff)	
	Design methods	Preliminary studies of water availability from roof and general runoff indicated ample supply for domestic uses
	Key Learnings	
Other Water for Re-use		
Roof runoff (if treated and used separately)	*Capacity (ML)*	Raintank capacities range from 9 to 15 kL
	(% mean ann. runoff)	
	(% total water use)	
	Collection	Stormwater pipes
	Treatment	First-flush pits separate first 2 mm of rainfall; reinforced concrete box placed over fibre reinforced concrete pipe, box contains a screen to filter debris and a baffle to separate first flush from inflow to raintank, water retained upstream of baffle infiltrates through holes in base of box to pipe and soil
	Storage	Five centralised underground tanks; reinforce concrete raintanks, contain inlet from first flush pit, clean out chamber for sludge removal, low water level monitor, outlet for domestic supply and overflow pipe to a recharge trench
	Re-use	Pumps with pressure cells supply rainwater from tanks to hot water systems and for toilet flushing, fail-safe systems include second pump in case of failure and solenoid to switches to mains supply if inadequate water pressure, electricity failure or low water level is detected; dual reticulation, backflow prevention devices used to isolate from mains supply
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	n/a
	(% total water use)	

A.2 Example of Detailed Table ...continued

Greywater cont…	*Collection* *Treatment* *Storage*	
Other Water for Re-use	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Implementation Issues		
Site Amenity		Provision made for conversion to conventional practices (i.e. can revert to mains supply) should water quality fall below accepted levels or drought occur Detention basin provides an open space recreation area during dry spells
Public Safety		Irrigation occurs during night hours to minimise risk of ingestion Survey of residents found that 48% of respondents used water from the hot tap for cooking; rainwater in hot water systems must be therefore compliant with drinking water standards Backflow prevention devices isolate recycled water supply from potable supply
Landscape Requirements		
Integration into total urban water cycle		Water saving appliances are used
Possible Problems		Potential for undetected contaminants being released into the groundwater and polluting the residents' irrigation supply and moving to locations downstream where off-site users of the resource may also be affected. Solution: If groundwater quality falls below acceptable levels, raintank overflow and runoff arriving at central recharge area are diverted to the Bus Station drainage system Possibility that water retention practices might produce a groundwater mound adversely affecting the footings of homes, as well as creating unacceptably wet conditions in local backyards and gardens. Conversely, dispersed recharge with extraction from a central well may lead to significant drawdown of groundwater near extraction point. Solution: modelling investigation showed that existing groundwater levels would be preserved except at recharge region where drawdown may be experienced during summer Potentional for drought conditions causing serious disruption to in-house supplies. Solution: backup connection to potable water suuply Possibility of extreme rainfall causing severe flooding of residential units on the site. Solution: floods of greater magnitude than 1:50 yr event flow overland to northern boundary of development and conventional drainage system

A.2 Example of Detailed Table ...continued

Possible Problems cont…		Indoor water consumption and proportion that is used for hot water and toilet flushing unknown for the region; presented difficulties in determining the volumes of tanks and capacity of pumps to deliver rainwater to the dwellings Potential for health problems resulting from ingestion of unsanitary water collected from roofs and used in hot water systems. Solution: roof water sampling project concluded that roof runoff was virtually equivalent to rainwater quality apart from high TSS and ash content; fail-safe provisions include: if health standards not met, hot water system converts to mains supply, signage at hot water taps, tenant education
Institutional		Significant delays during development stage caused by approval agencies - concerns that project not economically viable, dual reticulation was not compliant with Australian Standards and that contamination of mains supply could occur; no institutional framework for acceptance of WSUD design principles, long-term maintenance requirements and cost
Other		
Key Learnings		Delivery method plays crucial role in success or failure of innovative projects Imperative that standard of design documentation for novel techniques be above average Early involvement of constructing contractor who is sympathetic to project innovations Early involvement of approval agencies Survey of tenants revealed significant acceptance of in-house use of rainwater collected from roofs Fail-safe provisions and on-going monitoring program vital element of the project and reflects its experimental nature
Other Issues		
Operation and maintenance	*How*	Water levels in raintanks used to supply toilet flushing and hot water uses constantly drawn down; ensures tanks regularly have storage capacity available to accept roof runoff
	Who	Newmacq Community Housing Company manages site, Newcastle City Council and the NSW Stormwater Trust funds program to monitor performance
	Key learnings	
Monitoring	*Water quality*	Rainwater tanks, hot water systems and potable supply manually monitored monthly for faecal coliforms, total coliforms, heterotrophic plate counts, pseudomonas species, DO, temperature, pH, BOD, EC, colour, TP, NOx, chlorides, salinity, total solids, giardia, cryptosporidium Rainwater tank quality automatically monitored every six hours for pH, tem, EC, DO and turbidity Groundwater quality (colour and contaminant levels) regularly monitored
	Water quantity	Water use Pressure sensors in rainwater tank adjacent to recharge basin measure water depth every six hours Pressure sensors in bores monitor watertable every six hours

A.2 Example of Detailed Table ...continued

Monitoring cont…		Pressure sensors at central recharge area and recharge trench determine infiltration rates and quantity of runoff
	Other	Automated monitoring system (triggered by rain events) in addition to manual sampling program
		Maintenance
		Economic viability
		Social acceptance (via questionnaire of 26 tenants)
	Key learnings	Improved tankwater quality will result from separation of first flush rainfall from inflow to raintanks
		Hot water systems operate at temperatures sufficient to pastuerize tankwater to produce quality compliant with Australian Drinking Water Guidelines
		Water treatment processes of flocculation, settlement and bioreaction appear to operate in rainwater tanks
		Significant tenant acceptance (95%) of the use of roof runoff for irrigation, toilet flushing, hot water systems, clothes washing and cooking. Moderate acceptance (70%) of the possible use of roof runoff for drinking purposes.
Performance	*Against objectives*	Measurement of internal water use showed a 65% reduction in potable water consumption during the period June to December 1998
	Water quality	Groundwater: complies with Australian Drinking Water Standards for all parameters except pH; acceptable for irrigation and bus washing purposes
		Roof runoff: occasionally exceeded guideline values for ammonia, pH, iron and lead; overall samples from tanks and hot water systems were found compliant with chemical and metal parameters in the Australian Drinking Water Guidelines
	Water quantity	Infiltration basin: maximum observed emptying time less than that determined to indicate acceptable performance
		Raintanks: 11-44% reduction in mains water use (differences attributable to construction errors with respect to first flush pits - lower values because pits separating too much runoff); degree of reduced mains water use and roof water utilisation dependent on the volume of rainwater tank storage, roof area and water use per person, and the proportion of roof area to rainwater tank volume
	Assement methods	Raintanks: performance assessed using meter readings, rainfall data and tank levels
	Key learnings	Opportunities for improved design in the form of reduced plumbing, elimination of backflow prevention devices, exclusion of redundant elements and more efficient construction practices
Cost/Benefits		
Costs	*Capital outlay*	
	Annual operating	Analysis suggests that the redevelopment is cost-effective when considered as a component of "beyond capacity" urban infrastructure
	(costs/kL)	The existing design details can be further improved with consequent lower costs
	User price	Payback period for WSUD elements would be longer than the anticipated life of the project

A.2 Example of Detailed Table ...continued

Benefits	*Reduced demand for potable supply*	Overall reduction in potable water demand of ~60% (40-45% by residents) compared with conventional developments High rainfall ensures net excess aquifer recharge, water not required to meet on-site demands used by adjacent bus-washing facility (max 2000 kL/yr)
	Flow management	Designed to contains 83% of runoff for all events up to and including a 1 in 50 year event (surface runoff from seven units in NE corner passes directly to conventional drainage system); floods of greater magnitude will flow overland to street at northern boundary and pass into conventional drainage system Raintank overflow directed to soakaways (gravel trenches) via stormwater pipes and recharged to the aquifer; trenches 750 mm deep and 1000 mm wide layers of gravel enclosed in geofabric below 300 mm topsoil layer, overflow from raintanks distributed within trenches by slotted pipes
	Pollution control	
	Infrastructure	Stormwater discharge almost completely eliminated, reduced downstream flood peak and reduced strain on stormwater infrastructure, including pollution control installations
	Environmental flow	

A.3 Summary of Water Re-use Sites not Studied

Site	State	Contact	General Runoff	Other water?	Treatment type	Re-use type
Lake Ginninderra John Knight Park	ACT	Ian Lawrence	y		sand filters	irrigation
Tuggeranong Park	ACT	Ian Lawrence	y		sand filters	irrigation
Gungahlin Golf Course	ACT	Ian Lawrence	y		sand filters	irrigation
Gold Creek Golf Course	ACT	Ian Lawrence	y		sand filters	irrigation
Conder Sports Ground	ACT	Ian Lawrence	y		sand filters	irrigation
Southwell Park Sewer Mining Facility	ACT					
Fyshwick Wastewater Treatment Plan pilot plant	ACT					
Allambie Heights Water Quality Control Pond	NSW		y			
Alumy Creek and Eyre St Wetlands, Grafton	NSW	Peter Adcock	y		wetlands	
Bells Creek, Blacktown	NSW					
Blue Hills Wetlands, Glenmore Park, Penrith	NSW	Peter Adcock	y		wetlands	
Broken Head Coastal Retreat	NSW	GeoLINK		waste		irrigation
Cattle Saleyards, Casino	NSW	GeoLINK	y		sedimentation anaerobic digestion biological oxidation disinfection	irrigation yard washdown
Cellulose Valley Technology Park, Lismore	NSW	Peter Adcock	y		sediment ponds wetlands	infiltration
Cox's Creek Reserve Wetlands	NSW					
Domain Creek Innovative Technologies Project	NSW	Holroyd City Council			infiltration	irrigation
Duffy Avenue Wetland, Westleigh	NSW					
Lake Pillans, Lithgow	NSW					
Model Farms High School, Baulkham Hills	NSW	Joe D'Aspromonte Peter Morrison				
Moore Reserve Wetland, Kogarah	NSW	Peter Adcock	y		wetlands	
Mullet Creek, Wollongong	NSW	CUSI	y			irrigation
Rouse Hill, Sydney	NSW					irrigation toilet flushing
Surveyors Creek, Glenmore Park	NSW					
Sutherland Shire Council	NSW					
North Lakes Golf Course	Qld	Lindsay McCleod	y	y		irrigation
Carrara Catchment	Qld	Allan Lush				
Forest Lake, Brisbane	Qld	John Maclean				irrigation
Melvin St	Qld	Anne Simi	y		bioretention system	irrigation
BP Clean Fuels Refinery	Qld					

A.3 Summary of Water Re-use Sites not Studied ...continued

Site	State	Contact	General Runoff	Other water?	Treatment type	Re-use type
Hervey Bay	Qld	Wide Bay Water			detention basins advanced treatment	irrigation
Ace Chemicals	SA	PCWMB				
Banksia Park Water Re-use Scheme	SA		y			irrigation
Christie Walk	SA					irrigation toilet flushing
New Haven Village, Osborne	SA	Terry Chuah Graeme Hill	y		advanced treatment disinfection	toilet flushing irrigation
St Elizabeth Church Carpark	SA	UWRC	y		grass-pave filter gravel filled trenches geotextile fabric	irrigation
Brighton	TAS	Warren Lee	y		advanced treatment	irrigation
Kangaroo Bay Rivulet Constructed Wetland	TAS	Adrian Tanner			GPTs constructed wetland	up to 10% of annual flow from wetland used to irrigate Rosny Golf Course
Anglesea Golf Course	VIC	Peter Byrnes	y	y	wetlands ???	irrigation
City of Kingston	VIC	Brian Trower				
Dow Chemical, Altona	VIC	Land Energy				irrigation
Ford Geelong	VIC		y		settling pond ???	industrial re-use irrigation
Northern Memorial Park, Fawkner	VIC	Ecological Engineering	y			irrigation
Ross House rooftop garden, Flinders Lane	VIC	Terry White				irrigation toilet flushing
Sunbury-Melton Recycled Water Pipeline	VIC	Western Water				irrigation
Underground Gas Storage Plant, Port Campbell	VIC	Peter Adcock, Australian Wetlands	y		wetlands	
Sharland Park Estate, Bell Post Hill	VIC	John Maxwell				
Bayswater, Perth	WA					
Byford Village Multiple Tier WSUD	WA	Caversham P/L, Shire of Serpentine-Jarrahdale			swales artificial creeks wetlands aeration	irrigation
Henley Annex Land Division	WA	City of Charles Sturt	y			
Roof runoff only						
Carindale Pines, Brisbane	Qld		roof only			
Heritage Mews, Castle Hill	NSW	Peter Coombes	both roof and general runoff collected, however only roof runoff is re-used; general runoff is collected and treated prior to slow release			
King St estate, Prahran	VIC	Dino Kalivas	roof runoff stored in old fire service water tank in building's basement, filtered, used in subsurface drip irrigation			

A.3 Summary of Water Re-use Sites not Studied ...continued

Site	State	Contact	General Runoff	Other water?	Treatment type	Re-use type
Lightning Ridge Public School, DPWS	NSW	Northrop	roof only		Rocla ecoRain filter UV filter	irrigation toilet flushing
New Brompton	SA	UWRC	roof only			irrigation aquifer recharge
Northern Adelaide Plans	SA	Gerry Davies	roof only			irrigation
Ormond Road, Elwood	VIC	Louise Barbon-Elliott	roof only			toilet flushing
Rockdale Council Chambers	NSW	Michael Casteleyn	roof only			irrigation toilet flushing
International						
Henderson Valley	NZ	City of Waitakere	y			
Waitakere Hospital	NZ	Waitakere City Council	general runoff flows into swales & ponds for treatment prior to release into local creek; roofwater collected for toilet flushing			
BHP Steel, Glenbrook, Auckland	NZ					
Lower Seletar/Bedok	Sing					
Village Homes, Davis	USA					
Prairie Crossings, near Chicago	USA					
At development stage						
Bexley Municipal Golf Course, Bardwell Creek	NSW	Bill Woodcock	y	n		irrigation
Urban Environment Centre, Chipping Norton	NSW	Liverpool City Council			wetlands	irrigation
Victoria Park, Zetland, Sydney	NSW	Reid Butler John Dahlenburg	y	n	swales filtration wetlands GPTs	water feature aquifer recharge irrigation
Wyong Public School	NSW	Martin Lynch	y		GPT Rocla ecoRain filter	irrigation
Heathwood/Brazil Development	Qld	Ralph Woolley				
Edinburgh Parks - Holden Stormwater Management Project	SA	Colin Pitman	y		wetlands	re-use at Holden, irrigation
Atherton Gardens, Fitzroy	VIC	Dino Kalivas; EcoEng	y	y	oil removal swale	irrigation
Aurora, Epping North	VIC					
Bergins Green Initiative	VIC	Matt Francey Grace Mitchell			Yet to be decided	Yet to be decided
Portland Smelter	VIC	John Hill				
Racing Victoria	VIC	Melbourne Water	engaged Connell Wagner to conduct detailed assessment of 12 racecourses around Melbourne, plan to undertake demonstration project at Cranbourne track			
Royal Park Wetland & Water Re-use Project	VIC	City of Melbourne				

Appendix B

B.1 Altona Green Park

Contact Information		
Contact Name		Sam Sampanthar, Ian Brown
Location		Altona Meadows, VIC
Project Partners		Hobsons Bay City Council
References		(HBCC) S. Sampanthar, personal communication I. Brown, personal communication
General Site Details:		
Development Type		Redevelopment
Size		4 ha sports field + 30 houses
Date of commission		
Scale of implementation		Sub-catchment
Rainfall	*Rainfall (mm/yr)*	557.3
	(ML)	22.3
	No. rainfall days/yr	144.5
	Mean annual runoff (ML)	
	Potential evapotranspiration (mm)	1400-1500
Geology		
Aquifer	*Watertable*	
	Groundwater movement	
	Other	
Site History		
System Requirements		
Objectives		Water conservation and keeping local beaches and waterways clean
End-use requirements	*Quality*	

B.1 Altona Green Park ...continued

(regulation)	*Quantity*	
	Operational	
	Risk assessment	
Other		
System Components:		
Collection	*How*	Gutter, pipe, natural drainage Roof runoff collected in guttering of new homes along two streets drains into a piped system that crosses under the street; general runoff collected by street gutters directed through chute openings in the kerb; runoff from sports ovals also drains into collected area
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Treatment	*How*	Biofilter Grassed swale drain (removes litter and silt), central filter zone (biological treatment zone removes fine oil particles, dissolved organic matter and nutrients)
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Storage	*How*	Underground storage tank made up of small cells Atlantis tank, modules, polypropylene wrap
	Capacity (ML)	0.4
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Re-use	*What*	Irrigation of sports ovals
	How	Sprinkler system
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	

B.1 Altona Green Park ...continued

Re-use cont…	*Key Learnings*	Has been operational, currently not due to electrical problems with pumps
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Implementation Issues		
Site Amenity		If storage tank is at full capacity, runoff stills discharges along grassed swale and overflows into existing street drainage
Public Safety		
Landscape Requirements		
Integration into total urban water cycle		
Possible Problems		

B.1 Altona Green Park ...continued

Institutional		
Other		
Key Learnings		
Other Issues		
Operation and maintenance	*How*	Filters and pumps (as required)
	Who	
	Key learnings	
Monitoring	*Water quality*	Sensors in pits where water is pumped
	Water quantity	Sensors for monitoring tank level
	Other	
Performance	*Against objectives*	
	Water quality	
	Water quantity	
	Assessment methods	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	$250,000
	Annual operating (costs/kL)	
	User price	
Benefits	*Reduced demand for potable supply*	Reduction in demand for mains water to irrigate the sporting field
	Flow management	
	Pollution control	Limiting pollutants and litter entering Port Phillip Bay
	Infrastructure	Reduce the amount of stormwater entering the main drainage system
	Environmental flow	

B.2 Bobbin Head Road

Contact Information		
Contact Name		Christina Roman
Location		Turramurra, Sydney, NSW
Project Partners		
References		(Roman, 2003) C. Roman, personal communication
General Site Details:		
Development Type		Greenfields, medium density development of 66 units
Size		2 ha
Date of commission		Did not get beyond planning stage
Scale of implementation		Sub-division? & Allotment?
Rainfall	*Rainfall (mm/yr)* *(ML)* *No. rainfall days/yr* *Mean annual runoff (ML)* *Potential evapotranspiration (mm)*	1068.0 21.4 121.3 481 1500-1600
Geology		
Aquifer	*Watertable* *Groundwater movement* *Other*	
Site History		
System Requirements		
Objectives		Decrease potable water usage Decrease pollutants Decrease introduction of weed species Decrease frequency and severity of discharges Decrease erosion and scouring
End-use requirements	*Quality*	

B.2 Bobbin Head Road ...continued

Other Issues		
Operation and maintenance	*How*	
	Who	
	Key learnings	
Monitoring	*Water quality*	
	Water quantity	
	Other	
Performance	*Against objectives*	
	Water quality	
	Water quantity	
	Assessment methods	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	
	Annual operating (costs/kL)	
	User price	
Benefits	*Reduced demand for potable supply*	
	Flow management	
	Pollution control	
	Infrastructure	
	Environmental flow	

B.3 Bowies Flat Wetland

Contact Information		
Contact Name		Anne Simi
Location		Bowies Flat, Coorparoo
Project Partners		Water Resources - Urban Management City Design Pipelines - Brisbane City Works Local Asset Services
References		L. Peljo, personal communication A. Simi, personal communication (BCC, 2003) (BCC, 2003)
General Site Details:		
Development Type		Retrofit
Size		377 ha
Date of commission		May 2002
Scale of implementation		Catchment
Rainfall	*Rainfall (mm/yr)* *(ML)* *No. rainfall days/yr* *Mean annual runoff (ML)* *Potential evapotranspiration (mm)*	1146.4 4322.0 122.0 1297 1500-1600
Geology		
Aquifer	*Watertable* *Groundwater movement* *Other*	 Non-saline
Site History		Fully developed catchment, predominantly residential land use, flooding problem
System Requirements		
Objectives		Reduce stormwater pollution, specifically fine sediments and nutrients, entering the Brisbane River and Moreton Bay

B.3 Bowies Flat Wetland ...continued

Objectives cont…		Enhance the ecological values of Bridgewater Creek and downstream receiving waters
		Enhance the visual amenity and recreational values of Bowies Flat and its surrounds
		Improve community awareness, while providing educational and research opportunities for local, regional and national stakeholders, including local schools, research institutions and stormwater industries
		Ensure risks associated with the project such as flooding, public safety and mosquitoes are minimised
End-use requirements (regulation)	*Quality*	
	Quantity	
	Operational	
	Risk assessment	
Other		
System Components:		
Collection	*How*	Gutter, pipe, channel
		Conventional stormwater collection system, flows into a concrete lined open channel (Bridgewater Creek) to the pond
	Capacity (ML)	2.3 ML pond
	(% mean ann. runoff)	100% runoff passes through the pond; proportion stored depends on size of storm event
	Design methods	
	Key Learnings	
Treatment	*How*	GPTs at two major inlets to the pond, sedimentation in the settling pond
	Capacity (ML)	ARI 3 month
	(% mean ann. runoff)	
	Design methods	Hydraulic performance key influence in design process - want to maximise treatment performance but not exacerbate upstream flooding
		Edges between turf and planting areas designed as mowing strips for ease of maintenance
	Key Learnings	Embankment slops should be gentle to encourage plant establishment and for ease of maintenance
Storage	*How*	In the pond
	Capacity (ML)	2.3 ML
	(% mean ann. runoff)	0.17%
	Design methods	
	Key Learnings	

