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## **Sustainable subdivisions: Review of technologies for integrated water services**



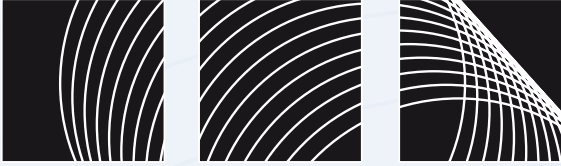
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**CRC** Construction Innovation  
B U I L D I N G   O U R   F U T U R E

## **Sustainable subdivisions: Review of technologies for integrated water services**

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Clare Diaper, Grace Tjandraatmadja  
and Steven Kenway

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# Contents

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<i>Introduction</i> . . . . .	<i>1</i>
<i>Residential water use</i> . . . . .	<i>2</i>
<i>SEQ — Current strategies and initiatives</i> . . . . .	<i>4</i>
<i>Factors affecting technology selection</i> . . . . .	<i>4</i>
Climate . . . . .	4
Topography . . . . .	4
Lot size and density . . . . .	4
Occupancy . . . . .	5
Socio-economics and regulatory environment . . . . .	5
Implementation and management strategy . . . . .	5
Technology assessment . . . . .	5
<i>Available technologies and case studies</i> . . . . .	<i>6</i>
Rainwater . . . . .	8
Stormwater . . . . .	11
Greywater . . . . .	12
Wastewater . . . . .	14
<i>Summary, recommendations and research needs</i> . . . . .	<i>16</i>
Summary . . . . .	16
Recommendations . . . . .	17
Suggested research needs . . . . .	17
<i>References</i> . . . . .	<i>19</i>



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Without the financial and collaborative efforts bringing together industry, government and applied researchers, this valuable report could not have been successfully delivered to our industry.

### Project partners

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Industry



Government



Research



**Queensland** Government  
Department of Public Works

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## Abbreviations used in this review

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ASR	aquifer storage and recovery
BaCC	Bayside City Council, Melbourne
BCC	Brisbane City Council
CH2	Council House 2
GCCC	Gold Coast City Council
IUWM	Integrated Urban Water Management
SEQ	South East Queensland
SEW	South East Water, Melbourne
WSAA	Water Services Association of Australia
WSUD	Water Sensitive Urban Design

## About the Cooperative Research Centre for *Construction Innovation*

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The CRC for *Construction Innovation* is a national research, development and implementation centre focused on the needs of the property, design, construction and facility management sectors. Established in 2001 and headquartered at Queensland University of Technology as an unincorporated joint venture under the Australian Government's Cooperative Research Program, *Construction Innovation* is developing key technologies, tools and management systems to improve the effectiveness of the construction industry. *Construction Innovation* is a seven-year project funded by a Commonwealth grant, and industry, research and other government support. More than 300 individuals and an alliance of 21 leading partner organisations are involved in and support the activities of this CRC.

There are three research areas:

Program A — Business and Industry Development

Program B — Sustainable Built Assets

Program C — Delivery and Management of Built Assets.

Underpinning these research programs is an Information Communication Technology (ICT) Platform.

Each project involves at least two industry partners and two research partners to ensure that collaboration and industry focus is optimised throughout the research and implementation phases. The complementary blend of industry partners ensures a real-life environment whereby research can be easily tested and results quickly disseminated.





## Introduction

Integrated Urban Water Management (IUWM) and Water Sensitive Urban Design (WSUD) are two sets of principles often applied in designing and managing water services in urban areas. The purpose of this report is to discuss IUWM technologies available at the household through to subdivisional level, as well as identify research gaps associated with these technologies and their adoption.

IUWM addresses drinking water, wastewater and stormwater systems while considering the whole water cycle including groundwater, surface water and water vapour. IUWM considers the economic, social and environmental benefits and issues over the life cycle of the water-servicing option. The incorporation of these three dimensions has been found to facilitate more sustainable water servicing.

WSUD was originally meant to encompass all water cycle issues; however, the design focus has been primarily on land use, topography and planning dimensions and the concept now mainly considers stormwater flow and quality. Consequently WSUD can be described as a subset of IUWM. Both IUWM and WSUD incorporate sustainability as they incorporate economic, social and environmental dimensions.

The fundamental objectives of IUWM are to reduce the need to abstract water from the environment and maintain environmental flows, as well as reduce discharges of contaminant to the environment. These objectives are combined with economic, social and other environmental objectives to provide more sustainable options for water servicing.

This review discusses technologies available at the household to suburban level which contribute to IUWM in the form of physical systems, as well as a range of water, wastewater and stormwater management technologies which offer alternative approaches to existing water services. The options are suitable for household, cluster and subdivisional scales and are all possible technologies that can be used when developing IUWM strategies.

In addition to technologies, there are many other options available, such as regulation, financial incentives, education campaigns and participatory approaches. These are not assessed in this report, but were identified as complementary options to the available technologies and were often influential in the adoption of technologies. Additionally, this review does not cover all aspects of the process of developing IUWM options, but focuses on technology options that are currently available and the identification of barriers and issues associated with their implementation.

The content of this publication combines a literature

review of existing alternative technologies in Australia and an investigation of eight case studies to provide a qualitative assessment of the barriers and issues associated with technology implementation. It also contains the condensed findings of a research report (Diaper, Tjandraatmadja & Kenway 2006) which provides detailed information on case studies and background literature.

The technologies presented are applicable across Australia, but the focus is on South East Queensland (SEQ) reflecting the partners represented in the CRC for *Construction Innovation* for this project. Most data presented in this report covers Brisbane City Council (BCC) and the Gold Coast City Council (GCCC) regions as information was readily available for these areas. SEQ encompasses many other areas and local government jurisdictions, from Noosa in the north through to the NSW border and westwards to Toowoomba. This area is currently under severe water stress.

The first section of this publication provides a review of the current and historical water usage patterns around Australia, and details strategies and issues particularly relevant to SEQ.

Factors that may influence the selection of alternative water-servicing approaches are discussed and the basics of option assessment detailed. Technologies appropriate for different scales of application are then provided, categorised by the water source:

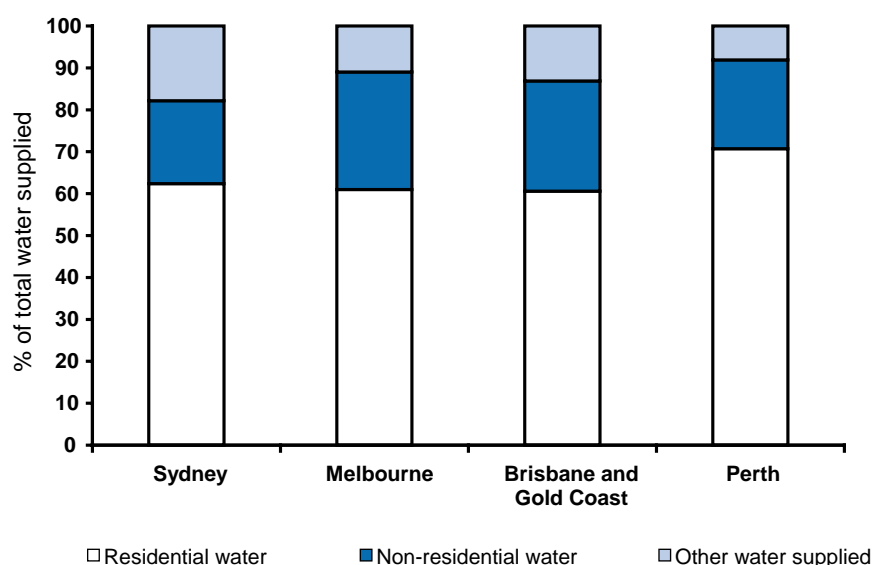
- rainwater – water collected from roofs
- stormwater – water collected from roofs, roads, pavements and open space
- wastewater – water that has been used
- blackwater – wastewater from toilet flushing
- greywater – wastewater from showers, baths, laundry and kitchen.

The benefits of, and issues concerning, the implementation of these technical solutions in an integrated water system are presented using case-study sites. A summary table presents the main outcomes of case studies and the literature review, and outlines potential future projects for understanding and mitigating the barriers to implementation.

## Residential water use

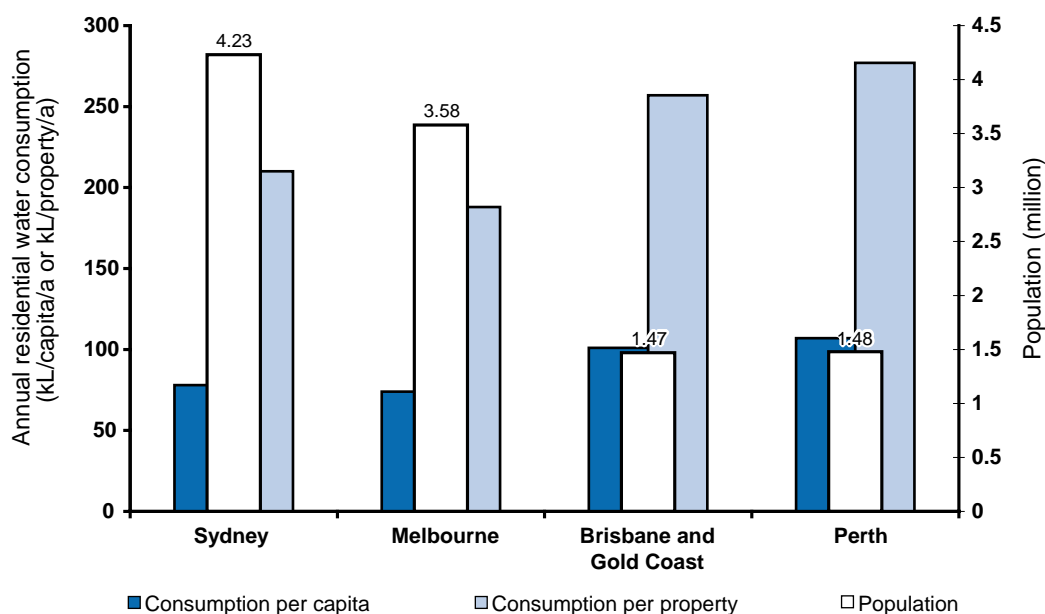
Water is a major national and local issue as much of the country experiences an extended drought. In January 2007, SEQ remains influenced by the longest recorded drought in Australian history (Natural Resources and Water 2006) and most other cities are similarly affected. Climate change has affected all aspects of the water cycle and it challenges current water-management practices and policy. In addition, predicted population growth and increased urban housing densities also impact on the water cycle and are important factors in considering water management into the future.

Residential water use comprised a substantial component of total urban water use in 2004–2005. Figure 1 shows that residential use accounted for around 60% of most Australian capital cities' total mains-supplied water; in Perth, it accounted for 70%. In SEQ, 54% of the population lived in BCC and GCCC regions in 2004, hence a combined usage is used to improve comparability with other major urban centres. Non-residential water, which is primarily commercial and industrial water use, constitutes around 20–30%. Around 10–15% of water is supplied or used for other purposes, including water losses, fire-fighting and system flushing (WSAA 2005).



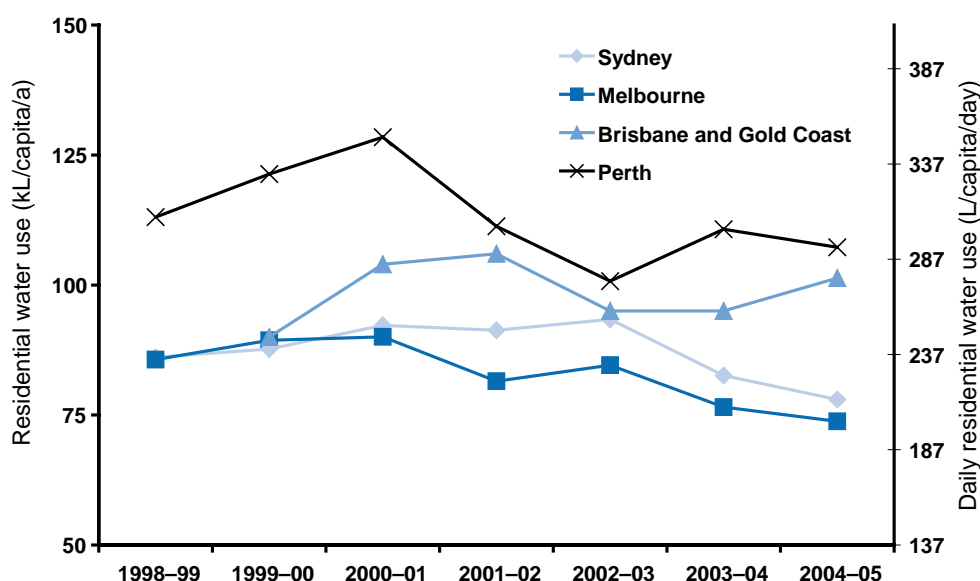
**Figure 1** Usage of mains water in major Australian cities, 2004–2005. (Source: WSAA 2005)

Figure 2 shows residential water consumption and population for major Australian cities. Annual consumption per capita and per dwelling in BCC and GCCC and Perth are high when compared with Sydney and Melbourne.



**Figure 2** Residential water consumption and population for major Australian cities (note: Brisbane and the Gold Coast data are averages for these two closely located areas of SEQ). (Source: WSAA 2005)