B.3 Bowies Flat Wetland ...continued

Re-use	*What*	Irrigation of parkland
	How	Pumped from pond with a portable pump
	Capacity (ML)	
	(% mean ann. runoff)	Small proportion
	Design methods	
	Key Learnings	
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	

B.3 Bowies Flat Wetland ...continued

Implementation Issues		
Site Amenity		Water can be sourced from mains supply during dry periods
Public Safety		Public can access pond and macrophyte zone however grates prevent unauthorised access to inlet and outlet structures "All weather" pedestrian crossing of main waterway
Landscape Requirements		
Integration into total urban water cycle		
Possible Problems		
Institutional		
Other		
Key Learnings		
Other Issues		
Operation and maintenance	*How*	Operation and maintenance manual developed during design phase, details recommended maintenance such as regular inspection and cleaning of GPTs, weed removal Intensive maintenance during plant establishment period
	Who	Local Asset Services - Customer and Community Services
	Key learnings	Ongoing costs may be minimised by involving maintenance staff early in the design process Safety of maintenance staff should be addressed in the design and installation of hydraulic structures
Monitoring	*Water quality*	TSS, TN, TP, VSS after storm events, as part of wetland monitoring program (rather than for re-use water quality)
	Water quantity	
	Other	Success against performance criteria to be measured over first five years of as part of BCC's SQUIDs Monitoring Program
Performance	*Against objectives*	
	Water quality	Effective at removing coarse silt and fine sand, but dependent on the size of the storm event and the characteristics of the inflowing particle size distribution and concentration
	Water quantity	
	Assessment methods	
	Key learnings	An on-site representative to oversee environmental controls and performance (under the supervision of the Environmental Auditor) is likely to increase environmental compliance with both the licence conditions and General Environmental Duty Assembling the full design project team early in the detailed design phase allows all disciplines to feed simultaneously into the design process and influence the wetland's performance

B.3 Bowies Flat Wetland ...continued

Performance cont…		Water quality should be monitored from prior to planting to establish a baseline for evaluating the treatment performance of wetland vegetation Good design and treatment performance are subsidiary factors in the eyes of community. Their primary concern is the direct impact of the project on their lifestyle or property value (project manager)
Cost/Benefits		
Costs	*Capital outlay*	$2.75m
	Annual operating (costs/kL)	
	User price	
Benefits	*Reduced demand for potable supply*	Small reduction achieved, park only irrigated during 12 month establishment period, currently not irrigated
	Flow management	Addresses former flooding problem in the area
	Pollution control	Removal of litter, sediment and nutrients prior to downstream release
	Infrastructure	
	Environmental flow	Habitat provision, flows of improved quality

B.4 Charles Sturt University, Thurgoona Campus

Contact Information		
Contact Name		David Mitchell
Location		10 km NE Albury
Project Partners		
References		(Mitchell et al., 2001) D. Mitchell, personal communication (Charles Sturt University, 2003)
General Site Details:		
Development Type		Greenfields
Size		87 ha
Date of commission		January 1999
Scale of implementation		Sub-catchment (7 across site, 3 initially developed)
Rainfall	*Rainfall (mm/yr)*	715.2
	(ML)	622.2
	No. rainfall days/yr	97.1
	Mean annual runoff (ML)	186.7
	Potential evapotranspiration (mm)	1500-1600
Geology		
Aquifer	*Watertable*	
	Groundwater movement	
	Other	No supplies of groundwater appear to be present
Site History		Land previously used over past 150 years for various forms of agriculture; most of the original woodland cleared and replaced by poor quality pasture
System Requirements		
Objectives		Environmentally efficient, on-site management of water resources (and other natural resources) in an undeveloped, green field site
End-use requirements (regulation)	*Quality* *Quantity*	

B.4 Charles Sturt University, Thurgoona Campus ...continued

End-use requirements cont…	*Operational*	
	Risk assessment	Possibility of using rainwater for human consumption investigated but considered to pose unacceptable risks to personnel
Other		
System Components:		
Collection	*How*	Natural drainage, swales Directed by contour banks to swales
	Capacity (ML)	Subcatchment 1: av annual yield of 7.5 ML, 1:10 yr yield of 11 ML Subcatchments 2 & 3: combined av annual yield of 42.7 ML, 1:10 yr yield of 61 ML
	(% mean ann. runoff)	
	Design methods	Swales meander over landscape to control erosion
	Key Learnings	
Treatment	*How*	In-stream treatment wetlands in each swale
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	Objectives: sedimentation of particulate matter, retention of plant nutrients, aeration of inflowing water, and self-sustaining and self-optimising aquatic ecosystems Position on swale selected with consideration given to effectiveness of treatment function, aesthetic appeal. Number of wetlands depends on length of swale and likely quality of runoff. Rock-based waterfall at point of inflow for aeration, sedimentation pool at least 4 m deep with steep sides, becomes more shallow to ~0.5m over distance of 5-10m as determined by slope of land, shallow area planted with emergent aquatic plants with decreasing tolerance to water depth to form marsh area where nutrient update is maximised and further sedimentation occurs.
	Key Learnings	
Storage	*How*	Subcatchment 1: reservoir Subcatchments 2 & 3: Three interconnected reservoirs at bottom of site
	Capacity (ML)	56.5
	(% mean ann. runoff)	30%
	Design methods	Sized so that the natural supply of rainfall will exceed requirements at least once every five years, to reduce build-up of salts in storages

B.4 Charles Sturt University, Thurgoona Campus ...continued

Storage cont…		Salinity control: Reservoir in subcatchment 1 designed to overflow every year into roadside drains and sewers previously constructed by civic authorities. Three interconnected reservoirs designed to discharge water in years of high rainfall into nearby creek.
	Key Learnings	
Re-use	*What*	Irrigation, some released into wetland system to keep the system alive
	How	Water from the lowest storage reservoir is pumped to turkey nest dams at the top of the site via a windmill and a solar energy powered pump
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	43 building-integrated rainwater tanks
	Re-use	Laundry, spray-mist cooling system
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	
	(% total water use)	
	Collection	
	Treatment	Intermittent-flow constructed wetlands
	Storage	Joins stormwater in three reservoir system at bottom of site

B.4 Charles Sturt University, Thurgoona Campus ...continued

Other Water for Re-use	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Implementation Issues		
Site Amenity		Access to additional supplies of water maintained so that essential requirements can be met during periods when natural precipitation is low
Public Safety		Water to be re-used must meet the criteria required for that form of re-use
Landscape Requirements		
Integration into total water cycle		Development principle: recycle water wherever possible
		Water on campus is circulated and stored in ways that are aesthetically pleasing and promote maintenance of good water quality
Possible Problems		
Institutional		High security water for human consumption, personal hygiene and some other domestic uses requires potable water from an authorised supplier (Albury City Council)
Other		
Key Learnings		
Other Issues		
Operation and maintenance	*How*	Wetlands constructed as low maintenance systems. Invading plants hand-weeded before they flower and establish a seed bank. Accumulated sediment in sediment pool removed with a mechanical shovel and incorporated into soil at a suitable site.
	Who	
	Key learnings	
Monitoring	*Water quality*	
	Water quantity	
	Other	Greywater wetlands monitored at three monthly intervals for coliform bacteria, BOD, TN, TP, temp, pH, DO, EC and turbidity
Performance	*Against objectives*	
	Water quality	Greywater wetlands performed well
	Water quantity	

B.4 Charles Sturt University, Thurgoona Campus ...continued

Performance cont…	*Assessment methods*	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	
	Annual operating (costs/kL)	
	User price	n/a?
Benefits	*Reduced demand for potable supply*	All water on the site is harvested; potable water purchased from Albury City Council only for drinking, cooking, laundry and personal hygiene
	Flow management	
	Pollution control	
	Infrastructure	Northern part of campus unsewered
	Environmental flow	Development of ecologically sustainable, natural, aquatic ecosystems encouraged

B.5 Figtree Place

Contact Information		
Contact Name		Peter Coombes
Location		Hamilton, Newcastle, NSW
Project Partners		Newcastle City Council Building Better Cities Program (federal government) NSW Department of Housing
References		(Coombes et al., 1998) (Coombes et al., 1999) (Coombes et al., 2000) (Coombes, 2002) (UWRC, 2003) (Melbourne Water, 2003)
General Site Details:		
Development Type		27 small- and medium-size inner city housing venture
Size		1.1 ha (Hamilton Bus Station site area = 3.0 ha)
Date of commission		April 1995 (concept investigation and design) Redevelopment opened on 21 June 1998
Scale of implementation		Streetscape and allotment
Rainfall	*Rainfall (mm/yr)*	1141.9
	(ML)	12.6
	No. rainfall days/yr	133.0
	Mean annual runoff (ML)	6.3
	Potential evapotranspiration (mm)	1600-1700
Geology		Sand to depth of 10m, substrate of clay, bedrock at 25m
Aquifer	*Watertable*	2-2.5 m, varies seasonally
	Groundwater movement	~4 m/yr
	Other	Prior to remediation, groundwater at 3-4 m depth showed dark discolouration due to presence of iron and manganese salts

B.5 Figtree Place ...continued

Site History		Previously used as a transportation centre since the early 1900s, initial use by trams, more recently buses; resulted in major contamination hot spots of PAH, TPH, heavy metals, pesticides, oil and grease
System Requirements		
Objectives		To retain stormwater on-site and reduce potable water consumption To demonstrate that normal urban living could be pursued with significantly less potable water consumption than used in conventional developments Planning indicated that sufficient water could be harvested on site to meet 50% in-house needs, 100% domestic irrigation needs, 100% bus-washing demand
End-use requirements (regulation)	*Quality*	
	Quantity	
	Operational	
	Risk assessment	
Other		Assessed against Australian Drinking Water Guidelines
System Components:		
Collection	*How*	Runoff from paved areas, lawns and gardens passes to central Detention Basin Recharge Area
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	Internal kerbed roadways Design flood capacity is 83% of runoff for all events up to and inc 1 in 50 year event High infiltration rates of sandy soil exploited to minimise overflows from the basin
	Key Learnings	
Treatment	*How*	Infiltrated through base of dry detention basin; 250 sq.m grassed depression, overlays 750mm layer of gravel enclosed in geofabric below 300mm topsoil layer
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Storage	*How*	Unconfined aquifer (ASR)
	Capacity (ML)	
	(% mean ann. runoff)	

B.5 Figtree Place ...continued

Storage cont…	*Design methods*	Flownet model of aquifer system used to explore possible groundwater impacts
	Key Learnings	No stormwater overflow from site up to 2000 and a maximum depth of ponding in the detention basin of 260mm with a residence time of 6 hours has been experienced
Re-use	*What*	Garden and open space irrigation, bus washing at adjacent depot, other outdoor use
	How	Submerged pump within recharge basin at depth of 10 m, pumped as required, dual reticulation, optionally treated (activated carbon) for colour removal
	Capacity (ML)	Max 2000 kL/yr supplied to bus depot
	(% mean ann. runoff)	
	Design methods	Preliminary studies of water availability from roof and general runoff indicated ample supply for domestic uses
	Key Learnings	
Other Water for Re-use		
Roof runoff (if treated and used separately)	*Capacity (ML)*	Raintank capacities range from 9 to 15 kL
	(% mean ann. runoff)	
	(% total water use)	
	Collection	Stormwater pipes
	Treatment	First-flush pits separate first 2 mm of rainfall; reinforced concrete box placed over fibre reinforced concrete pipe, box contains a screen to filter debris and a baffle to separate first flush from inflow to raintank, water retained upstream of baffle infiltrates through holes in base of box to pipe and soil
	Storage	Five centralised underground tanks; reinforce concrete raintanks, contain inlet from first flush pit, clean out chamber for sludge removal, low water level monitor, outlet for domestic supply and overflow pipe to a recharge trench
	Re-use	Pumps with pressure cells supply rainwater from tanks to hot water systems and for toilet flushing, fail-safe systems include second pump in case of failure and solenoid to switches to mains supply if inadequate water pressure, electricity failure or low water level is detected; dual reticulation, backflow prevention devices used to isolate from mains supply
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	

B.5 Figtree Place ...continued

Greywater	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Other Water for Re-use	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Implementation Issues		
Site Amenity		Provision made for conversion to conventional practices (i.e. can revert to mains supply) should water quality fall below accepted levels or drought occur Detention basin provides an open space recreation area during dry spells
Public Safety		Irrigation occurs during night hours to minimise risk of ingestion Survey of residents found that 48% of respondents used water from the hot tap for cooking; rainwater in hot water systems must be compliant with drinking water standards Backflow prevention devices isolate recycled water supply from potable supply
Landscape Requirements		
Integration into total urban water cycle		Water saving appliances are used
Possible Problems		Potential for undetected contaminants being released into the groundwater and polluting the residents' irrigation supply and moving to locations downstream where off-site users of the resource may also be affected. Solution: If groundwater quality falls below acceptable levels, raintank overflow and runoff arriving at central recharge area are diverted to the Bus Station drainage system Possibility that water retention practices might produce a groundwater mound adversely affecting the footings of homes, as well as creating unacceptably wet conditions in local backyards and gardens. Conversely, dispersed recharge with extraction from a central well may lead to significant drawdown of groundwater near extraction point. Solution: modelling investigation showed that existing groundwater levels would be preserved except at recharge region where drawdown may be experienced during summer

B.5 Figtree Place ...continued

Possible problems…		Potentional for drought conditions causing serious disruption to in-house supplies. Solution: backup connection to potable water suuply Possibility of extreme rainfall causing severe flooding of residential units on the site. Solution: floods of great magnitude than 1:50 yr event flow overland to northern boundary of development and conventional drainage system Indoor water consumption and proportion that is used for hot water and toilet flushing unknown for the region; presented difficulties in determining the volumes of tanks and capacity of pumps to deliver rainwater to the dwellings Potential for health problems resulting from ingestion of unsanitary water collected from roofs and used in hot water systems. Solution: roof water sampling project concluded that roof runoff was virtually equivalent to rainwater quality apart from high TSS and ash content; fail-safe provisions include: if health standards not met, hot water system converts to mains supply, signage at hot water taps, tenant education
Institutional		Significant delays during development stage caused by approval agencies - concerns that project not economically viable, dual reticulation was not compliant with Australian Standards and that contamination of mains supply could occur; no institutional framework for acceptance of WSUD design principles, long-term maintenance requirements and cost
Other		
Key Learnings		Delivery method plays crucial role in success or failure of innovative projects Imperative that standard of design documentation for novel techniques be above average Early involvement of constructing contractor who is sympathetic to project innovations Early involvement of approval agencies Survey of tenants revealed significant acceptance of in-house use of rainwater collected from roofs Fail-safe provisions and on-going monitoring program vital element of the project and reflect its experimental nature
Other Issues		
Operation and maintenance	*How*	Water levels in raintanks used to supply toilet flushing and hot water uses constantly drawn down; ensures tanks regularly have storage capacity available to accept roof runoff
	Who	Newmacq Community Housing Company manages site, Newcastle City Council and the NSW Stormwater Trust funds program to monitor performance
	Key learnings	

B.5 Figtree Place ...continued

Monitoring	*Water quality*	Rainwater tanks, hot water systems and potable supply manually monitored monthly for faecal coliforms, total coliforms, heterotrophic plate counts, pseudomonas species, DO, tem, pH, BOD, EC, colour, TP, NOx, chlorides, salinity, total solids, giardia, cryptosporidium
		Rainwater tank quality automatically monitored every six hours for pH, tem, EC, DO and turbidity
		Groundwater quality (colour and contaminant levels) regularly monitored
	Water quantity	Water use
		Pressure sensors in rainwater tank adjacent to recharge basin measure water depths every six hours
		Pressure sensors in bores monitor watertable every six hours
		Pressure sensors at central recharge area and recharge trench determine infiltration rates and quantity of runoff
	Other	Automated monitoring system (triggered by rain events) in addition to manual sampling program
		Maintenance
		Economic viability
		Social acceptance (via questionnaire of 26 tenants)
	Key learnings	Improved tankwater quality will result from separation of first flush rainfall from inflow to raintanks
		Hot water systems operate at temperatures sufficient to pastuerize tankwater to produce quality compliant with Australian Drinking Water Guidelines
		Water treatment processes of flocculation, settlement and bioreaction appear to operate in rainwater tanks
		Significant tenant acceptance (95%) of the use of roof runoff for irrigation, toilet flushing, hot water systems, clothes washing and cooking. Moderate acceptance (70%) of the possible use of roof runoff for drinking purposes.
Performance	*Against objectives*	Measurement of internal water use showed a 65% reduction in potable water consumption during the period June to December 1998
	Water quality	Groundwater: complies with Australian Drinking Water Standards for all parameters except pH; acceptable for irrigation and bus washing purposes
		Roof runoff: occasionally exceeded guideline values for ammonia, pH, iron and lead; overall samples from tanks and hot water systems were found compliant with chemical and metal parameters in the Australian Drinking Water Guidelines
	Water quantity	Infiltration basin: maximum observed emptying time less than that determined to indicate acceptable performance

B.5 Figtree Place ...continued

Performance cont…		Raintanks: 11-44% reduction in mains water use (differences attributable to construction errors wrt first flush pits - lower values because pits separating too much runoff); degree of reduced mains water use and roof water utilisation dependent on the volume of rainwater tank storage, roof area and water use per person, and the proportion of roof area to rainwater tank volume
	Assessment methods	Raintanks: performance assessed using meter readings, rainfall data and tank levels
	Key learnings	Opportunities for improved design in the form of reduced plumbing, elimination of backflow prevention devices, exclusion of redundant elements and more efficient construction practices The existing design details can be further improved with consequent lower costs
Cost/Benefits		
Costs	*Capital outlay*	$2.7m basic development, $109,900 for WSUD elements
	Annual operating (costs/kL)	Analysis suggests that the redevelopment is cost-effective when considered as a component of "beyond capacity" urban infrastructure
	User price	Payback period for WSUD elements would be longer than the anticipated life of the project
Benefits	*Reduced demand for potable supply*	Overall reduction in potable water demand of ~60% (40-45% by residents) compared with conventional developments High rainfall ensures net excess aquifer recharge, water not required to meet on-site demands used by adjacent bus-washing facility (max 2000 kL/yr)
	Flow management	Designed to contains 83% of runoff (surface runoff from seven units in NE corner passes directly to conventional drainage system) for all events up to and including a 1 in 50 year event; floods of greater magnitude will flow overland to street at northern boundary and pass into conventional drainage system Raintank overflow directed to soakaways (gravel trenches) via stormwater pipes and recharged to the aquifer; trenches 750 mm deep and 1000 mm wide layers of gravel enclosed in geofabric below 300 mm topsoil layer, overflow from raintanks distributed within trenches by slotted pipes
	Pollution control	
	Infrastructure	Stormwater discharge almost completely eliminated, reduced downstream flood peak and reduced strain on stormwater infrastructure, including pollution control installations
	Environmental flow	

B.6 Hawkesbury Water Re-use Scheme

Contact Information		
Contact Name		Sandy Booth
Location		Gomebeeree Environs, University of Western Sydney, Hawkesbury Campus
Project Partners		University of Western Sydney Sydney Water Corporation Richmond TAFE Hawkesbury City Council Clean Up Australia
References		(Booth and Adcock) (Booth et al., 2003) (Stewart et al., 2003) (Clean Up Australia, 2000) (2000) S. Booth, personal communication J. Stewart, personal communication
General Site Details:		
Development Type		Developing integrated environmental precinct focusing on long-term issues of sustainability
Size		415 ha catchment
Date of commission		
Scale of implementation		Catchment
Rainfall	*Rainfall (mm/yr)* *(ML)* *No. rainfall days/yr* *Mean annual runoff (ML)* *Potential evapotranspiration (mm)*	807.1 4322.0 114.8 1297 1500-1600
Geology		Tertiary sediments ~20 m thick with low porosity Complementary research regarding soil sustainability and monitoring
Aquifer	*Watertable* *Groundwater movement*	~7 m