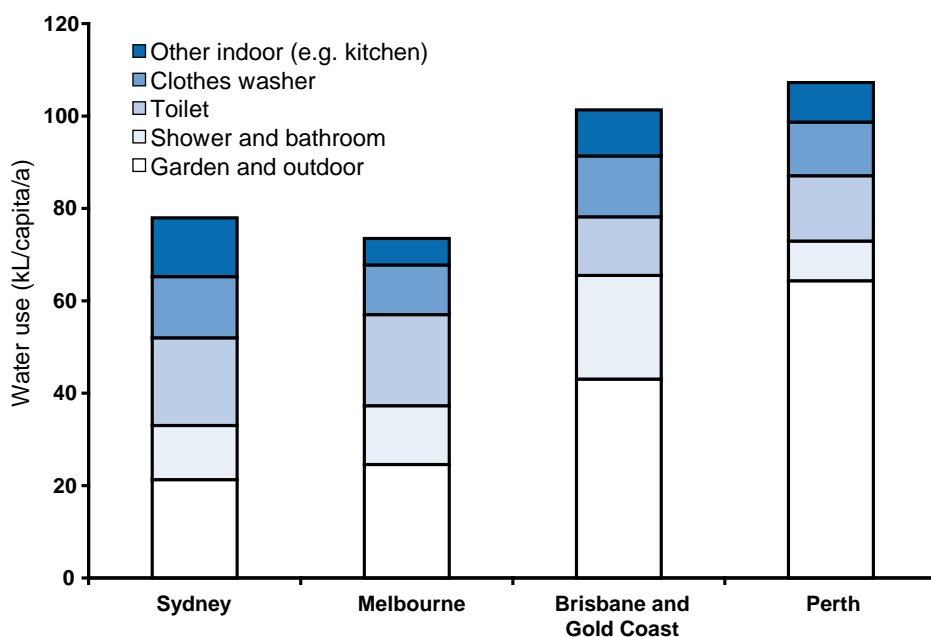
Figure 3 shows residential per-capita water use between 1999 and 2005 in major Australian urban centres. The average of BCC and GCCC data shows no reduction in usage compared to other cities over the six-year period. Water usage trends can be influenced by many factors, including climate, water restrictions and water use and efficiency policies. Separation of the influence of these factors is complex and has not been attempted in this study.



**Figure 3** Annual per-capita residential water usage for major Australian cities (note: no consumption data for Gold Coast was available for 1998–1999, hence that year was not included in the graph). (Source: WSAA 2005)

The four urban centres in Figure 3 are predicted to account for over 90% of Australia's population growth to 2026 (WSAA 2005). In Queensland, the *SEQ Regional Plan* (SEQ Office of Urban Management 2005) predicts medium-range population growth from 2.7 million in 2006 to 3.7 million in 2026. At this rate of annual growth, 20 000 new residences will be required per year in SEQ. The *SEQ Regional Plan* recommends 40% of new dwellings to 2016 be infill or redevelopment. This percentage figure is likely to increase if the number of greenfield sites becoming available does not keep pace with development.

Figure 4 shows the split of residential end uses of mains water on a per-capita basis for the major urban centres in Australia. This data has been compiled from water usage data published by the Water Services Association of Australia (2005) and public documents produced by water utilities regarding the approximate breakdown of water use. The figure suggests substantial variation in per-capita water use across Australian cities; however, further analysis would be necessary to validate this. Similar — and at times even higher — variation can occur within cities and it is important for developments in any particular location to have a good understanding of the factors which influence use.



**Figure 4** Household water uses for major Australian cities. (Source: WSAA 2005, Sydney Water 2006, BCC 2004)

## SEQ — Current strategies and initiatives

Strategies and initiatives in place to achieve reductions in water use in SEQ include:

- mandatory water restrictions on outdoor water use
- WSUD, rainwater tank rebates, and retrofitting (including redesign and re-engineering) incentives
- requirements for water recycling and efficient appliances in new developments
- water recycling targets
- 'fit-for-purpose' strategies for major industrial and commercial users
- progressive upgrades of capacity in wastewater treatment facilities.

These approaches also support the *SEQ Regional Water Supply Strategy* which sets water consumption targets of 270L/capita/day by 2010 and 230L/capita/day by 2020 (Department of Natural Resources and Mines 2006), which are reductions from the 2004 regional average of 300L/capita/day (Australian Water Association 2005). The targets should be readily achievable in Brisbane and the Gold Coast where residential use has been less than 270L/capita/day for most of the previous five years. However, other SEQ areas may find these targets harder to achieve if, as the Australian Water Association data suggests, some have much higher water consumption; for example, residential use in Beaudesert, Caloundra, Cooloola and Noosa at 370L/capita/day.

In SEQ, the installation of greywater systems has recently been accepted by the State Government, with final approval still resting with local councils. System type and management are important factors to consider, as some uncertainty exists regarding the potential impacts of greywater on soils and runoff water quality.

Whilst there has been national coverage of stormwater use, the Stormwater Industry Association Queensland has expressed concern that the SEQ Regional Plan did not highlight the resource value of stormwater (Stormwater Industry Association Queensland 2006).

The Message from the Minister in the *Towards Sustainable Housing in Queensland* Discussion Paper (Department of Local Government, Planning, Sport and Recreation 2004) suggests the use of water efficient appliances, rainwater tanks and pressure reduction devices as potential future options. The introduction of new water-saving measures followed a community consultation process of the discussion paper. New measures include the promotion of greywater and rainwater systems as well as various demand management approaches. These are being implemented

through the Standard Building Amendment Regulation (No. 1) 2006 which references Rainwater Tanks (Part 25) and Sustainable Buildings (Part 29) of the Queensland Development Code.

Some local governments in SEQ have a policy that all new urban developments reflect WSUD principles by 2010 (e.g. Brisbane City Council 2005b). This sound initiative, however, does not specify household water consumption targets to be achieved by new developments.

## Factors affecting technology selection

This section describes some of the key factors influencing the selection of alternative water-servicing approaches in residential subdivisions. All these factors influence appropriate applications of given technologies and the viability of potential options. A summary of assessment techniques is also included.

### Climate

Local climate influences selection of approaches to water servicing. While average annual rainfall is a critical indicator of available water in a new or existing subdivision, other factors must also be considered, including the variation in annual, monthly and daily rainfall and evaporation rates, and the climate's influence on water use, especially for irrigation.

### Topography

Topography can dictate plot and infrastructure layout, with graded slopes being the more desirable terrain. Steeper slopes impose more constraints on style and form of construction.

Steeper slopes lead to greater surface flows and loads which can increase sewage pumping and costs. On the other hand, slope can be exploited to allow gravity to assist in collection and supply of natural water or wastewater flows.

### Lot size and density

For most developments, lot size is strongly influenced by the financial viability of the development; however, changing demographics, dwelling types, consumer expectations and affordability are also influential. Lot size affects selection of water-servicing strategies. For example:

- A large irrigation area is required to distribute and absorb treated wastewater for many on-site wastewater treatments.
- Rainwater tanks and stormwater collection systems may need large areas to capture and store water volumes required for reliable supply.

Lot size and density also affect the capacity for large-scale management of stormwater and wastewater in wet months sufficient to cover supply in dry periods.



### Occupancy

Household occupancy patterns influence the volumes of potable water consumed and wastewater produced. Key factors when selecting water-servicing options are:

- Per-capita mains water consumption and wastewater generation decrease with increasing occupancy levels.
- Trends are for lower occupancy per dwelling and higher dwelling density per land area. Average household size in SEQ of 2.6 persons in 2001 is declining to estimates of 2.45 by 2011, and 2.29 by 2026 (SEQ Office of Urban Management 2005).

### Socio-economics and regulatory environment

Other factors which can influence the adoption of particular technologies include socio-economic and regulatory influences. For example, the perceived benefits of particular technologies, the direct costs and ongoing costs relative to centrally supplied water, the level of government subsidies and legislative ease of implementation, can all affect technology uptake.