B.6 Hawkesbury Water Re-use Scheme ...continued

Aquifer cont…	*Other*	Groundwater generally of low quality, not considered significant as a supply, salinity ~5 x higher than treated effluent, much higher than stormwater
Site History		Partly urbanised, rural catchment; university campus has history of agricultural and horticultural studies
System Requirements		
Objectives		To showcase an integrated approach to effluent and stormwater re-use and constructed wetland technologies, and provide a focus for community awareness of the potential benefits of water re-use
End-use requirements (regulation)	*Quality*	
	Quantity	Reliable supply of both harvested stormwater and treated effluent
	Operational	Environmental Management Plan prepared as technical reference, builds on the AS/NZS ISO 14000 series guidelines
	Risk assessment	Initial risk assessment identified the preliminary risk management needs of the broad rang of staff, contractors, students and general public who utilise the campus facilities
Other		Grant commitments for Major Infrastructure: (a) decrease pollution loads to Rickabys Creek (b) develop sustainable and integrated effluent and urban stormwater management and disposal best practices (c) pilot and showcase viable reputable urban and rural stormwater and treated sewage effluent re-use (d) harvest and store stormwater flows for re-use partly as higher quality environmental flows (e) develop sustainable stormwater management and disposal best practices (f) pilot and showcase viable and reputable urban and rural stormwater re-use Grant commitments for Community Awareness and Education (a) a central focues for passive recreation activities (b) provide a pivotal and meaningful link with the Stormwater Trust funded Yellow Fish Road Program in Richmond (c) develop community awareness and education through signage and education activities (d) provide ongoing focus for stormwater and effluent re-use research, education and training through UWS and Richmond College of TAFE
System Components:		
Collection	*How*	Runoff from university campus and residential areas of Richmond township collected via conventional gutter and pipe system into open grassed channels, collected in Stormwater Detention Basin at junction of two main stormwater drains

B.6 Hawkesbury Water Re-use Scheme ...continued

Collection cont…	*Capacity (ML)*	60 (Basin), 400 ML stormwater/yr
	(% mean ann. runoff)	~50%
	Design methods	Modelled by PhD student (Joel Stewart), verified through collected data; several features from existing models combined to create a spreadsheet model to represent the harvestable yield and associated water quality; series of surface moisture stores, log-normally distributed EMC pollutant distribution data
	Key Learnings	Stormwater quality from the catchment comparatively low in SS, average in TN, high in TP loads; model indicates that a relatively small part of the catchment may be responsible for high TP levels, representing a good opportunity for intervention on a small scale to produce large potential benefit
Treatment	*How*	Pumped from detention basin through four wetlands (construction nearing completion, stormwater currently pumped directly from detention basin to storage dam) to Settling Pond where fine sediments settle out
	Capacity (ML)	Wetlands: 1 ha area each, 150mm average depth for normal operating level, 950 mm top water level, 8 ML storage capacity of each wetland above maintenance levels, 300 mm freeboard Settling pond: 1.5 ha area, 2.1 m average depth, 31.5 ML total storage capacity, 25 ML effective storage capacity, 16.5 ML normal operating level, 15 ML normal freeboard capacity 15 ML designed freeboard for combined wetland system and settling pond
	(% mean ann. runoff)	
	Design methods	Alternating series of shallow wetlands areas and deeper oxidation ponds, 7 days transit time through wetlands, 14 days total treatment time (including detention in Settling Pond) Settling pond provides final treatment and storage capacity for treated stormwater from the wetlands for environmental flows to Rickabys Creek and storage in the Turkey Nest Dam
	Key Learnings	Design allows a multitude of wetland filling and holding scenarios, this will allow for future comparative studies to be made for a wide range of management and other factors
Storage	*How*	Currently water in the Detention Basin is pumped into a Stormwater Turkey Nest Dam; once the wetlands are complete, polished stormwater will be lifted from Holding Pond to Turkey Nest Dam
	Capacity (ML)	90 ML
	(% mean ann. runoff)	
	Design methods	Storage modelling, centred on a water and mass balance, has been utilised to describe the capture, treatment and storage of stormwater from the catchment. Activities within the catchment (including catchment management options) and the impact on stormwater quality can be investigated through model variables associated with pollution generation rates and the operation of the stormwater re-use infrastructure.

B.6 Hawkesbury Water Re-use Scheme ...continued

Storage cont…	*Key Learnings*	
Re-use	*What*	Environmental flows, supply Richmond TAFE's irrigation requirements (where it goes through its own series of storages and filters), backup supply for treated effluent (used to irrigated playing fields, pastures and Richmond golf club)
	How	Irrigation: Shandied with treated effluent
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	Harvesting and re-use modelled by PhD student (Joel Stewart)
	Key Learnings	
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Wastewater	*Capacity (ML)*	2.5 (average daily flow), 927 (average annual production)
	(% total water use)	
	Collection	Richmond STP
	Treatment	Trickling filter technology, disinfection (new intermittent decanted aerobic lagoon plant to be completed in late 2004); wet weather flows from STP captured and treated in wetlands prior to pumping to storage.
	Storage	93 ML Effluent Turkey Nest Dam, 84 ML Horticulture Dam, 76 ML Hillside Dam
Greywater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	

B.6 Hawkesbury Water Re-use Scheme ...continued

Other Water for Re-use cont…	*Treatment* *Storage*	
Implementation Issues		
Site Amenity		Spoil material from Settling Pond spread on immediately adjacent area creating ~5 ha suitable for passive community recreation
Public Safety		Shelterbelts at edge of pastures to prevent public from coming into contact with spray drift Environmental Management Plan (based upon ISO 14000), preliminary risk assessment and an ongoing program to develop effective risk communication and management strategies
Landscape Requirements		Consideration of the need for soil treatment to prevent groundwater accessions and to aid plant establishment in wetlands Complementary research into possible groundwater impacts
Integration into total urban water cycle		Re-use of harvested stormwater integrated with use of treated effluent Scheme is part of a developing integrated environmental precinct as a hub for wide ranging aspects of practical management, research and community outreach
Possible Problems		RAAF base nearby, increased birdlife as a result of constructed wetlands, minimisation of avifauna incorporated in wetlands design
Institutional		
Other		
Key Learnings		
Other Issues		
Operation and maintenance	*How*	The University and TAFE are each responsible for maintaining piping and related infrastructure (which is fixed to and situated on land owned or occupied by it) in good working order and condition Initial proposed project life is 10 years Weed management Variable nature of stormwater harvesting reflected in allowed wetting and drying of wetlands, and developing environmental flow regime above small discharges i.e. mimicking natural system of swamp and absorbing smaller flows and only discharging above this
	Who	
	Key learnings	
Monitoring	*Water quality*	Measured at taps located on outflow pipes from major water storages Weekly: faecal coliforms, eneterococci, pH, TDS, EC, DO, BOD, turbidity, tem, 254/510 nm

B.6 Hawkesbury Water Re-use Scheme ...continued

Monitoring cont…		Monthly: TN, TP, TSS, Chl a, chlorine residual Half-yearly: Na, K, Mg, Ca, Cl, SO_4, HCO_3, CO_3 Yearly: heavy metals (As, Cd, Cr, Hg, Pb), pesticides Soil and groundwater impacts
	Water quantity	Weekly: storage depths, water flows Flow meter at end of transfer pipe from the university to the TAFE; water supply recorded on a monthly basis Groundwater
	Other	
Performance	*Against objectives* *Water quality* *Water quantity* *Assessment methods* *Key learnings*	
Cost/Benefits		
Costs	*Capital outlay*	Considerable additional infrastructure in the form of pipes and pumps provided as in-kind contributions by a range of industry and business partners
	Annual operating (costs/kL)	
	User price	Users are not charged per kL, however Richmond TAFE contribute to captial infrastructure costs and meet a share of the ongoing operational costs, would be interesting to know if this leads to excess water use
Benefits	*Reduced demand for potable supply*	Reduced demand on potable water supplies
	Flow management	
	Pollution control	Minimising impacts of effluent discharges into Hawkesbury-Nepean River system
	Infrastructure	Nutrient recycling, harvesting and use for agricultural production
	Environmental flow	Some stormwater released to Rickabys Creek as environmental flows of improved water quality Harvested stormwater critical buffer within Scheme

B.7 Homebush Bay

Contact Information		
Contact Name		Andrzej Listowski
Location		Sydney, NSW
Project Partners		Sydney Olympic Park Authority
References		A. Listowski, personal communication (SOPA, 2003) (Melbourne Water, 2003) (United KG, 2003) (OCA, 1998) (OCA, 1999) (OCA, 2000) (SOPA, 2002) (DEH, 2003) (Innovation Online, 1999) (Innovation Online, 2000) (Rocla, 2003)
General Site Details:		
Development Type		Redevelopment (residential estate, state sporting facilities, business park and open space)
Size		760 ha, ~400 of which is parkland
Date of commission		Work on WRP and WTP commenced in September 1999, WRAMS commenced 27 July 2000
Scale of implementation		Catchment and allotment
Rainfall	*Rainfall (mm/yr)*	921.3
	(ML)	3349
	No. rainfall days/yr	106.4
	Mean annual runoff (ML)	614
	Potential evapotranspiration (mm)	1200-1300
Geology		
Aquifer	*Watertable* *Groundwater movement*	

B.7 Homebush Bay ...continued

Aquifer cont…	*Other*	
Site History		Formerly used for landfill, abbatoirs and a navy armament depot
System Requirements		
Objectives		Ensure compliance with the environmental undertakings made by the NSW Government in Sydney's Bid document, The Environmental Guidelines for the Summer Olympic Games (September 1993) Encourage development of innovative and effective wastewater treatment technologies and management practices Position the NSW Government in a leading role by demonstrating sound, sustainable water resource management in a high profile project Reduce demand for potable water from Sydney Water's systems Reduce sewage discharge to Sydney Water's systems. Improve the quality of stormwater entering Homebush Bay and the Parramatta River from the site
End-use requirements (regulation)	*Quality* *Quantity* *Operational* *Risk assessment*	NSW Recycled Water Co-ordination Committee
Other		Olympic Coordination Authority Act 1995 Protection of the Environment Operations Act 1997 Environmental Planning and Assessment Act 1997 State Environment Planning Policy No 38 - Olympic Games Projects Sydney Regional Environmental Planning Policy No 24 - Homebush Bay
System Components:		
Collection	*How*	Gutter and pipe system for high traffic areas, swales in low traffic areas Extensive use of permeable pavers (Rocla EcoTrihex) and engineered soils (that prevent compaction) throughout urban doman areas to maximise rainwater absorption for large amenity trees Some sporting venues collect own roof runoff
	Capacity (ML) *(% mean ann. runoff)* *Design methods*	

B.7 Homebush Bay ...continued

Collection cont…	*Key Learnings*	
Treatment	*How*	Prior to storage: GPTs, swales, constructed wetlands
		Runoff directed to litter and sediment control devices (GPTs, swales) and to constructed wetlands 3 water quality control ponds collect first flush, allow sediments to settle and absorb nutrients via aquatic plants
		Post storage: microfiltration, reverse osmosis, chlorine disinfection, dechlorination
	Capacity (ML)	Treatment plant: 7ML/day
	(% mean ann. runoff)	
	Design methods	Gabion walls ensure areas of open water
	Key Learnings	
Storage	*How*	Lower levels of disused brickpit Wetlands along Haslams Creek store stormwater from adjacent Parkalnds, Newington and the Hill road car park (secondary store); separate ponds for drawdown and ornamental/biodiversity conservation purposes
	Capacity (ML)	350 ML brickpit, 140 ML wetlands
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	Brickpit storage is cornerstone of scheme, storage capacity far greater than irrigation requirements, lowest level drawn down to is ~55% during summer 02/03
		System operational for 3 years, no topup with potable water required so far High nutrients levels in brickpit store, visible algal growth, currently investigating options for nutrient removal
Re-use	*What*	Irrigation, water features and other outdoor uses, toilet flushing, fire fighting, environmental flows
	How	Dual reticulation, 30 km of distribution pipelines
		Low volume irrigation systems installed where possible; separate irrigation systems in some areas for flexible irrigation (e.g. trees can be watered while grassed areas remain dry)
	Capacity (ML)	up to 2.5 ML/day, on average the scheme utilises 700 ML of sewage and 200 ML of stormwater per year
	(% mean ann. runoff)	35% total water use
	Design methods	
	Key Learnings	Careful inspection of dual reticulation system has resulted in only 2 cross-connections, neither in residential dwellings

B.7 Homebush Bay ...continued

Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	
	(% mean ann. runoff)	
	(% total water use)	
	Collection	Runoff from stadium and showground roofs
	Treatment	
	Storage	Underground tanks
	Re-use	Irrigation
Wastewater	*Capacity (ML)*	2.2 ML/day
	(% total water use)	30
	Collection	Sewer mining from Newington Village, sporting venues and showgrounds
	Treatment	Reclamation plant: BNR, UV disinfection, secondary effluent, capacity = 2.2 ML sewage/day Treatment plant: mixed with stormwater from brickpit, microfiltration, RO, chlorine disinfection, dechlorination, capacity = 7ML/day
	Storage	Following treatment, (solar powered) pumped into distribution network for re-use around the site; WTP has 7 ML/day underground storage tank which provides buffer storage during summer period; excess treated effluent stored in brickpit
Greywater	*Capacity (ML)*	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Implementation Issues		
Site Amenity		450 ha of parklands incorporate conservation of habitat of an endangered frog species and other fauna

B.7 Homebush Bay ...continued

Site Amenity cont…		Provision made for conversion to mains supply for emergency/infrequent events
Public Safety		210 ha identified as contaminated soils; reclaimed and treated prior to construction activities Outside taps are signed
Landscape Requirements		Low-water tolerant landscape species Rehabilitation of more than 100 ha of waterways and wetlands, most of which were in a degraded state prior to development. More than 1.4 million cubic metres of waste removed and placed in a containment area
Integration into total urban water cycle		Water cycle management considers potable water, sewerage services, collection, storage and use of stormwater for irrigation, reclamation of water from sewer mining, provision of GPTs and water quality ponds and wetlands to maintain stormwater quality, and the Water Reclamation and Management Scheme (WRAMS) Water saving appliances are used (reduce water consumption by 30% compared to traditional fittings)
Possible Problems		water quality problems in storage
Institutional		Developed Environmental Mangagement System that complies with ISO 14001; the EMS required Environmental Management Plans for all development stages for all venues and facilities WRAMS operates sewage treatment however Sydney Water collects money for this service Initially EPA wanted warning signs on toilets
Other		
Key Learnings		High level of public approval, survey indicates no sales of units at Newington lost due to recycled water
Other Issues		
Operation and maintenance	*How*	Little detail available about O&M, however system audits of projects undertaken to determine appropriateness of EMS procedures GPTs and pollution booms
	Who	United KG (environmental engineering company), for 25 years
	Key learnings	
Monitoring	*Water quality*	Monitored continuously; recycled water (metals, nutrients, bacteria, viruses) and streams 20 monitoring points plus all other signficant ponds and wetlands
	Water quantity	
	Other	Ecological studies of saltmarsh, benthic invertebrates, birds, mosquitoes, the Green and Golden Bell Frog, fish and aquatic plants Independent reviews undertaken by three organisations

B.7 Homebush Bay ...continued

Performance	*Against objectives*	Compliance reports and certificates Audit reports Monthly and quarterly environmental reports Compendium of ESD initiatives and outcomes Environment reports
	Water quality	Reduction in TN, TP, TSS in stormwater passing through water quality ponds ~40 tonnes of litter removed from Haslams Creek during 2000 by booms and physical cleaning of banks During 2001/2002 a total of 148 tonnes of litter, sediment and vegetation was collected from GPTs and pollution booms
	Water quantity	
	Assessment methods	Regulatory compliance and environmental performance reported in quarterly environmental reports
	Key learnings	To date, all water quality monitoring data of the recycled water complies with Australian water quality standards Recently received approval to use recycled water in washing machines
Cost/Benefits		
Costs	*Capital outlay*	WRAMS budget $15.88m
	Annual operating	$30m over 25 years (operation and maintenance)
	(costs/kL)	$1.80/kL
	User price	77.5 c/kL (set at 15 c/kL cheaper than potable water), "small quarterly service charges"
Benefits	*Reduced demand for potable supply*	~50% (up to 850 ML) reduction in annual consumption of potable water
	Flow management	Capacity: 1 in 10 year event, constructed wetlands off Haslams Creek act as bypass channel and increase capacity up to 1 in 100 year event Greater than 90% reduction in the discharge of sewage effluent to waterways and the ocean from the area served
	Pollution control	Receiving waters protected from stormwater and wastewater discharges
	Infrastructure	Reduced volume of discharge to Sydney's sewerage system
	Environmental flow	Habitat for threatened flora and fauna species protected and enhanced

B.8 Inkerman Oasis

Contact Information		
Contact Name		Gary Spivak
Location		33 Inkerman St, St Kilda, VIC
Project Partners		City of Port Phillip Inkerman Developments Pty Ltd Williams Boag Integrated eco-Villages Environment Australia National Heritage Trust South East Water
References		(Melbourne Water, 2003) (DEH, 2003) (CPP, 2003) (Savewater, 2003) (CPP, 2003) (2000) (Spivak and Kerans, 2001) G. Spivak, personal communication G. Kerans, personal communication
General Site Details:		
Development Type		Redevelopment (public-private partnership to develop 237-unit community-private housing development)
Size		1.223 ha
Date of commission		Stage 1 completed August 2002, Stage 2 completed August 2003 (not sure if this is true for Stage 2)
Scale of implementation		Sub-division and allotment
Rainfall	*Rainfall (mm/yr)*	657.3
	(ML)	8.0
	No. rainfall days/yr	147.0
	Mean annual runoff (ML)	7.6

B.8 Inkerman Oasis ...continued

Rainfall cont…	*Potential evapotranspiration (mm)*	3.4
Geology		
Aquifer	*Watertable* *Groundwater movement* *Other*	
Site History		Former City of St Kilda Municipal Depot site
System Requirements		
Objectives		Project to provide: (a) mixed private and community housing (b) high quality urban design and architecture, including integrated artworks (c) best practice ecologically sustainable design
End-use requirements (regulation)	*Quality* *Quantity* *Operational* *Risk assessment*	
Other		Developer subcontracted design of water recycling strategy and negotiation of regulatory approval
System Components:		
Collection	*How*	(a) Gutter and pipe (All first flush roof and ground runoff) (b) Natural drainage (water seepage off landscaped areas returns to wetlands and tertiary treatment tank, ensuring closed loop system)
	Capacity (ML) *(% mean ann. runoff)*	
	Design methods	
	Key Learnings	
Treatment	*How*	(a) GPT (b) primary treatment in constructed wetland (c) tertiary treatment by Kubota tank post storage: UV disinfection
	Capacity	0.04 ha wetland, 10.8 kL tertiary treatment tank
	(% mean ann. runoff)	
	Design methods	GPT on both ends of the wetland

B.8 Inkerman Oasis ...continued

Treatment cont…		Primary: filtration through soil-gravel medium and absorption by wetlands plants to remove particles and nutrients
		Wetland designed for both vertical and horizontal sub-surface flows to encourage full utilisation of media surface area
		Tertiary: membrane bio-reactor tank - aerobic sand filter, membrane microfiltration
	Key Learnings	
Storage	*How*	Combined stormwater and bathroom greywater held in storage tank
	Capacity (ML)	0.045
	(% mean ann. runoff)	0.60%
	Design methods	
	Key Learnings	
Re-use	*What*	Sub-surface garden irrigation, toilet flushing
	How	reticulated by two constant pressure pumps
	Capacity	2 500 sq.m. landscaped areas All toilets within the development
	(% mean ann. runoff)	
	Design methods	Irrigation: controlled to release water to dry areas through 5825m of slow release dripper piping by 12 solenoids triggered by a computer and moisture sensors Toilet: electrically powered pump which distributes water through the ring main system, mains pressure fed header tank as back up
	Key Learnings	First grey water recycling of its kind in Victoria and the only project combining stormwater and grey water in Australia of this type and in this density of housing
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	

B.8 Inkerman Oasis ...continued

Wastewater cont…	*Collection* *Treatment* *Storage*	
Greywater	*Capacity (ML)* *(% total water use)*	140 of the 237 units
	Collection	Greywater from bathrooms
	Treatment	Hair and lint traps, primary treatment in 15 kL aeration balance tank to remove suspended solids, then joins stormwater for tertiary treatment
	Storage	
Other Water for Re-use	*Capacity (ML)* *(% total water use)*	n/a
	Collection *Treatment* *Storage*	
Implementation Issues		
Site Amenity		Units generally have an energy star rating of between 3.5 and 4.5 starts through materials selection, unit design and encouragement of low energy/resource efficient appliances and fixtures
Public Safety		Contaminated soils required remediation prior to development Peak stormwater flows diverted to conventional drainage system Greywater diverted to conventional sewage system when rainfall is detected
Landscape Requirements		Primarily native and indigenous plant species
Integration into total urban water cycle		Roof gardens over 240 car sub-basement car park Domestic greywater from ~50% of units recycled; reduced sewer loadings into Bay via STP
Possible Problems		
Institutional		Land rezoned from Public Purpose-Local Government to Mixed Use Council acceptance of building heights and unit density Unable to reach an agreement with local water authority in terms of reduced water supply and drainage charges
Other		Undertook community consultation
Key Learnings		Some original ESD features (e.g. intensive roof gardens, solar power) omitted from plan because they were not commercially viable while other features were enhanced (e.g. water re-use)

B.8 Inkerman Oasis ...continued

Key Learnings cont…		Project achieves quadruple bottom line sustainability: social, environmental, economic and cultural The value of a joint venture between local government and a private developer to achieve a best practice project across a range of areas - have been able to combine both parties' skills, roles and experience Lack of water industry/authority experience and policies. For pioneering projects, the negotiation, assessment and approval process is extremely slow and resource intensive. Lack of developer front-end incentives. Capital costs for WSUD is unable to be recompensed at any time in the project since market demand for WSUD is not compensated by the prices units can sell for. Learning experience in terms of how WSUD dovetails with the construction process and construction requirements - i.e. scheduling construction of the wetlands and associated construction management issues, given a general unfamiliarity with constructing WSUD features.
Other Issues		
Operation and maintenance	*How*	Greywater diverted to convetional sewage system when rainfall is detected. After all the treated stormwater has been re-used into the toilets, the system reverts to collecting greywater again. Tertiary treatment tank is duplicated to permit maintenance on each individual membrane module without the system reverting to a conventional system (where waste goes to the sewerage system)
	Who	Body corporate responsible for long-term maintenance and servicing of the plant and equipment
	Key learnings	
Monitoring	*Water quality*	Currently monitoring out of treatment system and soil
	Water quantity	Plan to monitor flow at five points through system
	Other	
Performance	*Against objectives*	
	Water quality	
	Water quantity	
	Assessment methods	
	Key learnings	Plan to keep stormwater and greywater separate in future developments, stormwater is of higher quality, want to use for hot water supply
Cost/Benefits		
Costs	*Capital outlay*	$50 m, $434,000 for WSUD elements
	Annual operating	maintenance cost ~$25/yr/resident

B.8 Inkerman Oasis ...continued

Costs cont…	*(costs/kL)* *User price*	
Benefits	*Reduced demand for potable supply*	~40% in summer, ~20% in winter
	Flow management	Once first flush stormwater fills wetland, clean flows are directed to conventional stormwater drains
	Pollution control	Natural fertilisation of gardens from nutrients in treated wastewater and prevention of manufactured fertiliser applications
		~14 tonnes of nitrogen and phosphates will be prevented from entering Port Phillip Bay per year
	Infrastructure	Reduced loading on the sewage system and reduced sewer loadings going to Port Phillip Bay
		Prevention of the need for piping infrastructure to be upsized as would otherwise be required in a conventional development
	Environmental flow	

B.9 Kogarah Town Square

Contact Information		
Contact Name		Peter Smith
Location		Kogarah, Sydney, NSW
Project Partners		Kogarah Municipal Council Sydney Water Institute for Sustainable Futures High Trade Pty Ltd
References		(DEH, 2003) (KMC, 2003) P. Smith, personal communication (Mouritz, 2000) (Local Government Focus, 2001) (KMC)
General Site Details:		
Development Type		Redevelopment Mixed-use complex: retail and commercial space, 190 apartments, library, underground parking
Size		1 ha
Date of commission		early 2003
Scale of implementation		sub-catchment? (town square)
Rainfall	*Rainfall (mm/yr)* *(ML)* *No. rainfall days/yr* *Mean annual runoff (ML)* *Potential evapotranspiration (mm)*	1102.4 11.0 129.4 9.4 1500-1600
Geology		
Aquifer	*Watertable* *Groundwater movement* *Other*	

B.9 Kogarah Town Square ...continued

Site History		Situated on the ridge between the densely urbanised catchments of the Cooks River and the Georges River that flow into Botany Bay. Both rivers have degraded water quality and are subject to pressures from increasing urban consolidation, traffic densities and industrial activities.
System Requirements		
Objectives		Quantity - avoidance of flooding and the requirement for system amplification downstream Quality - all water discharging from the site should have minimal impact on receiving water Conservation - take advantage of the rain water to reduce the demand for potable mains water Aesthetic/social - the water system should be incorporated into the aesthetic element of the design and provide an opportunity for the community to gain an enhanced appreciation of water as an essential element of the urban environment
End-use requirements (regulation)	*Quality* *Quantity* *Operational* *Risk assessment*	
Other		
System Components:		
Collection	*How*	Underground pipes
	Capacity (ML) *(% mean ann. runoff)*	85% of 7500 kL of rainwater falling on site
	Design methods	First flush runoff diverted Surge tank handles high stormwater flows
	Key Learnings	
Treatment	*How*	Garden beds with biologically engineered soil Electromagnetic filter further treats water used in water feature
	Capacity (ML) *(% mean ann. runoff)*	
	Design methods	
	Key Learnings	
Storage	*How*	Underground storage tanks
	Capacity (ML)	3 header tanks, total detention: 0.128; 3 storage tanks, total storage: 1.31
	(% mean ann. runoff)	15%

B.9 Kogarah Town Square ...continued

Storage cont…	*Design methods*	
	Key Learnings	
Re-use	*What*	Toilet flushing, car washing, water features, irrigation
	How	
	Capacity (ML)	Supplies at least 70% of the toilet flushing demand
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
	Re-use	
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	

B.9 Kogarah Town Square ...continued

Other Water for Re-use cont…	*Storage*	
Implementation Issues		
Site Amenity		
Public Safety		In periods of high stormwater flow, surge tanks regulate the water flow
Landscape Requirements		
Integration into total urban water cycle		Water efficient fittings and appliances
Possible Problems		
Institutional		
Other		
Key Learnings		It is well worth trying to incorporate these types of initiatives in planning controls and especially public projects, but you need to spell out your objectives, but be flexible about the solution The tenderers and their design teams all responded well to the environmental objectives of this project Some developers can see the long term benefit of learning how to apply and demonstrate best practice design as part of a long-term business strategy to be seen as "green" You need to get the whole of the Council, plus the staff to support the innovation, and see that they have a role to play in making it happen A partnership approach needs to be adopted between the developer, their design team and the Council - it is a learning experience If you can get grants to help with $$$ that is good, but don't forget that managing grants takes lots of time and effort (something very few developers would bother with) A partnership approach with key agencies and researchers helps (in this case Sydney Water and Institute for Sustainable Futures) Communicating the innovations to the buyers and the wider community is important Start with talking to the community: this would have reduced costs to council and greatly reduced timeframes associated with the project's implementation Transparency: it is crucial that all stakeholders are kept informed Thoroughness: evaluating the whole process (from design all the way through) is essential
Other Issues		
Operation and maintenance	*How*	No formal maintenance plan, have taken a "wait and see" approach; expect that filters on pumps will need to be cleaned annually and tanks will need to be emptied and cleaned every 5-6 years

B.9 Kogarah Town Square ...continued

Operation and maintenance cont…	*Who*	
	Key learnings	
Monitoring	*Water quality*	Originally planned for Sydney Water to carry out an evaluation of the project and monitor water use as well as water quality No currently monitoring, plan to but consider non-critical because re-use is non-contact
	Water quantity	
	Other	
Performance	*Against objectives*	
	Water quality	
	Water quantity	
	Assessment methods	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	$1.6m total project, $629 000 urban stormwater initiatives
	Annual operating (costs/kL)	Incorporated into body corporate fee
	User price	WSUD elements add $1000/apartment to price
Benefits	*Reduced demand for potable supply*	Conventional development of comparable size and number of units would have a total water demand of ~33,000 kL for internal use and car washing - capturing and reusing ~5,700 kL of stormwater equates to a ~17% saving of mains water
	Flow management	
	Pollution control	Reduction in polluted stormwater entering the Cooks Rivers, George River and Botany Bay protects and enhances coastal and marine water quality
	Infrastructure	
	Environmental flow	

B.10 Manly Stormwater Treatment and Re-use (STAR) Project

Contact Information		
Contact Name		Joanne Scarsbrick, Paul Smith
Location		Manly Beach & Smith St North
Project Partners		Manly Council Environment Australia University of New South Wales
References		(DEH, 2003) (AC, 2003) J. Scarsbrick, personal communication P. Smith, personal communication (Local Government Focus, 2002) (Local Government Focus, 2000) (Scarsbrick, 2002) (McRae, 2002)
General Site Details:		
Development Type		Pilot project, stormwater management for Manly Ocean Beach/Pine Street catchment
Size		3 ha catchment
Date of commission		
Scale of implementation		sub-catchment
Rainfall	*Rainfall (mm/yr)*	1220.6
	(ML)	36.6
	No. rainfall days/yr	133.1
	Mean annual runoff (ML)	27.5
	Potential evapotranspiration (mm)	1500-1600
Geology		sandy soils
Aquifer	*Watertable*	
	Groundwater movement	
	Other	

B.10 Manly Stormwater Treatment and Re-use (STAR) Project ...continued

Site History		Fully developed ultra-urban suburb with a high population density and large numbers of tourists, urban runoff contains relatively high levels of pollutant loading
System Requirements		
Objectives		Protect and improve surface water quality by developing sub-catchment programs that pursue the following objectives: * Reduce the pollution load and concentration in stormwater * Attenuate the flow to reduce flooding * Infiltrate stormwater to ground water * Treat, collect and re-use stormwater * Reduce the transportation of pollutants * Find a cost effective and ecologically sustainable way to achieve these outcomes * Develop prototype model for use elsewhere
End-use requirements (regulation)	*Quality*	
	Quantity	
	Operational	
	Risk assessment	Initial risk assessment suggested the health risk associated with stormwater re-use was below the generally accepted limits for the re-use of water Mains supply linked to irrigation system as a risk management precaution
Other		
System Components:		
Collection	*How*	500 m section North Steyne captures stormwater from eastern camber of adjacent road and car park catchment
	Capacity (ML)	"high flows"
	(% mean ann. runoff)	
	Design methods	Roadbase is similar to normal transport authority standards except for the lower percentage of material that is less than 1mm in size
	Key Learnings	
Treatment	*How*	Permeable pavement, $160m^2$ (500x0.32m), Atlantis Aqua Pave Screens, both external (capture litter and sediment) and internal (capture oils, fine sediments and grease)

B.10 Manly Stormwater Treatment and Re-use (STAR) Project ...continued

Treatment cont…		Atlantis Ecosoils - expanded polymer made from recycled plastics designed with sufficient strength to carry normal pavement loads, contains naturally occurring and bio-engineered microorganisms to biologically degraded and remediate toxic chemicals
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	Soil has high cation exchange capacity, biofilm to remove bacteria
	Key Learnings	Concentrating pollutants to one point before running through treatment system decreases treatable flow rate and increases maintenance requirements
Storage	*How*	Stormwater infiltrates through Ecosoils into Atlantis Ecological Channels from which the water passes into Atlantis Ecological Tanks
	Capacity (ML)	0.4
	(% mean ann. runoff)	1.4%
	Design methods	Excess water overflows and percolates through the existing sandy soils to recharge groundwater
	Key Learnings	
Re-use	*What*	Irrigation of Norfolk Island pines and promenade area along the foreshore
	How	Mixed with mains supply, spray irrigation using a pump system
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	

B.10 Manly Stormwater Treatment and Re-use (STAR) Project ...continued

Wastewater cont…	*Treatment*	
	Storage	
Greywater	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Other Water for Re-use	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Implementation Issues		
Site Amenity		Four stormwater drains on Ocean Beach, removal of these pipes high on community agenda in terms of visual pollution, relocating pipes away from beach would be over $32 million (does not offer stormwater treatment) Smith St North: major issue for a traffic permeable surface is a suitable subsurface drainage system underneath
Public Safety		Mains supply also linked to irrigation system, town water mixed with treated stormwater as risk management precaution and to supplement supply in extended dry periods Excess stormwater bypasses to conventional drainage system
Landscape Requirements		Major tourist destination; intensive developments with high transient populations give rise to greater than normal amount of vehicles and litter Paving system must be strong and durable enough to handle traffic areas while retaining infiltration capacity
Integration into total urban water cycle		Smith St North: Rocla Ecoloc permeable pavers; concrete interlocking pavers that provide drainage (infiltration >200mm/hr) voids between pavers on a base of clean 5mm aggregate; no-fines roadbase enables stormwater to infiltrate through to sandy subgrade below
Possible Problems		
Institutional		Implications for planning regulation, urban design and community involvement
Other		
Key Learnings		Community call want stormwater pipes removed from the beachfront (visual pollution)

B.10 Manly Stormwater Treatment and Re-use (STAR) Project ...continued

Key Learnings cont…		Public acceptance of permeable pavers strong due to the reduction in surface flows and visual appeal
Other Issues		
Operation and maintenance	*How*	Manufacturer specification: once every 10 years ecosoils should be harvested and accumulated pollutants extracted
	Who	Maintenance program supposed to be devised by external body inc. treatable flow rates as a function of catchment loads, to date this hasn't been done
	Key learnings	There is currently no defined feedback mechanism to determine whether the maintenance frequency for the ecosoils is adequate
Monitoring	*Water quality*	UNSW's Water Research Laboratory and Sydney Water Comparative sub-catchment water quality monitoring and analysis between the treated and untreated catchments Monitoring of the effectiveness of interventions used Monitoring of the sediments collected Faecal contamination in storage tank, 200-600 cfu/?
	Water quantity	Infiltration rates Surface runoff
	Other	Currently a construction site directly across from Ocean Beach dewatering; provides an opportunity to assess system efficiency; water pumped to treatment tank, known discharge volume, 5 minute sampling regime - only missing polluted water! i.e. underlying groundwater of good quality, so can't measure pollutant removal rate, have detected slight decrease in salinity
	Key learnings	Only 1 sampling point to measure quality of runoff, no monitoring of outflow, possibly a sensitive point - council dissatisfied with monitoring program & may be taking this further Monitoring program for tanks considered inadequate in terms of sampling frequency and consideration of seasonal variance
Performance	*Against objectives*	
	Water quality	Monitoring parameters are within expected limits for urban surface flows Bore hole-testing results show that there is no change in analytes and contamination is within risk levels
	Water quantity	Surface runoff reduced by 70% Monitoring has not confirmed whether overflow has occurred, as yet tank has not been emptied
	Assessment methods	
	Key learnings	

B.10 Manly Stormwater Treatment and Re-use (STAR) Project ...continued

Cost/Benefits		
Costs	*Capital outlay*	$1.3 m
	Annual operating (costs/kL)	No formal operating costs calculated, nor lifecycle & energy appraisal (i.e. inc. externalities) Costs would include pump energy, maintenance (street sweeping, of ecosoils, trickle irrigation system, pumps etc.)
	User price	
Benefits	*Reduced demand for potable supply*	
	Flow management	Smith St North road sub-grade was engineered to contain a 1:10 year storm event, with a 30% storage capacity
	Pollution control	Improved stormwater quality discharging onto Ocean Beach Reduced potential health risk to the beach users Preventing pollution by education and signage
	Infrastructure	Cheaper alternative to removal of stormwater drains from beachfront (estimated cost of $32 m to relocate pipes only)
	Environmental flow	

B.11 Oaklands Park

Contact Information		
Contact Name		Bill Mole, Neil Kerby
Location		Oaklands Junction, VIC
Project Partners		HNJ Holdings Pty Ltd
References		(Foster, 2000)
		W. Mole, personal communication
		K. Furniss, personal communication
		N. Kerby, personal communication
		(Winkfield Pty. Ltd., 2003)
		(Winkfield Pty. Ltd., 2002)
		(AGP Consulting, 1994)
		(Savewater, 2003)
General Site Details:		
Development Type		Greenfields
Size		174 ha, 121 of which is open space
Date of commission		Begun in 1997
Scale of implementation		Catchment and allotment
Rainfall	*Rainfall (mm/yr)*	548.7
	(ML)	953.0
	No. rainfall days/yr	141.0
	1 yr intensity (1 hour duration)	12.72
	Mean annual runoff (ML)	75
	Potential evapotranspiration (mm)	1000-1100
Geology		Poor developed topsoil of clay, soil percolation <12.5 mm/hr, no evidence of water logging
Aquifer	*Watertable*	~30m, brackish
	Groundwater movement	
	Other	No highly permeable aquifers found in initial survey of site
Site History		

B.11 Oaklands Park ...continued

System Requirements		
Objectives		Pioneer ecologically sustainable principles (address triple bottom line)
End-use requirements (regulation)	*Quality*	
	Quantity	City of Hume for roads & drainage works
	Operational	Western Water technical standards for water reticulation construction
	Risk assessment	
Other		
System Components:		
Collection	*How*	(a) Roof-runoff used to harvest potable water, on an individual lot-basis (b) Runoff from roads and open space harvested; open swale drains along roads (c) Pumping from nearby river is a last resort (and subject to minimum river flow requirements)
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	Swales slow water flows, minimise erosion and increase point of contact groundwater infiltration; no evidence of design for specific treatment objectives. Used volumetric runoff coefficient scaled according to total monthly rainfall (to account for soil moisture). Based 'worst-case' demand and supply on 1982-83 drought.
	Key Learnings	Reliance on catchment external to the site (hence outside direct control) places supply reliability at risk.
Treatment	*How*	Non-potable water conveyed through open swale drains (treatment for sediment)
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	Swales designed used Manning's equation, to typical standards (to safely convey 5 year ARI flow). No real attention paid to type of vegetation, nor specific treatment performance requirements.
	Key Learnings	
Storage	*How*	Three lake system (with underground pipe reticulation back to individual lots)
	Capacity (ML)	Originally modelled to store 37 ML in three storages, due to modifications during constuction the dams currently contain 49 ML
	(% mean ann. runoff)	50% (design), 65% as constructed
	Design methods	Modelling based on projected demand for summer (3 months during Nov-Mar) peak (80kL/lot/month) and remaining period (6kL/lot/month); required storage did not include river pumping. 100 year ARI spillway installed on storages. Evaporation based on figure

B.11 Oaklands Park ...continued

Storage cont…	*Key Learnings*	100 year ARI flood protection needed. Evaporation can be made issue in drought period (hence SA:Vol is important - and so water preferentially stored in dam with lowest SA:Vol). Therefore, need to allow for water to be moved from one store to the other
Re-use	*What*	Non-potable and firefighting, some houses plumbed for toilet flushing
	How	Reticulation system, mains pressure
	Capacity (ML)	Guaranteed continuity of supply to 80 lots using 80,000 L/month/lot in summer and 6,000 L/month/lot at other times (based on 82/3 drought as worst-case scenario)
	(% mean ann. runoff)	Typical annual non-potable demand (6.9 Ml/a) approximately 10% of mean annual runoff (75 ML/a)
	Design methods	System built to Melbourne Water standards (uses piped reticulation from storages)
	Key Learnings	Important to undertake reliable modelling of likely demand. Will be interesting to monitor whether the lack of cost for use of non-potable water leads to above-average consumption.
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	Tanks have minimum capacity of 70,000 L (x 80 lots = 5.6 ML): modelled demand = 100L/person/day
	(% mean ann. runoff)	7%
	(% total water use)	63.9269406392694 (Tank storage volume / Potable water demand)
	Collection	Gutter
	Treatment	First flush diversion devices, natural sedimentation processes in tanks
	Storage	Tank
Wastewater	*Capacity (ML)*	
	(% total water use)	
	Collection	Each individual lot has a system to produce treated water suitable for irrigation
	Treatment	Septic tanks
	Storage	
Greywater	*Capacity (ML)*	see wastewater
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	n/a

B.11 Oaklands Park ...continued

Other Water for Re-use cont…	*(% total water use)* *Collection* *Treatment* *Storage*	
Implementation Issues		
Site Amenity		Provision for water to be pumped from Deep Creek (which forms one boundary of the development) to supplement storage pond filling in times of low rainfall; this provision will also more than compensate for any potential loss of catchment area (some is external) 180 m^2 minimum house size (to ensure adequate collection of potable water), roof material and slope requirements optimise collection efficiency
Public Safety		Ensured that road culverts had capacity up to 10 year ARI, storage spillways capacity up to 100 year ARI. Drainage system safely conveys 5 year (assume?) flows, without risk of erosion, or excessive depths (little detail given here).
Landscape Requirements		Residents are encouraged to plant drought tolerant local native plants to minimise irrigation needs Locally native trees, shrubs and grasses are planted along streets and in open space reserves
Integration into total urban water cycle		Non-potable mains pressure water is metered to discourage waste
Possible Problems		Economic viability - some buyer reluctance was experienced initially in the marketing of Oaklands Park because it was different; through persistence and over time the developer was able to persuade prospective purchasers that their ideas would work
Institutional		Reportedly little support or involvement from relevant instititutions
Other		
Key Learnings		
Other Issues		
Operation and maintenance	*How*	Weed management and removal program for open space areas Pumps have self-cleaning filters (backwash every week), removed and pressure washed every 3 months Lakes: maintain grass cover, ensure rock lining remains in place, attend to any leakage; in the long term silt removal may be required to maintain full storage capacity
	Who	Keith Furniss (site manager)
	Key learnings	Little maintenance required apart from pumping water between storages, dams do not leake
Monitoring	*Water quality*	