### Implementation and management strategy

Management strategies adopted influence the probability of successful implementation of more sustainable water services. Currently, stormwater, wastewater and mains water supply are largely separately planned. This acts as a barrier to implementing integrated water services (Mitchell 2004). Mitchell found successful projects often involve a high level of public involvement and strong partnerships, alliances or project champions providing impetus to see the project through to completion. Hence, implementation of alternative water services requires attention to existing, as well as new, management strategies.

### Technology assessment

There are a wide range of alternative water-servicing technologies available, including systems for the collection and use of rainwater and stormwater, and the treatment and use of greywater and wastewater. The task of assessing which type of technology is appropriate is a complex task and is not the focus of this report. The suitability of any particular technology will be influenced by a number of factors including the scale of application (e.g. from household to subdivisional level) as well as the performance required and operational and maintenance needs. This report focuses on the benefits of the technology in terms of the urban water cycle and on operational, practical and associated issues associated with implementation.

There are a number of methods which can be used to give a thorough and detailed assessment of the different technologies and aid in technology selection. Tools that have been used previously for assessment of options include:

- water balance analysis
- contaminant balance analysis
- life cycle costing (LCC)
- life cycle assessment (LCA) covering energy, materials and emissions
- risk assessment and management.

Water and contaminant balance assessment of technologies should consider impacts on the entire urban water cycle, particularly with regard to water flows and quality. This sort of assessment can evaluate the ability of a technology to meet IUWM objectives, such as reduction in mains water usage or return of surface flows to pre-development conditions.

LCC is a process to determine the sum of all the financial costs associated with a technology, including acquisition, installation, operation, maintenance, refurbishment and disposal.

LCA is an objective process to evaluate the environmental burdens associated with a product, process or activity from 'cradle to grave'. This is done by identifying energy and materials used and wastes released to the environment.

There are many risk assessment and management processes which are applied to urban water systems. The assessment of health, environmental, social, institutional and political risks should also be included in an IUWM process.



## Available technologies and case studies

The literature reviewed (Radcliffe 2004; Australian Water Conservation and Reuse Research Program 2004; Landcom 2006; Diaper et al. 2006) and the case studies examined for this project cover a large range of urban residential and commercial development water-management options and include both new build and retrofit case-study sites. The eight case-study sites were:

- Pimpama Coomera — SEQ, new build, residential subdivision
- Payne Road — SEQ, new build, small residential subdivision
- The Currumbin Ecovillage — SEQ, new build, residential subdivision
- CH2 — Melbourne, new build, offices
- South East Water (SEW) and Bayside City Council (BaCC) — Melbourne, retrofit, residential
- Atherton Gardens — Melbourne, retrofit, high density housing
- Sustainable House — New South Wales, retrofit, single residential
- 60L — Melbourne, retrofit, offices

Some sites have an overall sustainability theme encompassing energy, material and operating costs, while others focus only on water services (Table 1). Eight case-study sites were selected for further study from a full list of case-study sites (Diaper et al. 2006), with selection based on feedback from project stakeholders, BCC, Brookwater and Queensland Government departments and the following criteria:

- appropriate to individual dwelling through to complete subdivisions
- applicable to retrofitting or re-engineering of existing housing stock
- demonstrates alternative water-servicing technologies
- demonstrates transitioning of existing infrastructure
- provides detail of financial arrangements for project implementation
- implemented in social housing stock
- implemented in inner urban areas or commercial premises.

Some sites outside of SEQ were included to demonstrate valuable lessons and approaches applicable to SEQ.

The following section describes different technologies for rainwater, stormwater, greywater and wastewater collection, treatment and use. The primary benefits to the urban water cycle and the potential issues and barriers to implementation of each technology type are described, incorporating information gained from relevant case studies. A review of strategies and technologies implemented in SEQ is also provided.



**Table 1** *Overview of case-study sites*

Case-study site	Raintanks	Stormwater	Greywater	Wastewater	Status and research report reference
Pimpama Coomera	Household	Cluster WSUD, ponds for irrigation	Discharged with wastewater	Subdivision reduced infiltration gravity sewers and regional wastewater treatment to Class A and recycling via third pipe for non-potable use	Under development Section 4.1
Payne Road	Household and communal	Communal collection and WSUD for run-off treatment	Household for garden irrigation	Communal collection and timed discharge into sewer	Under development Section 4.2
The Currumbin Ecovillage	Household	WSUD	Discharged with wastewater	Mix of cluster and household	Under development Section 4.3
CH2	Rooftop collection for building use	Not applicable	Discharged with wastewater	On-site treatment and sewer mining for non-potable use	Completed Section 4.4
SEW and BaCC	Household	Current system	Current system	Current system	Underway Section 4.5
Atherton Gardens	Rooftop in one building collection for garden irrigation	WSUD treatment prior to discharge	Communal laundry greywater treatment for use in garden irrigation	Discharged to sewer	Completed Section 4.6
Sustainable House	Household	Household On-site mini-wetland	Discharged with wastewater	Household on-site treatment for non-potable use	Completed Section 4.7
60L	Communal	Not applicable	Discharged with wastewater	Communal collection and on-site treatment	Completed Section 4.8



## Rainwater

The Australian Bureau of Statistics (2005) reports that 17% of homes have rainwater tanks installed for all household water end uses. However, most of these tanks are installed in rural areas. In urban areas, the aesthetic form and physical size of a tank are critical factors for selection, rather than capacity to provide reliable supply. The many designs in the market range in size, shape, fabrication material, collection system and treatment technology to be appropriate for various lot sizes, dwelling types and end-user needs.

Rainwater systems involve collection, storage, treatment and distribution technologies. The three main types of collection systems are:

- dry systems (the most common type) — all pipes are above ground
- wet systems — collection pipes are buried to reduce aesthetic impact and pipes contain a residual volume of water
- siphonic systems — the collection system is designed to maximise pipe flow rates using siphonic full bore flow.

Collection systems employ gutter guards, first-flush diverters and inlet filters to reduce ingress of contaminants such as leaves, animal faecal matter and airborne pollutants. Gardner et al. (2004) found first-flush devices reduced rainwater tank contaminant levels at the cost of collection efficiency. Although the use of first-flush devices is frequently advocated by manufacturers and in guidance notes, statistically relevant data showing their relative contaminant-removal efficiency or improvement in stored water quality is lacking.

Distribution of rainwater is usually via a pump, although in certain situations, end uses can be gravity fed. If mains water is used as a back-up supply, it is not recommended to top up the tank, as the mains water loses potential energy when supplied to the tank and then has to be repumped to required end uses (Gardner et al. 2006). An automatic diverter device, in which mains water pressure is used when mains water back-up is required, is more efficient in terms of energy use.

Treatment of rainwater depends on the intended end use and three main types are used: filtration, thermal disinfection and ultraviolet (UV) treatment. Filtration provides a barrier to micro-organisms and both micro- and ultra-filtration are used. Thermal disinfection using the hot water service is currently being investigated, and results have shown that bacteria do die off at temperatures relevant to domestic hot water systems. None of the treatment processes provide residual disinfection, and all have associated maintenance and replacement requirements.

Householder awareness of what is in their rainwater tank is important so that usage can be adjusted accordingly and also so they know when mains water back-up is being used. A number of innovative float systems are available to monitor tank water level, and some can be retrofitted to existing tanks.