B.11 Oaklands Park ...continued

Monitoring cont…	*Water quantity*	
	Other	
Performance	*Against objectives*	
	Water quality	No problems, site manager drinks water from lakes
	Water quantity	Pumping from Deep Creek required only once (to initially fill the lakes) Only problems experienced with supply to date have occurred during power shortages (pumps switch off)
	Assessment methods	
	Key learnings	Water supply adequate for non-potable requirements, no residents have used their full 150 kL/yr allocation
Cost/Benefits		
Costs	*Capital outlay*	Non-potable water supply $73,000
	Annual operating (costs/kL)	
	User price	Body corporate fee $800/lot/yr, includes cost of 150 kL recycled water, users charged for any extra
Benefits	*Reduced demand for potable supply*	Site not connected to mains water
	Flow management	
	Pollution control	
	Infrastructure	
	Environmental flow	

B.12 Parafield Stormwater Harvesting Facility

Contact Information		
Contact Name		Colin Pitman
Location		Parafield Airport
Project Partners		City of Salisbury Parafield Airport Management SA State Government Northern Adelaide and Barossa Catchment Water Management Board GH Michell & Sons Australia Pty Ltd
References		(Pitman, 2003) (CS, 2003) (DEH, 2003) (CS)
General Site Details:		
Development Type		Retrofit (Stage 1)
Size		1600 ha catchment, 11.2 ha site
Date of commission		Early 2003
Scale of implementation		Catchment
Rainfall	*Rainfall (mm/yr)* *(ML)* *No. rainfall days/yr* *Mean annual runoff (ML)* *Potential evapotranspiration (mm)*	460.5 7368.0 116.8 2210 1100-1200
Geology		
Aquifer	*Watertable* *Groundwater movement* *Other*	 Saline limestone aquifer
Site History		
System Requirements		

B.12 Parafield Stormwater Harvesting Facility

Objectives		Flood protection Provision of recreational amenities Environmental management, including habitat creation, protection of the Barker Inlet (breeding ground and nursery for much of SA's fisheries), decreased dependence on Murray River Economic development Showcase development in converting stormwater from an urban nuisance and pollutant threat into a valuable resource for industry and the community
End-use requirements (regulation)	*Quality*	Recharge water quality has to meet the EPA requirements
	Quantity	
	Operational	
	Risk assessment	EMP included risk analysis to control and minimise impact from dust, transmission of pathogens, chemicals, fuels and other pollutants, erosion, noise and traffic movement
Other		
System Components:		
Collection	*How*	Gutter, pipe, channel Stormwater from local catchment diverted from the trunk drain into a series of capture, holding and cleansing basins A weir in the Parafield Drain diverts flow into an instream capture basin via seven 1050 mm diameter culverts A 300 mm diameter bypass culvert located through the weir to re-direct low water flows detected to be of unsatisfactory quality for capture Pumped from capture basin to holding basin
	Capacity (ML)	Up to a 1:10 year storm event, 50 ML capture basin (39000 m3), similar capacity holding basin
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Treatment	*How*	Wetlands Gravitates to and flows continuously through densely-planted reed bed, biologically filtered
	Capacity (ML)	2 ha (150000 m^3)
	(% mean ann. runoff)	
	Design methods	Residency period of water in treatment ponds is between 7 and 10 days, depending on quality of inflow water

B.12 Parafield Stormwater Harvesting Facility ...continued

Treatment cont…		Bird-proof neeting over ponds to reduce bird populations around airport and risk of bird strike
	Key Learnings	Removes ~90% of nutrient and pollutant loads
Storage	*How*	ASR, cleansed stormwater excess to the needs of local industry is stored in natural underground aquifers for recovery at times of low rainfall
	Capacity (ML)	~650 ML injected underground annually (design)
	(% mean ann. runoff)	
	Design methods	ASR well field comprises two wells, both 190 m deep, 35 L/s injection rate Initial buffer of 2,000 ML as balancing storage to overcome yearly variations in ASR
	Key Learnings	
Re-use	*What*	Wool cleansing (GH Michell & Sons Australia Pty Ltd major recipient), irrigation
	How	Cleansed water pumping station pumps discharge from the reedbed via 300 mm diameter rising main, distributed by pipeline to a tank at GH Michell & Sons Australia
	Capacity (ML)	1500 ML/yr max yield, GH Michell use ~1100 ML
	(% mean ann. runoff)	90%
	Design methods	Annually, 500 ML pumped directly to GH Michell, 500 ML drawn from ASR, up to 400 ML to other consumers along pipeline
	Key Learnings	150-250 ppm supply water salinity, which is less than the salinity of the River Murray (usually greater than 400 mg/L)
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	n/a

B.12 Parafield Stormwater Harvesting Facility ...continued

Greywater cont…	*(% total water use)* *Collection* *Treatment* *Storage*	
Other Water for Re-use	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Implementation Issues		
Site Amenity		Consideration of possible disruption to airport activities Access to system (because airport is a secure area) Emergency Response Plan developed for the project in order to ensure effective and efficient responses to incidents that may threaten to adversely impact the project
Public Safety		Bird strike management Mosquito management
Landscape Requirements		Wind shear control (changes in topography)
Integration into total urban water cycle		Competitive water pricing
Possible Problems		
Institutional		Council opted for payback period of 10 years & will ensure recycled waters always competitively priced compared to mains water Model for industry, local, state and federal government partnership Regulatory and legal reforms tested Required licenses (from EPA and Department of Water Resouces) and development approvals; undertook detailed technical and legal assessment of the project in order to ensure regulatory approvals received in time to keep to timing schedule
Other		Council provides economic incentives to existing and new industries in the region Indigenous heritage issues
Key Learnings		
Other Issues		
Operation and maintenance	*How*	O&M Manual developed for project

B.12 Parafield Stormwater Harvesting Facility ...continued

Operation and maintenance cont..		System control & data acquisition (SCADA) system linked to central control system at Council offices
	Who	On-going quality control provided Technical Advisory Committee, comprised of expert personnel from council, airport, GH Michell, NABCWMB, EA
	Key learnings	
Monitoring	*Water quality*	Parafield Drain, basins, groundwater Using in-line real time monitoring (pH, TDS and settleable solids), grab samples & composite sampling
	Water quantity	Groundwater levels
	Other	Macro-invertebrates, native fish, terrestrial invertebrates (mosquitoes and other insects), sediments (within basins)
Performance	*Against objectives*	
	Water quality	ASR injection water quality meets Australian Drinking Water Guidelines Harvesting and treating stormwater through wetlands typically reduces the nutrient and pollutant loads by up to 90%, while the the salinity of the treated stormwater is less than 250 mg/L (these are the general figures for all of Salisbury's wetlands)
	Water quantity	
	Assessment methods	
	Key learnings	GH Michell & Sons Australia are pleased with the quality of the water Provides solution to stormwater flooding of Parafield Airport, rental income helps to offset cost of running airport
Cost/Benefits		
Costs	*Capital outlay*	$4.5m
	Annual operating (costs/kL)	30 c/kL (excluding cost of capital, compared with cost of mains water from River Murray of $1.00/kL)
	User price	
Benefits	*Reduced demand for potable supply*	1.5 billion litres of water that was pumped annually from the River Murray stays in the river
	Flow management	Flooding problems at Parafield Airport eliminated
	Pollution control	Contributes to the elimination of ~5000 ML of stormwater flowing into the Barker Inlet annually and associated pollutants

B.12 Parafield Stormwater Harvesting Facility ...continued

Benefits cont…	*Infrastructure*	Enhanced local job opportunities and economic stability - costs to GH Michell in mains water use and sewage disposal were otherwise sufficiently high to force the company to consider relocating
	Environmental flow	More than a billion litres of water that was pumped annually from the River Murray stays in the river to help enhance flow and arrest rising salinity

B.13 Parfitt Square

Contact Information		
Contact Name		UWRC
Location		Bowden, SA
Project Partners		City of Charles Sturt Urban Water Resources Centre, University of South Australia
References		(UWRC, 2003) (PCWMB et al., 2002)
General Site Details:		
Development Type		Re-development in an inner surburb (27 residences, 250 m of road, a car park and an open space reserve)
Size		1.3 ha recreational park with 0.3 ha adjoining medium density housing
Date of commission		March 1997
Scale of implementation		Catchment
Rainfall	*Rainfall (mm/yr)*	558.4
	(ML)	7.3
	No. rainfall days/yr	120.3
	Mean annual runoff (ML)	2.2
	Potential evapotranspiration (mm)	1600-1700
Geology		Dominant soil is a low permeable clay, permeability tests reveal the soil to have low hydraulic conductivity (k60=8x10^{-7} m/s)
Aquifer	*Watertable*	12 m
	Groundwater movement	~12 m/yr
	Other	Quaternary aquifer, ~1.5 m thick, comprises coarse river gravel, TDS 1800 mg/L
Site History		
System Requirements		
Objectives		To retain all storm runoff flows up to and including the 1:100 yr storm runoff To retain and manage all surface pollution generated in the catchment in all storm events up to and including the 1:100 yr event To divert the bulk of retained storm runoff to storage in the underlying upper Quaternary aquifer

B.13 Parfitt Square ...continued

Objectives cont…		To retrieve stored stormwater to provide irrigation for the 0.6 ha reserve To provide a quality environment for passive recreational activity
End-use requirements (regulation)	*Quality*	
	Quantity	
	Operational	
	Risk assessment	
Other		
System Components:		
Collection	*How*	Gutter, single entry point in car park area
	Capacity (ML)	All stormwater from the upstream sub-catchments Design caters for two 100-yr ARI storm conditions, peak design flow = 200 L/s (critical storm = 20 mins), design runoff volume = 1200 m^3 (4 hr storm)
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Treatment	*How*	30m long grated sediment trap and 300 m^2 gravel reed bed (sedimentation, filtration and adsorption), overflow and infiltration from reed bed enters subterranean gravel-filled trench beneath a grassed swale (further filtration), cleansed stormwater is then conveyed to recharge wells for storage; bore headworks includes double thickness of geotextile to provide final filtering
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	Forebay of reed bed designed to convey peak flow Designed to store all suspended material expected to be mobilised in the catchment over an estimated 100 yr period Both the gravel reed bed and trench are separated from the surrounding soil by geotextile Trench 100 m long and 4 m^2 in cross-section, entrance to bore situated 100 mm above bottom of trench to allow for filtration of stormwater through to surrounding soil and vegetation in between storm events Analysis of drainage design performed using ILSAX computer software, obtained peak flow into park, inflow hydrograph and peak storage height
	Key Learnings	
Storage	*How*	Four recharge wells in a ponding area, ASR

B.13 Parfitt Square ...continued

Storage cont…	*Capacity (ML)*	trench: ~135 m3, park acts as 900 m3 detention basin Quaternary 1 aquifer underlies most of Adelaide Metropolitan area and is estimated to have a storage capacity of 50,000 ML
	(% mean ann. runoff)	
	Design methods	Storage volume needed within landscaped reserve designed by determining rate of recharge using a simple computer model, developed using standard spreadsheet techniques and assumes transient conditions (particular parameters given in "Parfitt Square Stuff" doc) Landscaping of reserve provides 900 m3 storage below carriageway invert, with all above-ground storage utilised in a 4 hr 100 yrs event the four recharge bores are expected to convey 20 L/s of clean stormwater to the aquifer Anticipated annual recharge ~ 1.7 ML
	Key Learnings	
Re-use	*What*	Irrigation
	How	Discharge bore and pump 10m downstream from nearest recharge bore, allows "plug" of stormwater injected in winter to be centred around production bore in summer Cleansed stormwater mixes with groundwater, supply with salinity around 500 mg/L suitable for irrigation
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	If recharge and retrieval volumes are kept approximately in balance adverse pressure fluctuations will be avoided and the aquifer will in time show a gradual reduction in salinity
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	
	(% mean ann. runoff)	
	(% total water use)	
	Collection	Roof runoff from newly constructed houses directly connected to gravel trench via PVC pipes
	Treatment	GPTs (mesh traps), 100 m long, gravel-filled trench for storage and infiltration
	Storage	ASR
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	

B.13 Parfitt Square ...continued

Wastewater cont…	*Collection*	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Implementation Issues		
Site Amenity		Community expectations for active and passive recreation Needs of an adjacent school
Public Safety		
Landscape Requirements		
Integration into total urban water cycle		
Possible Problems		
Institutional		
Other		Strong sense of community in neighbourhood - require resident mandate for stormwater system - community involvement and cooperation sought at earliest stage of development
Key Learnings		
Other Issues		
Operation and maintenance	*How*	
	Who	
	Key learnings	
Monitoring	*Water quality*	Long-term monitoring

B.13 Parfitt Square ...continued

Monitoring cont…	*Water quantity*	
	Other	
Performance	*Against objectives*	
	Water quality	
	Water quantity	
	Assessment methods	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	
	Annual operating (costs/kL)	
	User price	
Benefits	*Reduced demand for potable supply*	Reduction, and in some cases the elimination of, mains water for irrigation
	Flow management	Reduces downstream flooding; all storm runoff up to and including the 1:100 yr storm event retained
	Pollution control	Pollution generated in the catchment in all storm events up to and including the 1:100 yr event treated on-site
	Infrastructure	Localised treatment of stormwater will not contribute to downstream problems
	Environmental flow	Replenishment of the aquifer

B.14 Powells Creek

Contact Information		
Contact Name		Jake Matuzic
Location		Concord, NSW
Project Partners		City of Canada Bay Council Atlantis Corporation NSW EPA
References		(NSW EPA, 2003) (AC, 2003)
General Site Details:		
Development Type		Demonstration project, retrofit kerb gully bypass system
Size		~0.133 ha/street (x 5 streets = 0.67 ha)
Date of commission		December 1998
Scale of implementation		catchment
Rainfall	*Rainfall (mm/yr)*	921.3
	(ML)	6.1
	No. rainfall days/yr	106.4
	Mean annual runoff (ML)	3
	Potential evapotranspiration (mm)	1500-1600
Geology		Native sub-surface consists of topsoil and fill, overlaying silty clays and weathered shale. Natural silty clays present at depths of 2.1-3.0 m with pockets of man-made fill. Soil permeability tests indicated a clay with permeability of 10-7 cm/s
Aquifer	*Watertable* *Groundwater movement* Other	
Site History		Project site is a series of streets in Concord that run westward from George St to Powells Creek. The Creek at the points of discharge from these streets is a tidal concrete lined trapezoidal channel, however the more natural section of Powells Creek consisting of mangrove wetlands is just downstream.
System Requirements		

B.14 Powells Creek ...continued

Objectives		To collect and treat road runoff from the catchment area of five streets running from George Street towards Powells Creek, demonstrating best practices for managing stormwater runoff To provide a breakthrough role model for ecologically sustainable and cost effective suburban development To implement an innovative distributed-source solution for stormwater filtration and management system for a suburban area To protect wildlife habitats, restore biological diversity, improve recreational areas and Concord community amentities and beautify the creek
End-use requirements (regulation)	*Quality*	
	Quantity	
	Operational	
	Risk assessment	
Other		
System Components:		
Collection	*How*	Gutter, infiltration system Kerb gully bypass system, porous road shoulder consisting of Atlantis Grass Cells and selected turf grass
	Capacity (ML) *(% mean ann. runoff)*	
	Design methods	Design based on the Atlantis Stormwater Purification and Re-use System for Roads, with appropriate modifications for this scheme Drainage cell designed to re-oxygenated stormwater High density polyethylene grid structure, distributes loads from pedestrian and vehicle traffic to base course, minimises grass and root compaction (maintains infiltration capability), lateral design capabilities prevent cell blocking
	Key Learnings	
Treatment	*How*	Filters through grass cells and then through Atlantis Ecosoil into Atlantis Ecological Channel which continues filtration process Irrigation water absorbed into the surrounding soils or evapo-transpired through surrounding vegetation "phyto-remediate" heavy metals and nutrients Ecosoil physically and biologically engineered to treat PCBs, PAHs, organophosphates, coal tars, pesticides and herbicides, and tailored to suit the site's specific soil and water properties

B.14 Powells Creek ...continued

Treatment cont…	*Capacity (ML)*	
	(% mean ann. runoff)	
	Design methods	Considerations include suitable compaction of the filter medium to maintain road surface integrity, maintaining optimum infiltration rates, supporting growth of grass; required to achieve a permeability of at least 0.1 cm/s (1.01 l/s/m^2) Ecological Channel comprised of Atlantis vertical cells with dimensions of 1800x300x80 mm and wrapped in 2 mm Atlantis Filtration Geotextile. One side of the channel is flush with the excavation, the other with the tank. Channel is also designed to re-oxygenate stormwater. Channel designed to follow inherent contours of landform (emulating flow of natural sub surface waterway), this design creates vertical flow, turbulence and reduces overall flow velocity, permeable walled channels allow interaction of water with soils (increasing aerobic capacity of channel)
	Key Learnings	
Storage	*How*	Diverted by Ecological Channel into underground Atlantis Ecological Tanks, comprised of 15 cells, each 410x467x610 mm
	Capacity (ML)	0.00175
	(% mean ann. runoff)	0.06%
	Design methods	Due to low permeability rate of the subsoil, system would be unable to infiltrate all water stored in the tank
	Key Learnings	During large storm events an overflow system diverts excess treated water to an appropriate outlet
Re-use	*What*	Irrigation, groundwater recharge, discharge to Powells Creek
	How	
	Capacity (ML)	4500 m^2 irrigation area
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	

B.14 Powells Creek ...continued

Roof runoff cont…	*Treatment*	
	Storage	
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Implementation Issues		
Site Amenity		Subsurface system frees up space
Public Safety		
Landscape Requirements		Specific vegetation types used for evapo-transpiration form part of the system
Integration into total urban water cycle		
Possible Problems		
Institutional		
Other		
Key Learnings		
Other Issues		
Operation and maintenance	*How*	
	Who	
	Key learnings	

B.14 Powells Creek ...continued

Monitoring	*Water quality*	Monitored for six months following construction; stormwater tested at surface level, after infiltration and storage in tanks; 10 rainfall events sampled, tested for pH, TN, TP, PAH, EC, turbidity, SS, Cu, Zn, Pb
	Water quantity	
	Other	
Performance	*Against objectives*	
	Water quality	Over 90% efficiency in removal of metals, ~25% removal rate for nutrients
	Water quantity	
	Assessment methods	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	$400,000
	Annual operating (costs/kL)	
	User price	
Benefits	*Reduced demand for potable supply*	Use of recycled water for irrigating parks and other landscape areas
	Flow management	
	Pollution control	Micro-organisms in Ecosoils biologically degrade pollutants
	Infrastructure	Reduced maintenance of stormwater systems
	Environmental flow	Excess remediated water discharged into Powells Creek as environmental flows of improved water quality

B.15 Santa Monica Urban Runoff Recycling Facility

Contact Information		
Contact Name		
Location		Santa Monica, USA
Project Partners		City of Santa Monica
References		(Amaro, 2001) (Antich et al., 2002)
General Site Details:		
Development Type		
Size		Pico-Kenter and Pier storm drains drain 1,680 and 360 ha respectively (4,200 and 900 acres)
Date of commission		Began operation in February 2001
Scale of implementation		Catchment
Rainfall	*Rainfall (mm/yr)* *No. rainfall days/yr* *1 yr intensity* *Potential evapotranspiration (mm)*	
Geology		
Aquifer	*Watertable* *Groundwater movement* *Other*	
Site History		City of Santa Monica is a primarily urban area with 85,000 residents, occupies 2.2. miles of coatal zone
System Requirements		
Objectives		Primary: To eliminate pollution of Santa Monica Bay cause by dry-weather runoff Secondary: To treat and produce cost-effective and high-quality water for re-use in landscape irrigation; to raise public awareness of Santa Monica Bay pollution through appropriate educational exhibits at or near the treatment facility; to construct an aesthetically pleasing and functional facility with an appropriate emphasis on art elements

B.15 Santa Monica Urban Runoff Recycling Facility ...continued

End-use requirements (regulation)	*Quality*	Irrigation re-use of recycled wastewater is regulated by Title 22 of the California Deparment of Health Services, although it was developed for wastewater recycling and does not currently cover recycled urban runoff and stormwater. Regulatory compliance was judged on the basis of the application of best available technology as a best management practice covered under the Los Angeles County Minicipal Stormwater National Pollutant Discharge Elimination System Permit Removal of oil, grease and large solids during the preliminary treatment process Removal of organic and inorganic compounds and turbidity during secondary treatment Removal of pathogens during the disinfection stage
	Quantity	Average dry-weather flows from Pico-Kenter and Pier storm drains assumed to be around 225,000 gpd and 40,000 gpd respectively based on visual observations and actual field measurements; peak flows estimated to be 450,000 and 50,000 gpd
	Operational	
	Risk assessment	
Other		
System Components:		
Collection	*How*	Low-flow dry-weather runoff diverted from Pico-Kenter and Pier (city's two main) storm drains Operates in dry weather season (April to October)
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Treatment	*How*	Treatment train consisting of: coarse and fine bar screens, flow equalisation, dissolved air flotation, degritting systems, microfiltration and UV disinfection
	Capacity (ML)	~1.9 ML/day (500,000 gallons/day)
	(% mean ann. runoff)	
	Design methods	An evaluation was conducted of various water treatment processes to determine their ability to produce a reclaimed effluent suitable for landscape irrigation and toilet flushing based on specific regulations, discharge limitations, and minimum treatment requirements Preliminary: processes evaluated include racks, screens, comminutors, grinders, grit chambers, flotation units, and flow-equalization basins; processes chosen were deemed best from the viewpoint of space constraints, operation and maintenance, and residuals management

B.15 Santa Monica Urban Runoff Recycling Facility ...continued

Treatment cont…		Secondary: processes evaluatied include fine screening, sand filtration, microfiltration, two-stage filtration, lime softening, reverse osmosis, granulated activated carbon, and ion exchange filters; selection criteria were ability to remove the identified contaminants and for issues that limits applicability including footprint, residuals management, and familiarity of operation and maintenance; microfiltration chosen for its small footprint, the ability to handle a wide range of variable influent water quality, and it would also allow cost-effective conversion to reverse osmosis in the future and possibly use the treated water for groundwater recharge Disinfection: processes evaluated include the use of ozone, UV radiation and sodium hypochlorite; selection criteria included footprint requirements, community safety, regulatory acceptance, piloting experience, operation and maintenance, regrowth, organics removal, cost, and environmental impact; UV selected for its small physical site layout requirements, minimal chemical handling, reduced environmental impact, and present low-worth cost
	Key Learnings	
Storage	*How*	Concrete tank
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	One side needed to be designed as a retaining wall for a freeway on-ramp
	Key Learnings	
Re-use	*What*	Irrigation (inc. two parks, a cemetery, a middle school, several greenbelt roadway medians, the civic center area, a major office building complex), toilet flushing
	How	Dual-plumbed systems for toilet flushing
	Capacity (ML)	A study of the number, type and location of potential re-use sites indicated that 33 sites within a two-mile range of the SMURRF had an average daily demand of ~4.5ML (1.2 M gal)
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	

B.15 Santa Monica Urban Runoff Recycling Facility ...continued

Roof runoff cont…	*Storage*	
Wastewater	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Greywater	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Other Water for Re-use	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Implementation Issues		
Site Amenity		
Public Safety		
Landscape Requirements		
Integration into total urban water cycle		
Possible Problems		
Institutional		
Other		Education information plazas located in plant overview areas; art and architectural elements designed to 1. Explain the workings of the facility, 2. Place the facility in the larger context of the Santa Monica urban watershed, and 3. Inform citizens what they can do to decrease or eliminate pollution in urban runoff
Key Learnings		Collaborative design approach between the artist, engineer, and public works transforms a potentially unsightly wastewater facility into a major public destination Additional cost of incorporating art in public works miniscule compared to the long-term public educational benefits and the public acceptance of a treatment facility near a major tourist attraction

B.15 Santa Monica Urban Runoff Recycling Facility ...continued

Other Issues		
Operation and maintenance	*How*	Daily maintenance of pre-treatment system Major challenge is the control of algae; weekly cleaning is required to prevent the buildup of algae
	Who	
	Key learnings	Initial design required the injection of a background level of chlorine within the distribution line. However, the City has found that algae grows almost everywhere within the facility, especially in the finished reservoir. The City is considering adding chlorine earlier in the treatment train to reduce algal growth
Monitoring	*Water quality*	Oil and grease are monitored to avoid high concentrations (from spills) from entering the facility and exceeding the system's parameters "Special monitoring of microfiltration system to ensure proper operation and long-term durability and reliability"
	Water quantity	
	Other	
Performance	*Against objectives*	
	Water quality	
	Water quantity	
	Assessment methods	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	US$12 m
	Annual operating (costs/kL)	US$1.53/L (US$5.80/gal)
	User price	
Benefits	*Reduced demand for potable supply*	Cost-effective source of alternative water supply for the City of Santa Monica; displacement of up to 4% of potable water demand
	Flow management	
	Pollution control	Reduces pollution in the Santa Monica Bay
	Infrastructure	Resource conservation, pollution prevention, public health protection aspects; opportunity to educate public wrt sustainability
	Environmental flow	

B.16 Solander Park

Contact Information		
Contact Name		Leanne Dallmer-Roach, Peter Donley
Location		Erskineville, Sydney
Project Partners		South Sydney Council
References		(Dallmer, 2002) (Dallmer Roach, 2001) (SSCC, 2002) L. Dallmer Roach, personal communication P. Donley, personal communication
General Site Details:		
Development Type		Redevelopment (of a suburban park) Stage 1 of a three stage project that will eventually combine to upgrade stormwater quality from approximately 75% of the sub-catchment before it enters the downstream receiving waters of Alexandra Canal
Size		~220 ha catchment, ~65 ha current collection area
Date of commission		GPT installed in mid-2001
Scale of implementation		Catchment
Rainfall	*Rainfall (mm/yr)*	1102.4
	(ML)	716.6
	No. rainfall days/yr	129.4
	Mean annual runoff (ML)	250.8
	Potential evapotranspiration (mm)	1500-1600
Geology		
Aquifer	*Watertable*	
	Groundwater movement	
	Other	
Site History		Catchment is predominantly residential with some commercial and open space Park is former recreation area and council depot

B.16 Solander Park ...continued

System Requirements		
Objectives		Improve stormwater quality entering Alexandra Canal Use techniques and devices to improve other catchments Integrate current systems with a holistic approach to stormwater pollution prevention Demonstrate safe stormwater re-use Provide and develop educational opportunities for students and the community to learn from and understand these processes
End-use requirements (regulation)	*Quality*	
	Quantity	
	Operational	
	Risk assessment	
Other		Approval of design and installation of Sydney Water required (owner of stormwater drains)
System Components:		
Collection	*How*	(a) GPT intercepts flows from two parallel trunk drains passing through Solander park (b) overland flow infiltration
	Capacity (ML) *(% mean ann. runoff)*	GPT: accomodates 6 month ARI Overland flow: grading of park incorporates on-site storage capacity of ~450 m^3 or 100% of rainfall up to a 1 in 20 year ARI storm event
	Design methods	In-line GPT, pipe discharge calculated using a small weir in the pipe and a doppler current meter to measure velocity when the weir was no longer valid, design flowrate of 4 m^3/s, 15.5 m long x 4.5 m wide x 3.9 m deep
	Key Learnings	
Treatment	*How*	From trunk drains: Ecosol RSF 6000 GPT, holding tank, "Electropure" electrolysis treatment unit Overland flow: sand filtration bed, sub-surface drainage pipes then convey water to retention tank
	Capacity (ML)	12 kL holding tank 2 x 1kL treatment tanks
	(% mean ann. runoff)	
	Design methods	GPT: designed to capture 95% of gross solids and 95% of sediment particles over 2 mm in diameter

B.16 Solander Park ...continued

Treatment cont…		Sand filtration: 0.3 m topsoil, 0.6 m sand, 0.1 m gravel
	Key Learnings	Electrolysis alternative treatment technique, shown to remove 98-99% of suspended solids down to and including large dissolved molecules (inc. bacteria, algae)
		Typically requires less than 25% of the amount of aluminium added electrolytically to clear a water sample than when added as alum
Storage	*How*	Underground retention tank
	Capacity (ML)	0.225
	(% mean ann. runoff)	0.09%
	Design methods	
	Key Learnings	
Re-use	*What*	Park irrigation
	How	Irrigation system, pop-up sprinklers
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	
	Key Learnings	Allows for over 90% of water used for irrigation within the park to be sourced from re-use stormwater
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Wastewater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Greywater	*Capacity (ML)*	n/a

B.16 Solander Park ...continued

Greywater cont…	*(% total water use)* *Collection* *Treatment* *Storage*	
Other Water for Re-use	*Capacity (ML)* *(% total water use)* *Collection* *Treatment* *Storage*	n/a
Implementation Issues		
Site Amenity		Improved visual amenity as result of redevelopment of park, all elements are integrated into a total management approach and do not obstruct the aesthetics or the useability of the park Interpretative artworks Provision for mains water to top up retention tank during dry conditions
Public Safety		Remediation of contaminated soils on the site Overflow from treatment unit, flush tank and retention tank into GPT by gravity, excess released to receiving waterway GPT is bypassed once capacity exceeded
Landscape Requirements		
Integration into total urban water cycle		
Possible Problems		
Institutional		
Other		Public consultation and involvement from beginning of project
Key Learnings		Construction originally commissioned in last 1999, however installation was delayed until mid-2001 due to "site related issues" Community consultation and artwork development has resulted in local community interest and ownership of the scheme
Other Issues		
Operation and maintenance	*How* *Who*	GPT cleaned every 3-4 months and at each cleaning there are 6-8 tonnes of material removed

B.16 Solander Park ...continued

Operation and maintenance cont…	*Key learnings*	Maintenance may have been neglected as time since completion of construction has increased, no information about progress of subsequent stages of project
Monitoring	*Water quality*	Pre-construction: event & baseline monitoring upstream of GPT
		Post-construction: event & baseline monitoring upstream & downstream of GPT, video surveillance during storm events, grab samples from re-use tank, Electropure system
		Parameters: heavy metals (Ca, Cu, Pb, Fe, Zn), grease & oils, FC, pH, SS, DS, N & P
	Water quantity	Effectiveness of GPT wrt head loss
	Other	Manly Value Hydraulics Laboratory installed and operated monitoring and sampling equipment
		Post-construction: sediment impact monitoring
Performance	*Against objectives*	Number of organisations interested in the scheme and the SSC is seeing a number of developers incorporating WSUD principles and using similar technologies in the area
	Water quality	Pre-construction: heavy metals, FC, SS, N & P elevated (cf ANZECC Guidelines for Fresh and Marine Water Quality 1992)
		Post-construction report not available
	Water quantity	
	Assessment methods	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	$615 000 for design and construction, $200 000 for park redevelopment, $400 000 for remediation, $100 000 for community artworks
	Annual operating (costs/kL)	Electropure unit costs $20-50/ML for most polluted water (ref: (Robinson, 1999))
	User price	
Benefits	*Reduced demand for potable supply*	On-site stormwater storage and retention represents a significant saving of potable water
	Flow management	Flood mitigation and overland flow path management (there was an existing flood problem within local streets and an overland flood route through the park contributed to regular flooding of houses surrounding the park)
	Pollution control	Gross pollutant capture, rehabilitation of the park's soils
	Infrastructure	Council apply information and techniques developed to other catchments that discharge to Alexandra Canal
	Environmental flow	Stormwater entering receiving waterway (Alexandra Canal) of improved quality

B.17 Taronga Zoo

Contact Information		
Contact Name		Daryl Edwards
Location		Mosman, Sydney, NSW
Project Partners		Taronga Zoo Clean Up Australia Sydney Water
References		(TZ, 2003) D. Edwards, personal communication (1997) (ATS, 2003)
General Site Details:		
Development Type		Retrofit
Size		0.83 ha
Date of commission		September 1996
Scale of implementation		Sub-catchment
Rainfall	*Rainfall (mm/yr)* *(ML)* *No. rainfall days/yr* *Mean annual runoff (ML)* *Potential evapotranspiration (mm)*	1219.8 10.1 138.2 6.6 3.9
Geology		
Aquifer	*Watertable* *Groundwater movement* *Other*	
Site History		
System Requirements		
Objectives		

B.17 Taronga Zoo ...continued

End-use requirements (regulation)	*Quality*	
	Quantity	
	Operational	
	Risk assessment	
Other		
System Components:		
Collection	*How*	First flush stormwater collects in stormwater basin in front of treatment plant
	Capacity (ML)	1200 kL/day
	(% mean ann. runoff)	6.6%
	Design methods	Basin acts to provide flow equalisation when required
	Key Learnings	
Treatment	*How*	Screen and grit collection chamber, biological treatment (ANI-Kruger process removes N and P), aeration (pasveer channel), clarifier, buffer tank, microfiltration and disinfection (Memtec Continuous Microfiltration, MCF) and UV disinfection (post-holding tank)
	Capacity (ML)	
	(% mean ann. runoff)	
	Design methods	Backwash from CMF unit returns to aeration tank Weir diverts any excess flow entering buffer tank to the UV disinfection chamber prior to harbour discharge
	Key Learnings	
Storage	*How*	Pumped to holding tank at top of site
	Capacity (ML)	0.5
	(% mean ann. runoff)	7.6%
	Design methods	
	Key Learnings	
Re-use	*What*	Animal exhibit wash down, exhibit and ornamental moat filling, toilet flushing, irrigation Excess treated water discharged to Sydney Harbour
	How	Recycled water supply pipe, includes 1,300 m of ring main (100mm diameter PVC pipe) and 1,200 m of various sized branch lines; hose taps, sprinkler systems, moat filling valves and toilet blocks
	Capacity (ML)	

B.17 Taronga Zoo ...continued

Re-use cont…	*(% mean ann. runoff)*	
	Design methods	
	Key Learnings	
Other Water for Re-use		
Roof runoff if treated and used separately	*Capacity (ML)*	n/a
	(% mean ann. runoff)	
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Wastewater	*Capacity (ML)*	
	(% total water use)	
	Collection	Wastewater from animal cage hosedowns
	Treatment	Incorporated with stormwater
	Storage	
Greywater	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Other Water for Re-use	*Capacity (ML)*	n/a
	(% total water use)	
	Collection	
	Treatment	
	Storage	
Implementation Issues		
Site Amenity		
Public Safety		
Landscape Requirements		
Integration into total urban water cycle		

B.17 Taronga Zoo ...continued

Possible Problems		Pressure in hoses used for cage washdown
Institutional		
Other		
Key Learnings		
Other Issues		
Operation and maintenance	*How*	Alarm system monitors operation of treatment plant
	Who	Zoo operates treatment plant, contractor maintains reticulation and pumps
	Key learnings	
Monitoring	*Water quality*	Zoo: overflow and discharge to harbour monitored monthly for BOD, SS, pH Contractor: overflow, discharge and filtration unit monitored monthly for coliforms and every six months for bacteria, parasites and faecal coliforms
	Water quantity	Flow in and out of plant, water use
	Other	
Performance	*Against objectives*	
	Water quality	
	Water quantity	
	Assessment methods	
	Key learnings	
Cost/Benefits		
Costs	*Capital outlay*	\$2.2 m
	Annual operating (costs/kL)	
	User price	
Benefits	*Reduced demand for potable supply*	Reduced reliance on mains water supply Save \$70,000/yr on water costs
	Flow management	Reduced dry weather discharge into Sydney Harbour
	Pollution control	
	Infrastructure	
	Environmental flow	

Appendix C

This appendix contains information on stormwater treatment measures built for re-use but designed using the same principles as systems used solely for pollution control.

C.1 Swales and Buffers

CSU Thurgoona – Appendix B.4

At this site contour banks are used to direct runoff to swales. The swales are both grassed and rocky and allow sedimentation to occur (Figure C.1). Treatment wetlands are also positioned on swales. The swales meander over the landscape to control erosion as well as provide aesthetic features.

Oaklands Park – Appendix B.11

Grassed swales alongside roadways are used to collect general runoff as well as slow water flow, minimise erosion, increase point of contact for infiltration and convey runoff to storage (Figure C.2). The swales are designed to typical minor/major standards; believed to safely convey 5 year ARI storm event as suggested by Australian Rainfall and Runoff (2003) (where <5yr ARI is conveyed within the drainage system, and >5 yr ARI is conveyed along the road). No real attention appears to have been paid to type of vegetation or specific treatment performance requirements. 'Worst-case' demand and supply was based on the 1982-83 drought.

Homebush Bay – Appendix B.7

A conventional gutter and pipe system is used to collect runoff in high traffic areas at Homebush Bay,

Figure C.1 Grassed Swales for Collection and Rocky Swales between Treatment Wetlands at CSU Thurgoona (source: CSU)

Figure C.2 Swales Alongside Roadways at Oaklands Park Collect Runoff and Allow Sedimentation (source: savewater.com.au) however vegetated swales have been constructed alongside roadways in low traffic areas (Figure C.3). These swales facilitate collection, sedimentation and convey of runoff to the treatment wetlands.

C.2 Bio-filters

Parfitt Square – Appendix B.13

A gravel-filled trench beneath a grassed swale conveys treated water from the treatment wetland to the infiltration basin at Parfitt Square (Figure C.4). It also serves to further filter the stormwater and provides 135 kL of temporary storage. The trench, which is 100 m long and has a cross-section of 4 m^2, is separated from surrounding soil by geotextile. The outlet pipe is situated 100 mm above the bottom of the trench to allow for some infiltration of stormwater through to the surrounding soil and vegetation.

Altona Green Park – Appendix B.1

Beneath the grassed swale at Altona Green Park is the central filter zone, which consists of a layer of sand and a porous pipe at the bottom of the trench to convey treated water to storage. The trench also facilitates sedimentation and biological treatment (removal of fine oil particles, dissolved organic matter, and nutrients).

Figure C.3 Swales Collect Runoff from Low Traffic Areas at Homebush Bay

Figure C.4 Grassed Gravel-filled Trench at Parfitt Square (source: UniSa)

C.3 Porous Pavement

There were three types of porous pavement found incorporated into stormwater re-use schemes, as described below:

1. The ***Manly Stormwater Treatment and Re-use (STAR) Project (Appendix B.10)*** uses Atlantis Aqua Pave permeable pavers in the Ocean Beach carpark for the collection and initial treatment of general runoff (Figure C.5). These pavers have a crush strength of ~14,000 kN/m^2 and can infiltrate up to 20 $L/s/m^2$.
2. Sydney Olympic Park in ***Homebush Bay (Appendix B.7)*** incorporates ~6.7 ha of Rocla EcoTrihex pavers to collect, treat and infiltrate runoff directly to trees (Figures C.6, C.7). These pavers have a compressive strength of 55×10^{-6} N/m^2 and an abrasion resistance of 4.

Figure C.5 Atlantis Aqua Pave at Manly Beach (source: Atlantis Corporation)

Figure C.6 Rocla Ecotrihex Pavers at Homebush Bay (source: Rocla and B. Hatt)

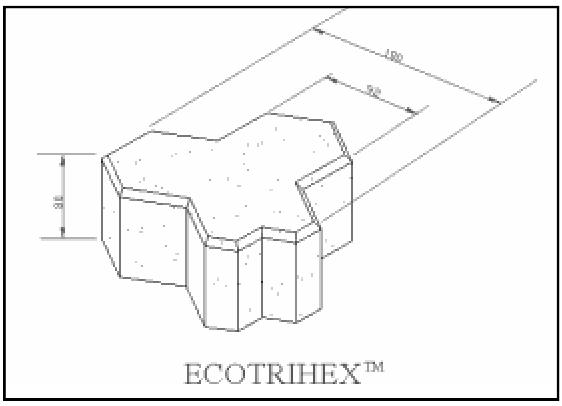


Figure C.7 Rocla EcoTrihex Pavers (source: Rocla)

3. The stormwater treatment and re-use system at ***Powells Creek (Appendix B.14)*** in Sydney, NSW uses Atlantis Turf Cells (Figure C.8) as part of the treatment process. These cells are a grid structure designed to house turf grass and are constructed using high density polyethylene (Figure C.9). This structure enables the distribution of loads from pedestrian and vehicle traffic to the base course and has a crush strength of 1457.60 kN/m^2. Infiltration capacity is maintained through the use of individual cells in the grass paver to minimise grass and root compaction.

C.4 Infiltration Basins/Trenches

Figtree Place – Appendix B.5

The 250 m^2 grassed dry detention basin is located in the centre of the Figtree Place development (Figure C.10). General runoff filters through 300 mm of topsoil overlaying a 750 mm layer of gravel enclosed in geotextile followed by infiltration to the underlying aquifer. Infiltration trenches around the perimeter of the development capture, filter and infiltrate overflow from the rainwater tanks. This system is designed to detain 83% of all runoff up to a 1:50 year ARI storm event.

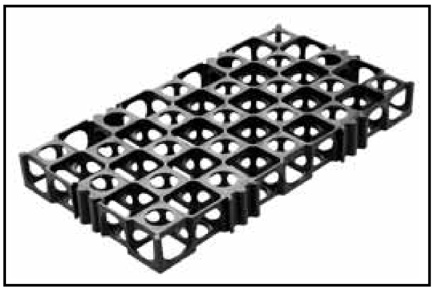


Figure C.8 Atlantis Turf Cell (source: Atlantis Corporation)

Figure C.9 Atlantis Turf Cells at Powells Creek (source: NSW Stormwater Trust)

Figure C10 Detention Basin (dry and during a storm event) at Figtree Place (source: Coombes)

Parfitt Square –Appendix B.13

The detention basin at Parfitt Square acts to detain treated stormwater for injection to the underlying aquifer. There are four recharge wells within the basin which are expected to convey up to 20 L/s of clean stormwater to the aquifer. The required detention volume was designed by determining the rate of recharge using a simple computer model which was developed using standard spreadsheet techniques and assumes transient conditions. The parameters required for the model are as follows:

bore diameter	0.150 m
aquifer thickness	3 m
depth to aquifer	10 m
watertable level	11.5 m
transmissibility	336 m^2/day
storage coefficient	0.09

In addition, the detention basin provides 900 kL of temporary storage for large storm events.