Mains water savings due to the installation of raintanks will be dependent primarily on the volume and timing of runoff into and out of the raintank. This means that factors affecting the savings will include: climate, collection area, tank size, water usage, irrigation requirements and end uses of the rainwater.



*Rainwater collection system — 60L*



Modelling studies have shown that, dependent on rainfall patterns, improved water savings can be achieved when rainwater is supplied to non-seasonal uses, such as toilet, laundry and bathroom, rather than seasonal uses such as irrigation (Institute of Sustainable Water Resources 2006). Other studies have shown that additional savings are possible for higher density development for non-seasonal end uses (Gray 2004). Additional benefits of rainwater tank installation are the reduced energy requirement compared to large-scale water resource options such as desalination, reduced stormwater flows and, if designed accordingly, reduced mains water peak flows (Marsden Jacob Associates 2007).

Individual household raintanks are an integral part of rural Australia, but there are few studies which thoroughly assess the effectiveness and performance of these systems in urban areas. Two case studies where this is being done are the Sustainable House in Sydney (Diaper et al. 2006, Section 4.3) and Payne Road in Brisbane (Gardner et al. 2006; Diaper et al. 2006, Section 4.6). At the Sustainable House, rainwater is collected from the roof via enclosed gutters for removal of leaves, a sloping mesh trap at the downpipe, and a first-flush diverter. There is a sump for sediment removal before the 9.5kL concrete raintank. Rainwater is used as drinking water, in the shower and as cold water for the washing machine, with an overflow into a mini-wetland.

**Key learning** *Established buildings and sites impose limitations. For example, the roof area imposes limitations on the amount of water which can be collected.*

At Payne Road, 18kL to 22kL rainwater tanks are installed for each household. The collected water is treated by activated carbon filters (1µm) and UV before use in all household applications. Excess rainwater is diverted to communal tanks located at the bottom of the development. These communal tanks are used to provide fire-fighting flows.

**Key learning** *Mains water top-up to a rainwater tank requires repumping of mains water supply to provide household demands.*

Two larger-scale developments with raintanks installed at individual dwellings are Pimpama Coomera (Diaper et al. 2006, Section 4.1) and the Currumbin Ecovillage (Diaper et al. 2006, Section 4.7). In all Pimpama Coomera subdivisions, 3kL and 5kL rainwater tanks are fitted to all households for use in laundries, bathrooms and hot water systems. At the Currumbin Ecovillage, a 110ha subdivision currently under development, rainwater collection will be at household level with a range of tank sizes depending on house size. The tanks will supply all uses in the home, including drinking, as well as a 5kL firefighting requirement. The treatment of rainwater prior to use will be at the discretion of the householder. All dwellings will have 3A- or 4A-rated appliances. Restrictor valves fitted on rainwater supply to the house provide feedback to inform occupants of low water levels.

**Key learning** *Calculation of tank sizing is dependent on end uses.*



**Rainwater collection system — Payne Road**

Case-study sites where rainwater is collected from a number of roofs for communal use are Payne Road (Gardner et al. 2006), Atherton Gardens, CH2 and 60L. At Payne Road, an urban residential development, a combination of household tanks and communal tanks is used to satisfy both domestic water demands and firefighting flows. Although there are distinct maintenance and operational responsibilities for the householder at single-house scale, at cluster scale the boundaries for these responsibilities are not so clearly defined, and this may be an issue in the successful implementation of rainwater systems. In the case of CH2 and 60L, the management of the building infrastructure and the water resource is undertaken by a central body.

**Key learning** *Different scales of collection can be incorporated into one development.*

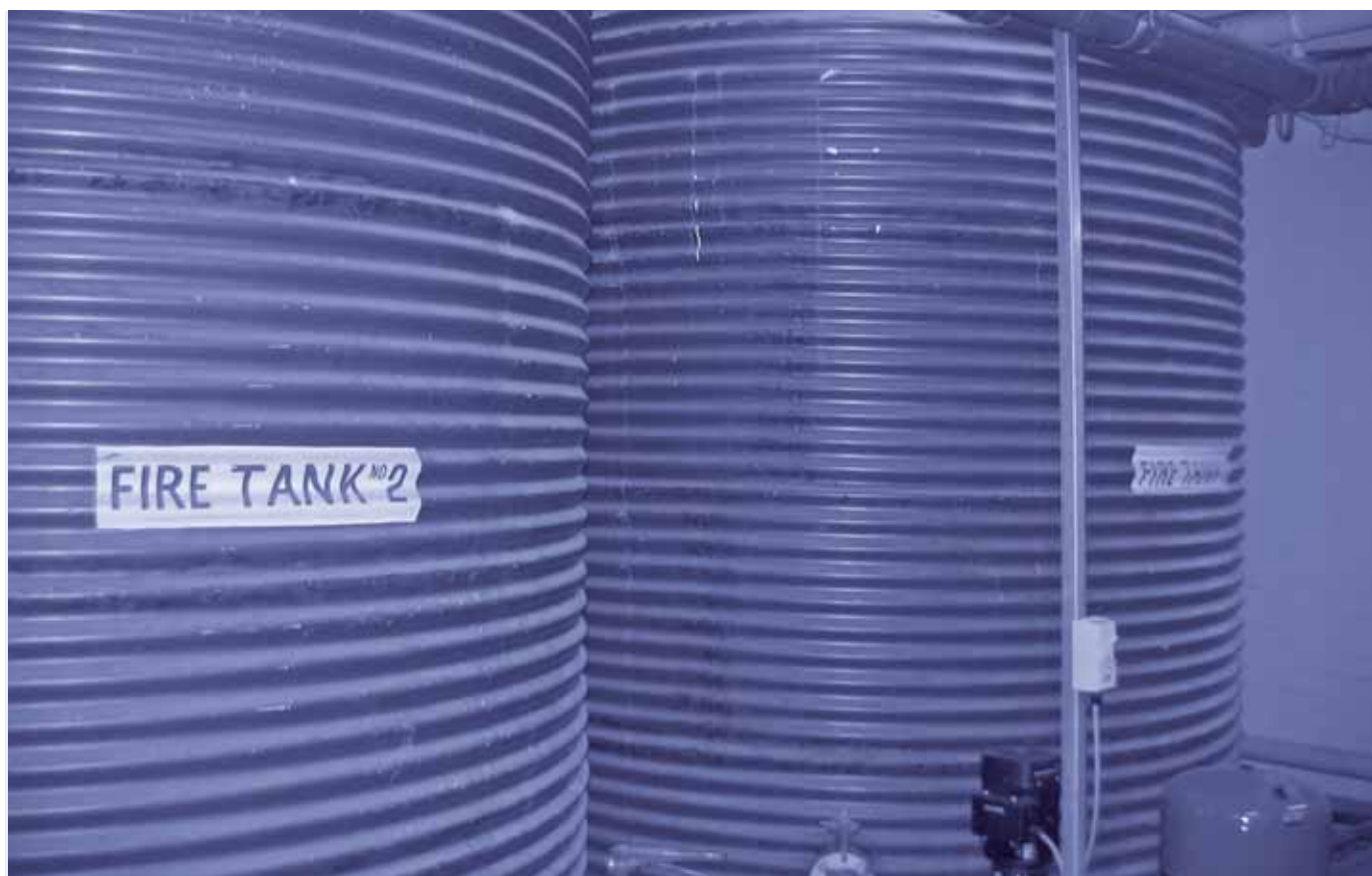
In the SEW and BaCC study, 60% of respondents were prepared to use rainwater for showers, laundry, toilet flushing, car washing and garden watering, but only 5% had installed systems, stating ‘too expensive’ or ‘too difficult to organise’ as reasons.

**Key learning** *The costs and practicalities of retrofitting rainwater tanks need to be considered.*

### **Key issues**

From the literature review and case-study analysis, a number of key issues associated with the implementation of rainwater tanks are:

- Water quantity and quality need to be considered in the design of rainwater collection, storage and distribution systems.
- Water savings and reliability of supply depend on climate, storage volume, collection area and end uses.
- The design of back-up supply should consider energy balance and controls to ensure householder awareness of back-up supply use.
- Additional energy requirements for raintanks will depend on the amount of pumping and treatment methods.
- Maintenance and operational responsibilities of cluster systems are not well defined.



**Rainwater collection system — Atherton Gardens**

## Stormwater

Stormwater is the surface runoff from all pervious and impervious areas and will have a different quality compared to rainwater. Stormwater is collected via drainage systems and generally diverted to stormwater mains that are maintained by municipal councils. There are few stormwater technologies specifically for household-scale application, except permeable paving and the reduction of impervious paved areas to reduce stormwater flows.

Recently, use of stormwater as a large-scale supply source has gained media attention throughout Australia (Urban Stormwater Initiative Executive Group 2004; State Government of Victoria 2004; Stormwater Industry Association Queensland 2006). Treatment and storage of rainwater and stormwater are most often addressed at subdivisional level, and at this scale a number of approaches apply to collection, treatment, storage and redistribution. An inventory and review of Australian practices in integrated stormwater treatment and harvesting found that stormwater reuse was largely restricted to smaller-scale sites and that treatment is still based on systems designed for environmental protection, not domestic use (Hatt et al. 2004). This is a concerning trend, as the water quality may not be suitable for reuse. Further work is required to develop reliable, robust techniques and technologies to provide water of a quality suitable for drinking water substitution.

Many available technical documents and guidelines provide detailed design guidelines and strategies for implementing stormwater systems for environmental protection (City of Melbourne 2004; Wong 2006; Brisbane City Council 2005a). To make stormwater suitable for use as a substitute for municipal potable water supply, technologies and techniques used need to deliver higher and more consistent levels of treatment. A recent document providing technical guidance for stormwater treatment and harvesting (Institute for Sustainable Water Resources 2006) suggests UV as a preferred disinfection technique, non-seasonal end uses to minimise storage requirements and no requirement for closed storages for minimisation of evaporation. The report also identified stormwater harvesting systems need to be robust and to provide a buffer against quality and quantity variability.

At the scale of groups of houses or subdivisions, rainwater (as opposed to stormwater) collection, storage and treatment tend to be in underground tanks, as space is often limited in urban areas. Sub-surface tanks have the advantages of reducing light penetration, stabilising water temperatures and reducing evaporation losses. However, care is needed in selecting location and design of access to avoid contaminant ingress, while still allowing easy access for maintenance. Innovative designs for sub-surface storage also provide

some stormwater treatment, and systems have been used in single dwellings, residential aged-care facilities, parks and schools (Atlantis Water Management 2007).

A stormwater collection and treatment technique appropriate to the cluster or subdivisional scale which can overcome the storage requirement, is aquifer storage and recovery (ASR). The use of this method is dependent on local geology and accessibility of the aquifer. Examples of test sites for stormwater ASR can be found in South Australia (Dillon et al. 2006) and New South Wales (Argue & Argue 1998), and opportunities have been explored in other states. In addition to the general advantages of stormwater use, ASR also has the benefits of potential reduction in groundwater salinity, reduced storage costs and storage which does not take up land area. ASR can also be used for the storage of wastewater.

The Atherton Gardens high-density residential development in Melbourne, consists of an estate with four high-rise towers. The Department of Housing site has four water systems retrofitted: two stormwater, one greywater and one rainwater collection system. The stormwater systems recover stormwater for passive landscape irrigation and treat it before discharge into the stormwater drain reducing contaminant loads. The greywater system collects laundry greywater and, after coarse filtering, flows to a landscape feature wetland. The rainwater system collects from the roof of one of the towers to be used for garden irrigation. Extensive surveying of the site was required to identify the possibilities and potential design constraints.

**Key learning** *The process of retrofitting technologies requires a large amount of planning and surveying.*

CH2 and 60L are Melbourne office buildings, the former a new build infill and the latter a retrofit of a commercial building (i.e. the facade of the original building was preserved, but the rest of the building was redesigned and reconstructed). At 60L, two large rainwater storage tanks are located inside the building and provide water for toilets and washbasins. The tanks are open to occupants' view and are very much an educational feature of the site. At CH2, water is collected from the roof of the office building in one 20kL tank and used for potable applications. Wastewater from the building is treated and mixed with treated wastewater mined from a sewer pipe and used for cooling towers, irrigation of plants, toilet flushing, Melbourne Council's street-sweeping machines and other external uses. Both sites use traditional cylindrical and rectangular storage tanks for storage of the collected water. In the Atherton



Gardens housing development the water features contribute to improving the amenity of communal areas. Associated benefits, such as greater use by families, larger number of people using the gardens as a throughfare and reduction in the number of vandalism incidents, have been highlighted by the project managers and are currently under study.

**Key learning** *Alternative water-servicing approaches can be an educational feature of a building or a community amenity.*

### Key issues

A number of key issues associated with the implementation of stormwater collection, storage, treatment and use are:

- Robust and reliable methods of treatment need to be developed in order to provide stormwater suitable for mains water substitution.
- Large storage volumes for stormwater may be required when used for seasonal end uses.
- Space limitations in existing urban areas may limit the feasibility of stormwater collection in this application.
- Retrofitting of stormwater systems requires additional planning and surveying compared to greenfield implementation.
- There are currently no legislative guidelines for use of treated stormwater.



**Greywater system — Ecocare diverter**

### Greywater

The main sources of greywater are the bathroom, laundry and kitchen. Most greywater systems are designed to collect and treat greywater from the bathroom and laundry only, as kitchen wastewater usually contains higher concentrations of gross contaminants and fats, oils and greases.

Greywater does offer the advantage over rainwater systems of a continuous supply available during dry periods. The potential water savings associated with greywater treatment and use are well documented and will be primarily dependent on end use (Gardner & Millar 2003; WAWA 1993; Priest et al. 2003; Diaper et al. 2003).

Modelling data suggests that more than a 20% saving can be made with a 1000L tank collecting both bathroom and laundry greywater and supplying both garden uses and toilet flushing (Gray 2004).

The two basic types of greywater system are the direct diversion systems and the collection, treatment, storage and distribution systems which produce higher quality water. Direct diversion systems are available for sub-surface irrigation and toilet flushing, while greywater treatment systems can be used for gardens, toilets and potentially laundries.