Solander Park – Appendix B.15

The grassed infiltration bed at Solander Park (Figure C.11) has a detention capacity of 450 kL or 100% of rainfall in a 1:20 year ARI storm event. A 300 mm layer of topsoil overlays 600 mm of sand on top of 100 mm of gravel. Perforated pipes beneath the gravel layer then convey the filtered water to the storage tank.

C.5 Wetlands

The design of constructed wetlands varies widely, however they typically have a pollution control/inlet zone, which serves to trap coarse sediment (it is important to reduce the frequency of required maintenance for the macrophyte component) and distribute flow, followed by densely vegetated marshes that trap fine sediment and soluble pollutants. Generally, the longer water is detained within the wetland the more improved the water quality is. However, as a rule there is a time threshold above which water quality is likely to deteriorate due to chemical and biological processes within the wetland.

Figure C.11 Looking Across Solander Park to Infiltration Bed

Local climate affects the behaviour of a wetlands system; however pollutant removal is predominantly influenced by the catchment runoff characteristics of the site, and the design and surface area of the pond (Wong *et al.*, 1998).

Bobbin Head Road – Appendix B.2

The constructed wetland at Bobbin Head Road was designed to settle sediments, and remove nutrients and heavy metals. It was to be a subsurface flow wetland, have a surface area of 200 m^2 and an average depth of 0.8m

Parfitt Square – Appendix B.13

The gravel reed bed at Parfitt Square (Figure C.12) has a surface area of 300 m^2 and provides initial treatment for low quality flow from the roadways and carpark (roof runoff flows directly to bio-filter). This wetland facilitates sedimentation, filtration and adsorption, and is designed to store all the suspended material expected to be mobilised in the catchment over an estimated 100 yr period. The wetland is separated from the surrounding soil by a geotextile layer. The drainage design was analysed using ILSAX computer software, including peak flow into park, inflow hydrograph and peak storage height.

Inkerman Oasis – Appendix B.8

The treatment wetland at Inkerman Oasis is a baffled subsurface flow rock filter with a surface area of 400m2. The wetland offers sedimentation and nutrient removal. It contains a soil-gravel filter medium and emergent plants, and is designed for both vertical and horizontal flow to fully utilise the media surface area.

CSU Thurgoona – Appendix B.4

The instream treatment wetlands at CSU Thurgoona provide sedimentation, nutrient removal and aeration of inflowing runoff. At the point of inflow is a rock-based water baffle to aerate the stormwater, followed by a sedimentation pool at least 4 m deep with steep sides (Figure C.13-a). This pool progressively becomes shallower over a length of 5-10 m, leading to a macrophyte zone (Figure C.13-b). These system are self-sustaining and self-optimising, and their positions on the swales are selected with respect to function and aesthetic appeal.

Figure C.12 Gravel Reed Bed (in foreground) at Parfitt Square (source: UniSA)

Figure C.13 (a) Sedimentation Pond and (b) Macrophyte Zone at CSU Thurgoona (source: CSU)

Hawkesbury – Appendix B.6

The stormwater treatment wetland system at UWS Hawkesbury is comprised of four one hectare surface flow wetlands. Within each wetland is an alternating series of shallow wetlands areas and deeper oxidation ponds. The normal operating level has an average design depth of 150 mm and a detention time of seven days. The design allows for multitude of wetland filling and holding scenarios, this allows studies of management and other factors to be incorporated into the scheme. Another design consideration was the minimisation of avifauna since there is a nearby RAAF base.

Homebush Bay – Appendix B.7

Homebush Bay incorporates over 100 ha of constructed wetlands and waterways that follow the original drainage line (Figure C.14). Three water quality control ponds collect and detain first flush runoff, this allows sedimentation. Aquatic plants throughout the system facilitate nutrient removal. Submerged gabion walls contain microphyte growth to ensure areas of open water and hence aerobic conditions. There is a bypass channel for high flows, which also acts as secondary storage.

Parafield – Appendix B.12

The treatment system at Parafield is a two hectare, densely planted, surface flow reed bed which facilitates sedimentation, and the removal of nutrients and pollutants. There is bird-proof netting over the system to minimise avifauna and thus reduce bird strike for the airport. Detention time may be varied between seven and ten days depending on the quality of the incoming stormwater

It can be seen that the Surface Area / Catchment Area ratio varies widely for small catchment areas (Figure C.15 (a)). This is most likely due to space constraints.

Figure C.14 (a) Wetland System at Homebush Bay. (b) Gabion Walls Visible in Pond Drawn Down for Maintenance

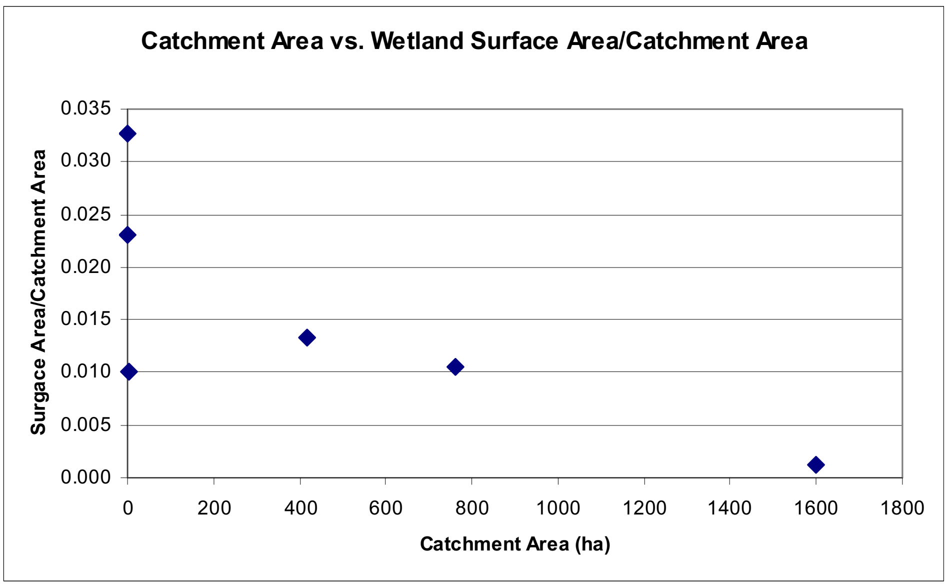


Figure C.15 (a) Catchment Area vs. Surface Area/Catchment Area for Treatment Wetlands

However, as catchment area increases, the Surface Area/Catchment Area ratio decreases. This may indicate that wetlands are more efficient for larger catchments than for smaller.

An approximate decrease in the Surface Area / Catchment Area ratio as annual rainfall increases can be seen in Figure C.15 (b), although the treatment wetlands at Parafield do not follow this trend. There does not seem to be any relationship between rainfall seasonality and the wetland Surface Area / Catchment Area ratio (Figure C.15 (c)).

Water quality emanating from these systems can be highly variable. It is not clear how this was incorporated into the designs (i.e. is treated stormwater always fit for re-use?).

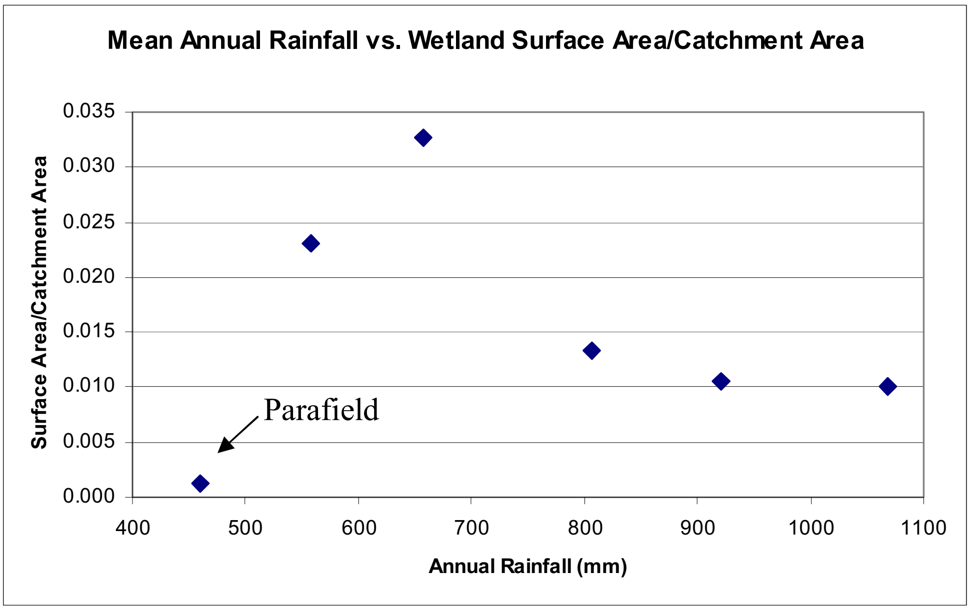


Figure C.15 (b) Mean Annual Rainfall vs. Surface Area/Catchment Area for treatment wetlands

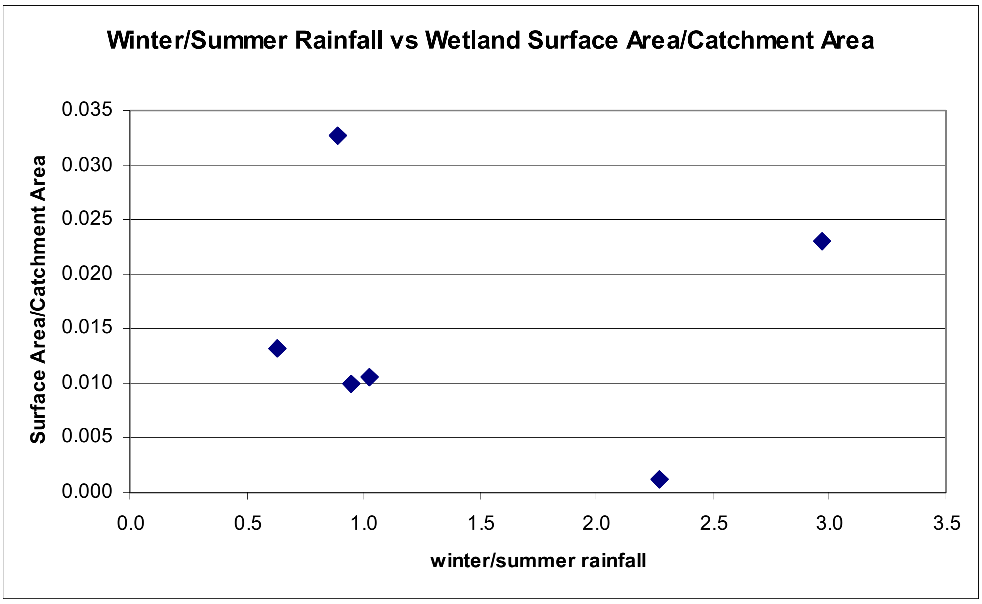


Figure C.15 (c) Winter/Summer Rainfall vs. Surface Area/Catchment Area for treatment wetlands

Provision of a bypass channel is important to protect wetland systems from potential re-suspension and scour during high flows. Homebush Bay incorporates a bypass channel that upgrades the storm capacity from a 1:10 year ARI to a 1:100 year ARI event. Hawkesbury and Parafield also both have provision for flood protection of a different form. At Hawkesbury the large detention basin prior to the wetland system offers flood protection, and if the capacity of this were exceeded inflowing water can be pumped past the wetland system. Parafield also has a detention basin prior to the reed bed that will provide some flood protection. In addition, beyond a certain storm event, water will overflow the diversion weir in the conventional drainage system.

C.6 Ponds, Basins and Lakes

Bowies Flat – Appendix B.3

The main design objective for the Bowies Flat treatment system was to provide flows of improved quality to Bridgewater Creek; re-use of stormwater for park irrigation was an afterthought and not specifically incorporated into the design. Stormwater for re-use is pumped from the settling pond (Figure C.16), which primarily serves as the inlet zone for the treatment wetlands, hence it is considered under this category (wetland system is downstream of the intake for re-use). The pond has a surface of 0.1 ha, a constant design depth of around two metres and is fringed by aquatic vegetation. The pond serves to remove coarse sediments and associated pollutants. It is designed for easy maintenance and there is a high flow bypass spillway.

Hawkesbury – Appendix B.6

Stormwater collected from the conventional drainage system is detained in a 60 ML basin (Figure C.17 (a)). This allows some sedimentation to occur prior to entry into the treatment wetlands. A settling pond at the end of wetlands allows further settling (Figure C.17 (b)). This pond has a surface area of 1.5 ha, an average depth of 2.1 m, and an effective storage capacity of 25 ML (6.5 ML water quality proportion). The pond provides final treatment and temporary storage for cleansed stormwater from the wetlands prior to either re-use as environmental flows or pumping to the 90 ML storage dam.

Figure C.16 Settling pond at Bowies Flat Wetland (source: BCC, 2003)

Figure C.17 (a) 60 ML detention pond and (b) 25 ML settling pond at Hawkesbury

CSU Thurgoona – Appendix B.4

Three interconnected reservoirs at the bottom of CSU Thurgoona store clean stormwater (Figure C.18). The stored water is pumped by windmill and solar powered pump up to a turkey nest dam as required for re-use as environmental flows or for irrigation. The three reservoirs have a combined storage capacity of 56.5 ML, and are sized so that natural supply of rainfall will exceed requirements at least once every five years. Overflow will discharge into a nearby creek to reduce salt buildup in the storages.

Oaklands Park – Appendix B.11

A system of three interconnected dams at Oaklands Park is used for storage (Figure C.19). This system was originally modelled to store 37 ML or 50% of mean annual runoff, in the three storages. However due to modifications during the construction of the dams, the storages currently contain 49 ML (or 65% of mean annual runoff). Modelling was based on projected demands for the summer peak (80kL/lot/month for three months) and the remaining period (6kL/lot/month). Modelling of the required storage did not include river pumping, although there is provision for this as a backup supply (subject to flow). There is a 1:100 yr ARI spillway on the bottom storage, which discharges to the nearby creek. Water can be pumped or siphoned between storages, to ensure that the storage with the lowest Surface Area/Volume ratio can be used during drought (to minimise evaporation).

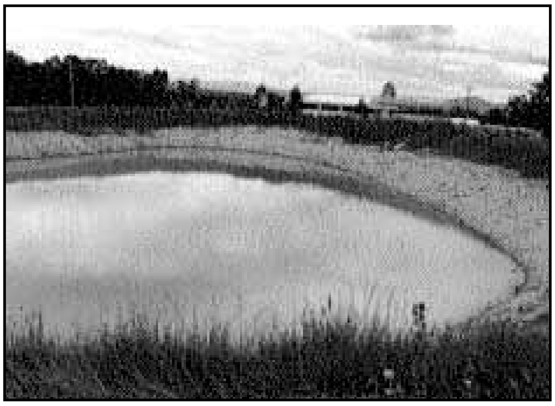


Figure C.18 Turkey nest dam at top of site (source: CSU)

Figure C.19 Front storage and bottom storage at Oaklands Park (source: Neil Kerby and B. Hatt)

Homebush Bay – Appendix B.7

Following consideration of storage options it was decided to use lower levels of an on-site disused brickpit (Figure C.20). This storage has a 350ML capacity and is the cornerstone of re-use scheme at Homebush Bay; the storage capacity is far greater than demand. Shallow ponds surrounding the brickpit also provide habitat for a local endangered frog species.

Parafield– Appendix B.12

Stormwater is diverted from the main Parafield trunk drain into a 50 ML capture basin then pumped to similar capacity holding basin prior to flowing into the treatment wetlands. These ponds have a 1:10 year ARI storm event capacity and are covered in netting to minimise avifauna.

From Figure C.21 (a), it can be concluded that there is no evident relationship between the Storage Capacity / Catchment Area ratio and Catchment area, however this is not unexpected, since the ponds studied here incorporate different combinations of functions.

Figure C.20 Stormwater stored in old brickpit at Homebush Bay, shallow ponds in foreground provide habitat for local endangered frog

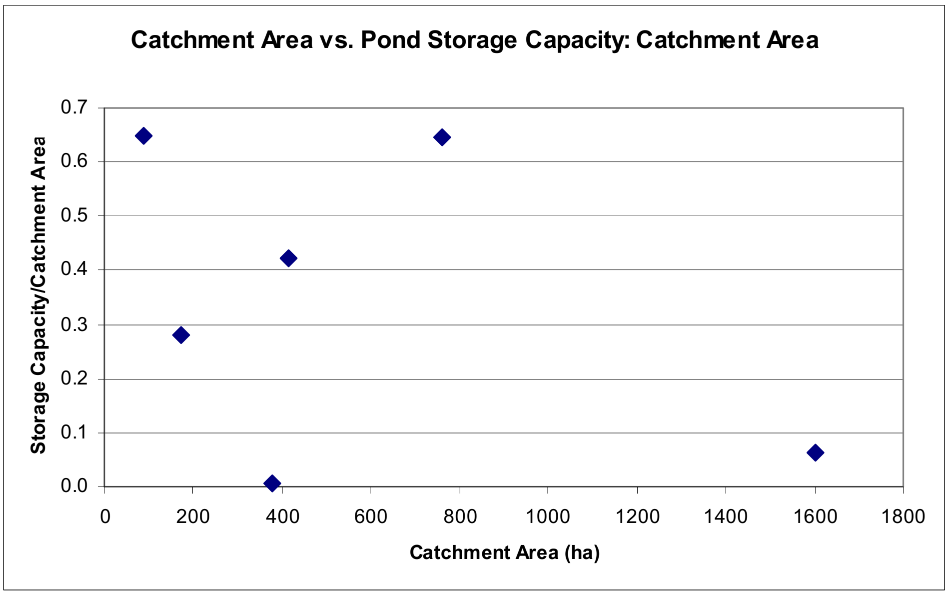


Figure C.21 (a) Catchment Area vs. Storage Capacity / Catchment Area for Ponds

It can be seen that the Storage Capacity / Catchment Area ratio increases with annual rainfall (Figure C.21 (b)). Only the Bowies Flat pond/wetland does not follow this trend; it is likely that this is entirely due to its unique construction (the settling pond of a primarily pollution control wetland is used for re-use storage as an afterthought). The same is true for the relationship between PC/CA and the seasonality of rainfall, although this graph is not shown.

C.7 Litter and Sediment Traps

The following are some examples of the litter and sediment traps utilised:

- The GPT installed at Solander Park is an Ecosol RSF 6000; a wet vault trap that straddles the two trunk drains passing under the park. A weir diverts runoff into a deep separation chamber, then through a 3 mm mesh screen into a parallel by-pass flume. The GPT is designed to capture 95% of sediment greater than 2 mm and accommodate a 6 month ARI flowrate of 4 m^3/s.
- External screens capture litter and sediment at Manly, while internal screens trap oils, fine sediments and grease.
- The first stage in the treatment plant Taronga Zoo involves passing the collected stormwater through 10mm bar screens followed by a grit collection chamber.
- GPTs are positioned on the inlets to the wetland at Inkerman Oasis and the settling pond at Bowies Flat.
- Floating booms in Haslams Creek collect floating debris prior to entry into the wetland system at Homebush Bay.
- Parfitt Square features a 30 m long grated sediment trap prior to the gravel reed bed.
- Coarse and fine bar screens and a degritting system form part of the treatment process at Santa Monica.

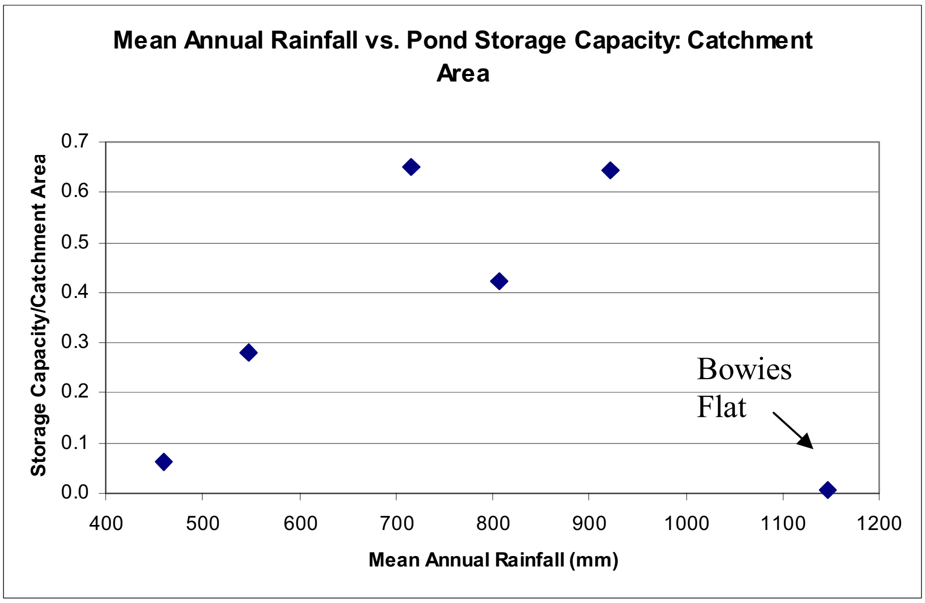


Figure C.21 (b) Mean Annual Rainfall vs. Storage Capacity/Catchment Area for ponds

C.8 Tanks

There are a wide variety of tanks utilised by the surveyed re-use schemes for storage. These include conventional above ground tanks, underground concrete structures, underground tanks made up of small cells, underground tanks that incorporate infiltration into the surrounding soil and header tanks.