Consideration of greywater quality is important in assessing potential uses for different source streams. Greywater can contain:

- human pathogens
- nutrients such as phosphorus and nitrogen
- dissolved salts such as sodium and sulfates
- biodegradable organics.

Greywater components can have detrimental environmental impacts on groundwater and soil structure.

Many greywater recycling systems are available and cost depends on house design, space availability and piping requirements. Systems range from simple filtration and diversion systems to complex treatment trains (Diaper et al. 2006). The different systems provide different greywater qualities, some meeting Victorian and New South Wales guidelines for recycled wastewater. Although most systems are suitable for retrofitting or re-engineering, the need to separate greywater from blackwater may limit application in existing houses built on slabs. The prevalence of Queenslander-style houses in existing housing stock in SEQ makes collection and reuse of individual household wastewater streams more feasible due to ease of access to pipework.

**Key learning** *Housing style can improve the feasibility of greywater use.*



Penetration of household-scale greywater technologies can increase community awareness and understanding of broader water resource issues (Alternative Technology Association, 2005). Also, for single dwellings, greywater use has broad community acceptance. While studies have gauged acceptance of wastewater reuse at larger scales (Po et al. 2003; Po et al. 2005; Hurlimann & McKay 2003, 2004), none reviewed have examined public perceptions of large-scale greywater reuse.

**Key learning** *Household technologies can provide increased community understanding of water resource issues.*

At Payne Road, greywater from individual households is treated via a Biolytix system and the treated effluent is used for sub-surface garden irrigation. Irrigation volumes are controlled by soil moisture sensors and solenoid valves which divert greywater to the sewer if the soil becomes saturated. All unused wastewater is collected to common tanks in the subdivision and discharged to the sewer system at non-peak hours.

**Key learning** *Storage and use of greywater can reduce sewer peak flows.*

Similarly to the finding for raintanks, the SEW and BaCC survey showed a high percentage, 60%, of respondents were prepared to use greywater for toilet flushing, car washing and garden watering, but only around 5% had installed systems.

### Key issues

From the literature review and case-study sites, a number of key issues with the implementation of greywater collection, storage, treatment and use were identified:

- Components of household products found in greywater may affect the environment through soil structural degradation, increased soil pH and poor plant growth.
- There are lengthy approval processes when new techniques or technologies are used and there is no national guideline for greywater system testing.
- Separation of greywater from blackwater may require extensive plumbing alterations, especially in retrofit or re-engineering situations.
- There is a lack of information on garden design and watering requirements when greywater is used for irrigation.
- High-technology treatments may have high embodied and operating energy requirements and the capital costs may be high.
- The maintenance and management of household and multi-dwelling greywater systems needs to be considered.



**Greywater system — Pontos Aquacycle**



**Greywater system — New Water**

## Wastewater

Wastewater is all the used water leaving a dwelling and can be split into greywater (discussed previously) and blackwater, with blackwater carrying toilet wastes. A large proportion of wastewater is water, with only 1–2% of the total mass as organic and inorganic suspended solids. In domestic wastewater, organic matter comprises carbohydrates, fats and proteins, and inorganic matter comprises dirt, grit, salts, metals and other contaminants. Wastewater also contains human faeces, a major source of pathogens in such water.

In Australia, on-site wastewater management is present mostly in unsewered areas to ensure sanitation. On-site wastewater management occurs by either reducing volume of water used for transport of waste or by on-site treatment and reuse of wastewater. Reduction of water volume measures (demand management options) have a direct impact on the wastewater produced and, at single household scale, options for reduced wastewater production include:

- elimination or reduction of water used for solid transport, such as dry toilets and water-saving appliances (e.g. low-flush toilets)
- separation and treatment of solid and liquid fractions, such as urine-separating toilets.

Compared to large-scale wastewater treatment, there are some distinct advantages with treating wastewater at the household scale. The wastewater tends to have a lower level of persistent contaminants and pollutants from stormwater runoff (hydrocarbon residues), and so simpler treatment methods can be employed.

At a household level around Australia, the treatment and reuse of wastewater has been implemented in a number of sites (e.g. Sustainable House). Due to the high faecal micro-organism concentration and thus potential pathogen presence, there is a need to prevent human health risks and environmental contamination. Thus, there are added challenges when considering wastewater use compared to greywater and rainwater. Effluent is reused in non-potable applications including garden irrigation and, after disinfection, for toilet flushing. Sludge is usually removed by a contractor or disposed of to sewer (e.g. CH2).

A potential barrier to implementation of on-site wastewater systems is the minimal information and guidance on system use provided to householders. Research and proof of effectiveness of a system is often the responsibility of the individual interested in setting up the system. Consequently, only committed and determined homeowners have adopted such technology.

Geolink (2005) and Landcom (2004) have reviewed the range of advanced wastewater treatment technologies available for on-site treatment. At the cluster or subdivisional scale, collection systems vary from the use of vacuum and low-pressure sewerage with low-diameter flexible pipes and shallow burial depths, through to 'smart pipes' of flexible material with fused joints and inspection points rather than manholes.

Selection of source water type depends on water balance, end-use application and regulatory requirements. Technologies for wastewater treatment and recycling can be based on biological, chemical and physical processes, or combinations of these. Some are appropriate for both greywater and wastewater treatment. Appropriate scale, end uses, physical footprint, and capital and operating costs also need to be considered (Landcom 2004). Wastewater and greywater can be treated to many different qualities determined by intended uses, such as irrigation of public places or indoor non-potable uses. Generally, effluent for household supply must be treated to a high Class A standard.

At a cluster level, key features of wastewater management are:

- individual household collection
- a shared treatment facility
- management by body corporate, council or householder association
- maintenance conducted via a service contract with the treatment technology provider or operator.

Such systems remove the onus of maintenance from individual householders and allow the governing authority to exert a greater degree of control on upkeep of the infrastructure system. Also, benefits are generally achieved through economies of scale, with treatment facilities shared across multiple dwellings.

In the eight case studies examined, wastewater treatment and use options range from single-house systems at the Sustainable House and Payne Road, through medium-scale cluster options at the Currumbin Ecovillage, CH2 and 60L, to large-scale treatment and dual reticulation of supply of treated wastewater at Pimpama Coomera.

All wastewater at the Sustainable House is collected into a concrete tank to which food scraps are also added. The tank contains three filter beds of sand and geofabric with worms and other organisms. The effluent is disinfected via a solar-powered UV system as it exits the tank and is used for non-potable applications in the house, such as toilet flushing, washing machine hot water and garden irrigation.

At the cluster scale, wastewater at the Currumbin Ecovillage will be collected from the majority of households and treated by an Orenco AdvanTex textile

filter coupled to a Memcor micro-filtration system. Polyethylene pipes are used for all wastewater and water supply transport because the developers did not want to use PVC. The recycled water will be of Class A quality and will be recirculated to the households for toilet flushing, laundry use and garden irrigation.