Performance targets for storage tanks include:

- sufficient capacity to ensure re-use demand can be achieved, or provision for topping up the tank with mains water as a backup;
- sufficient capacity to ensure that available capacity prior to storms will provide flood mitigation storage;
- noise emissions from pumps (there is a limit on how much the ambient background noise levels can be exceeded by).

From Figure C.22, it can be seen that there is a decrease in the tank capacity: catchment area ratio as catchment area increases. This is not surprising, given that the larger the catchment area the more runoff there is to be collected i.e. storage tanks will fill faster in larger catchments.

Solander Park is excluded from the graph presented in Figure C.22 (a) because it is a huge outlier and as a result the relationship is difficult to see. While the storage capacity of the tank at Solander Park is comparable to the capacities of tanks at other sites, its catchment area is much larger relative to other sites with tank storages. While the GPT and infiltration basin are each capable of detaining up to a 1:20 year ARI storm event, it is suspected that the tank would not be capable of storing such a volume. The treated stormwater is used to irrigate a small park, hence the demand would be very low relative to the potential supply. Most treated stormwater would be released downstream as flows of improved quality.

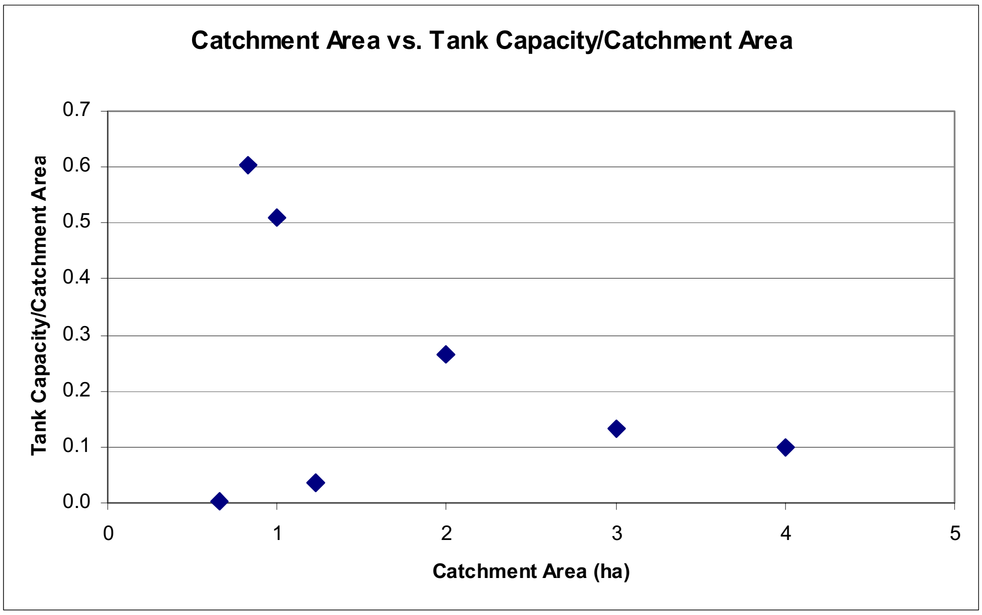


Figure C.22 (a) Catchment Area vs. Tank Capacity / Catchment Area

It must also be noted that the tanks at Taronga Zoo and Inkerman Oasis stores treated wastewater as well as stormwater. While Taronga Zoo fits the trend, Inkerman Oasis does not. A possible reason for this is that Inkerman Oasis only collects first flush and discharges subsequent runoff to the conventional drainage system.

A general decrease in the Tank Capacity / Catchment Area ratio as annual rainfall increases can be seen (Figure C.22 (b)). The exception to this trend is Kogarah, however this is likely to be explained by a number of factors; high imperviousness in the catchment, collection of first flush runoff only, and separate collection and storage of rainwater.

C.9 General Storage

There is a clear increase in the Tank Capacity / Catchment Area ratio as rainfall seasonality increases (Figure C.22 (c)), although there a couple of exceptions (Manly, Kogarah and Powells Creek).

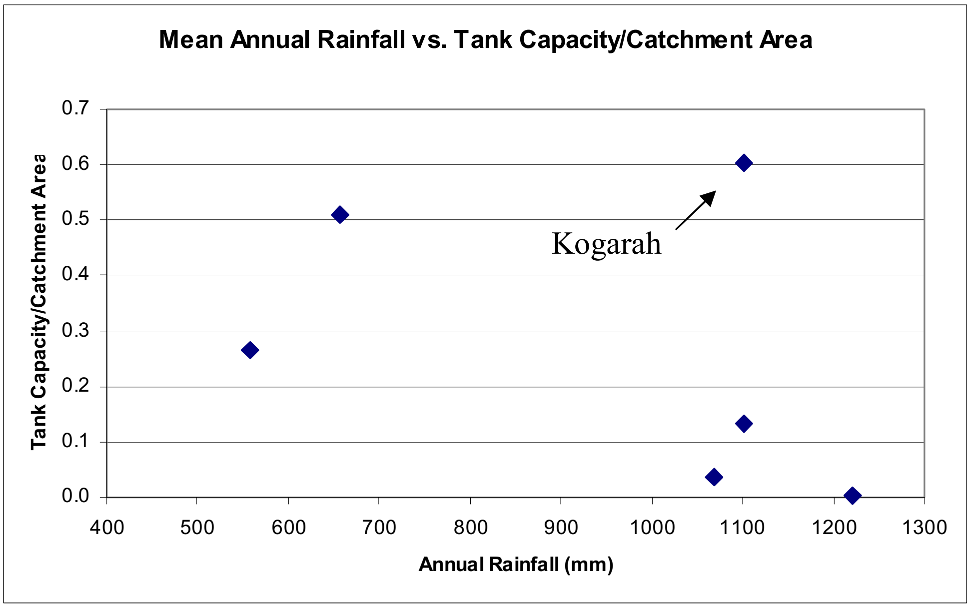


Figure C.22 (b) Mean Annual Rainfall vs. Tank Capacity / Catchment Area

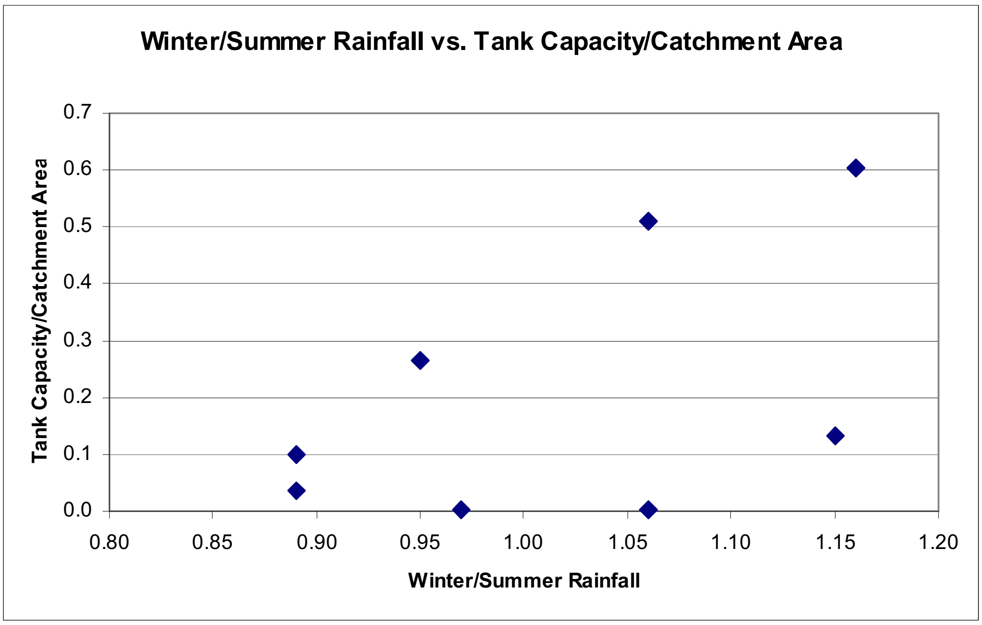


Figure C.22 (c)Winter/Summer Rainfall vs. Tank Capacity / Catchment Area

It can be seen that there is a clear positive correlation between catchment area and storage capacity (Figure C.23). This is not surprising, since the larger the catchment area the more runoff that is available for collection for re-use.

When all study sites are considered there is no apparent pattern between Winter : Summer rainfall ratio and storage capacity evident (Figure C.24). However, when only the smaller catchments (i.e. <5ha and 5-200 ha) are considered, a positive correlation is apparent (Figure C.24). At these sites the storage method employed is for storage for re-use only i.e. no other benefits such as habitat provision, aesthetic appreciation etc. Multi-functionality therefore has an importance influence on the design storage capacity.

There is a clear positive correlation between mean annual runoff and storage capacity (Figure C.25). Bowies Flat does not fit the trend, however this scheme was initially designed only to control runoff pollution. Re-use for irrigation purposes was added in as an afterthought.

It must be noted that mean annual runoff was estimated. It was not possible to obtain actual impervious area figures so land use type and other information was used to estimate imperviousness.

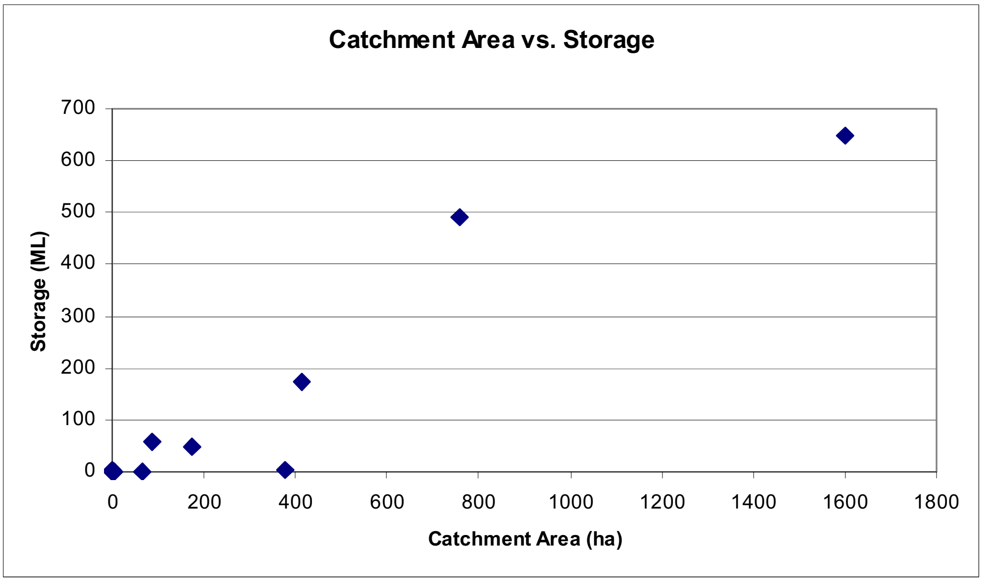
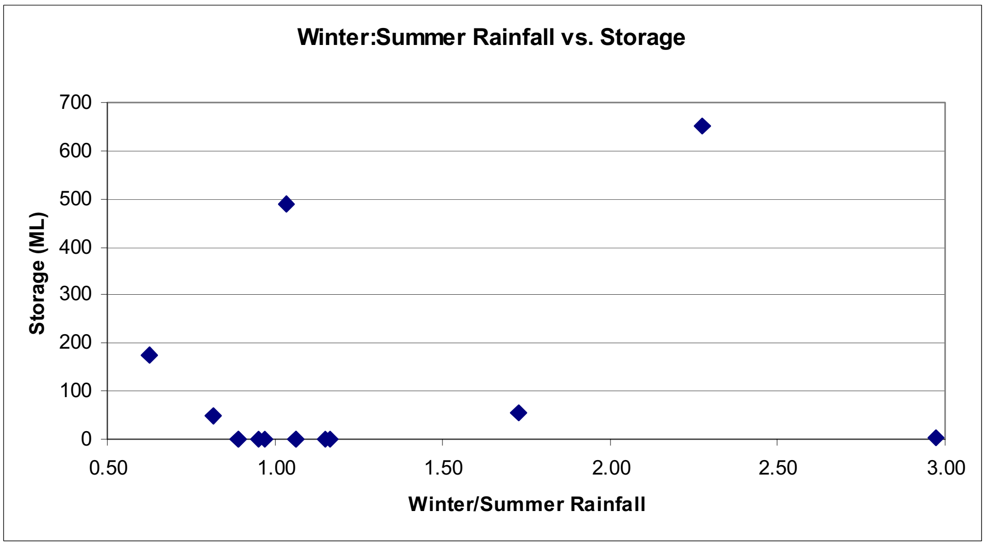


Figure C.23 Catchment Area vs. Storage Capacity



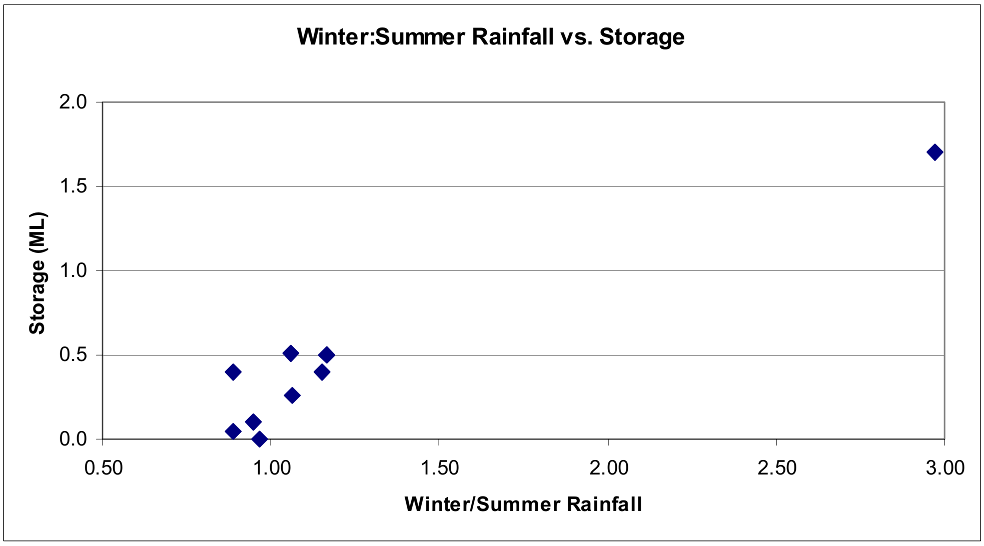


Figure C.24 Relationship between Winter:summer Rainfall Ratio and Storage Capacity

It follows that, as rainfall increases, the storage/rainfall ratio should decrease, since less provision is needed. Figure C.25 reveals a general decrease in storage/rainfall ratio as rainfall increases.

For large surface storage systems, such as ponds, urban lakes, or wetlands, an attempt was made to find information on the ratio of their total volume and storage capacity, as well as the designed variations in their water levels. These are important design features; the ratio is important for water quality in the store (if majority of the water is drawn from the system, water quality will deteriorate dramatically), while the level variation is important for aesthetics and safety of the system.

Almost no data was gathered on total volume/storage capacity and the maximum level variations. The only relevant finding was that at Homebush Bay the brickpit storage was drawn down to 55% in summer 2002 resulting in high nutrient levels in the store.

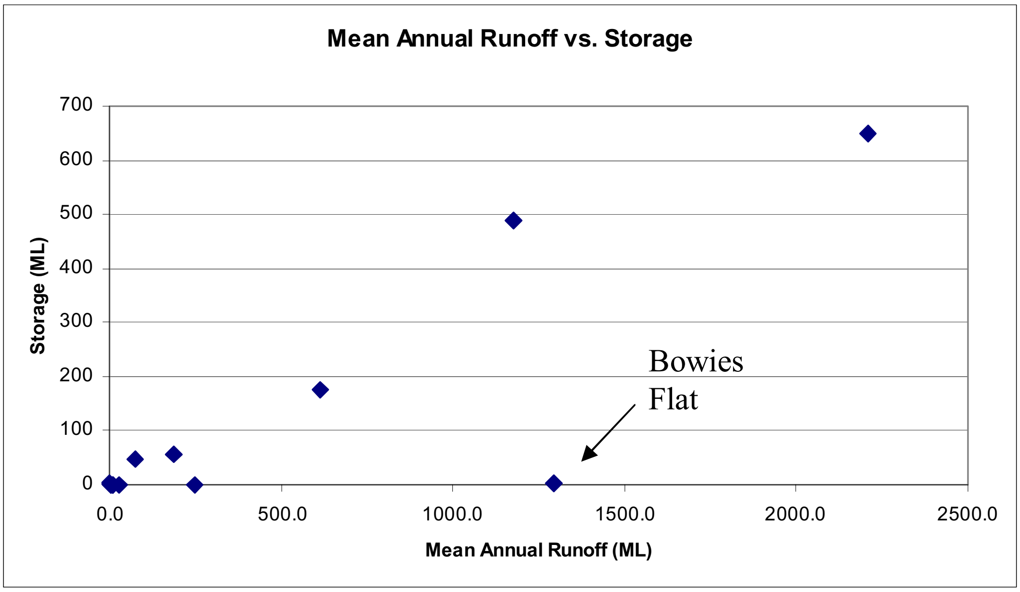


Figure C.25 Relationship between Mean Annual Runoff and Storage Capacity

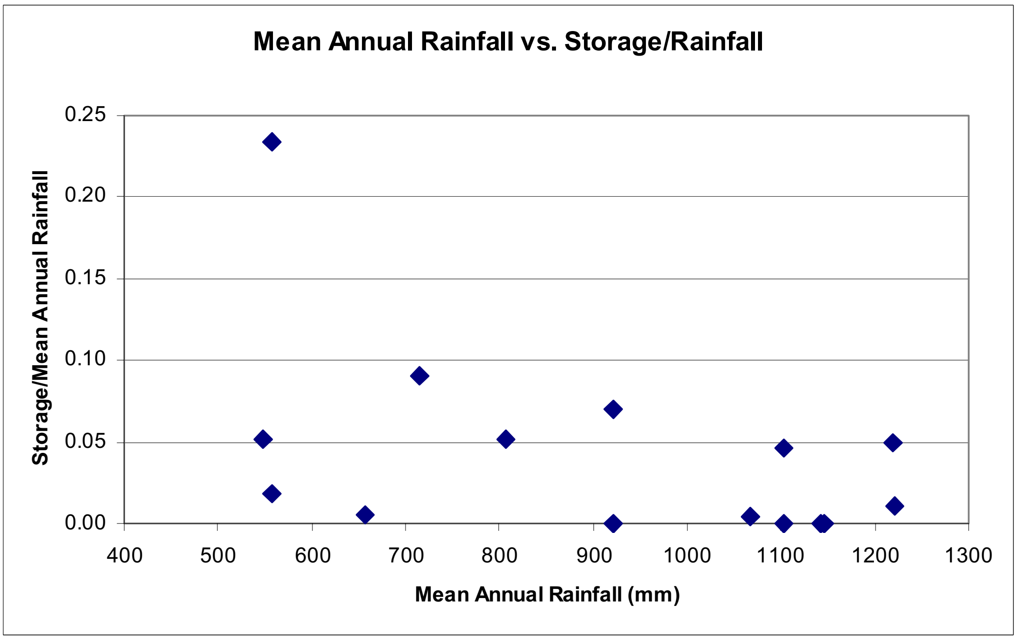


Figure C.26 Relationship between Storage : Rainfall and Mean Annual Rainfall

CENTRE OFFICE

CRC for Catchment Hydrology
Department of Civil Engineering
Building 60
Monash University
Victoria 3800
Australia

Tel +61 3 9905 2704
Fax +61 3 9905 5033
email crcch@eng.monash.edu.au
www.catchment.crc.org.au

The Cooperative Research Centre for Catchment Hydrology is a cooperative venture formed under the Australian Government's CRC Programme between:

- Brisbane City Council
- Bureau of Meteorology
- CSIRO Land and Water
- Department of Infrastructure, Planning and Natural Resources, NSW
- Department of Sustainability and Environment, Vic
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ASSOCIATE:

- Water Corporation of Western Australia

RESEARCH AFFILIATES:

- Australian National University
- National Institute of Water and Atmospheric Research, New Zealand
- Sustainable Water Resources Research Center, Republic of Korea
- University of New South Wales

INDUSTRY AFFILIATES:

- Earth Tech
- Ecological Engineering
- Sinclair Knight Merz
- WBM

Established and supported under the Australian Government's Cooperative Research Centre Program