At 60L and CH2, two different wastewater treatment approaches are used in addition to the rainwater and stormwater systems already mentioned. In 60L, all wastewater from the site is collected to a central point and treated through a biological treatment process coupled to membrane treatment. Effluent from the plant will be used for flushing toilet pans and irrigating a 135m<sup>2</sup> rooftop garden. Excess recycled water will be directed to a water feature in the atrium that contains aquatic plants feeding on residual nutrients, before being discharged to sewer. At CH2, wastewater from the building is collected and supplemented with wastewater extracted from the sewer. This combined stream is treated by a membrane water reuse plant with ultra-filtration and reverse osmosis process stages. The treated blackwater and greywater are used for supply of non-potable water for plant irrigation, cooling, toilet flushing, street washing and open spaces, uses that currently demand 72% of water use. In CH2 and 60L, the minimisation of odour and noise pollution was considered in the selection of the site and design of the treatment plant. The plant in CH2 is located in the sub-basement and the plant at 60L is located at the back of the building. Both original treatment systems in 60L and CH2 were upgraded after the commissioning period, as the original systems were not operating optimally with the wastewater collected. The wastewater was of different strength to conventional domestic wastewater for which the systems were designed, as water use activities in commercial buildings are not the same as residential uses.

**Key learning** *When designing wastewater treatment systems, allow for changes in wastewater flows and concentrations due to increased water efficiency.*

**Key learning** *Consider noise and odour when siting on-site wastewater treatment plant.*

**Key learning** *Allow additional time in the project schedule for verification of innovative wastewater treatment systems.*

The Currumbin Ecovillage and the 60L building are examples of sites where the owners and tenants are required to abide by body corporate rules for management of the alternative water-servicing system.

At a larger scale, Pimpama Coomera is a fast-growing greenfield development area with a mix of residential, commercial and industrial use in a water-constrained region. To allow the development of the region, the local council (Gold Coast City Council), in consultation with other stakeholders, conducted an extensive study of the area and developed a masterplan and strategy for sustainable development in the region. The strategy involves developing an institutional framework that facilitates the implementation and uptake of integrated water-management services. This will be done through revision of council policies, regulations and approval schemes, and the provision of infrastructure, such as wastewater collection and treatment plants, aquifer storage, and a dual-pipe scheme for provision of treated wastewater for toilet flushing and external uses. While the wastewater treatment plant is not yet commissioned, the necessary infrastructure for providing gardens and toilets with recycled water is in place.

### Key issues

A number of key issues were identified with the implementation of wastewater collection, treatment and use. Some of these issues are similar to those observed for greywater systems and are as follows:

- Current wastewater operation, maintenance and management arrangements are not geared for decentralised systems. No current systems are in place to ensure compliance and enforcement of proper maintenance of on-site wastewater systems and current approval processes can be complex.
- Adequate treatment is needed to safeguard residents' health.
- Chemical requirements and embodied and operating energy for treatment technologies need to be considered.
- Changes in wastewater quality and biosolids management need to be considered during the design of wastewater treatment systems.
- The maintenance and management responsibilities of household and multi-dwelling wastewater systems need to be considered.
- Knowledge and understanding of the interactions between the built environment, specific site aspects and the wastewater technology is necessary.



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## Summary, recommendations and research needs

### Summary

Improved planning and management of water in Australia is essential to ensure reliability of water services and to support the continued growth of our cities. Drought, population growth and influences related to climate change are increasingly affecting existing water stocks. At the time of writing, many Australian cities are under water restrictions, with SEQ facing unprecedented regional level 5 restrictions. SEQ is under further pressure because of high per-capita and household water use and a high projected population growth.

Many water issues are being addressed through state and federal government initiatives. However, this review argues that further attention is required at the subdivisional and individual household scale to ensure the most efficient solutions are identified and appropriate technologies are adopted. This review focuses on currently available technologies, while recognising that the economics, social acceptability and impact of planning processes also significantly influence the uptake of any particular technology.

Alternative water-servicing initiatives have been implemented around Australia at scales ranging from single household through clusters to larger subdivisions. Experiences from case studies have helped gain valuable knowledge for future schemes. Water conservation initiatives, such as low water-use appliances, are essential for reducing water consumption. The installation of water-efficient appliances and demand management were common to most case studies. Additional savings can be achieved with measures such as substitution of mains water with water from other sources for non-potable applications.

This review found a wide range of integrated water technologies being used or under development at the household through to sub-divisional scale. While the technologies themselves are relatively well understood, the integration of the technologies and impacts on other systems is less clear. Selecting the most appropriate systems depends on many site-specific factors. To fully reap the benefits of implementing alternative technologies, clear understanding is needed of:

- proposed uses of the water and the quality necessary for each use
- design area or system requirements
- technology or project characteristics and limitations.

Most case studies required improved householder understanding and involvement in their water-use behaviour compared to traditional systems. Additional investment in education and information dissemination to householders, council officers, regulatory bodies, developers, water providers and the broader community appears warranted.

Further identification of barriers to adoption needs to be undertaken to support existing educational programs. This is particularly important as other studies have found that despite high community knowledge about water-saving devices, there have been low rates of uptake of water-saving systems such as greywater use. For example, costs, home ownership versus rental status, perceived poor performance, and difficulty in organising installation all hinder technology uptake (Clarke & Brown 2006).

Increased uptake of alternative systems requires clear guidelines for the selection, design, installation and operation of alternative systems. Simplification of regulatory and approvals requirements is also necessary. This applies at the single household as well as larger development scale. For example, the wastewater system for the case-study site 60L is 5kL in size. This was not big enough to require approval of the Environment Protection Authority of Victoria, which meant that, despite the project manager's efforts to engage local water authorities and council officers in the selection process, it was difficult to identify regulatory requirements and appropriate water quality objectives.

Many technologies are currently being tested at demonstration sites and implemented in small- to large-scale developments. New applications and uses for existing technologies are also evolving as new issues and site characteristics are presented. While the knowledge base is growing as more schemes are implemented, there is still a lack of understanding of risks involved in many applications and both industry and regulators are unfamiliar with many of the new systems. Technology issues identified in this study include:

- selecting appropriate technologies to treat higher-concentration waste streams produced by household and subdivisional systems which are increasingly water efficient
- considering downstream (off-site) impacts of the alternative water-servicing approach on, for example, sewage transport and treatment infrastructure
- considering chemical and energy use of systems
- considering biosolids production and management in the initial design of on-site wastewater management systems
- that the necessary infrastructure is not available for technology application in existing houses (brownfield).



Following from the last point, future thinking in terms of other infrastructure to allow flexibility in design is required. For example, greywater reuse as an option may currently be limited due to the inability to separate this water from wastewater. Source separation in new build houses would allow flexibility in future approaches.

In the retrofit or redesign of existing properties, a number of specific issues were identified. Full understanding of the existing system is required prior to the development of alternative water-servicing approaches, and the incorporation of existing infrastructure in the design may help to reduce costs and civil works.

Technologies can be applied at a range of scales from single house to subdivisions. Consideration of integrated approaches can have additional benefits. For example, communal stormwater tanks at Payne Road eliminate the need for water mains designed for fire flows. Correspondingly, pumping and treating wastewater from the sewer main at the CH2 site allowed other building water requirements to be met.

All innovative approaches require a learning period and this applies to development and implementation of alternative water-servicing systems. This is particularly because there are no universal solutions, only more appropriate ones for particular situations.

### Recommendations

It is recommended that a strategy be developed to outline how government, the private sector and the community could work to improve the uptake of alternative and efficient water technologies. As a component of this strategy, the following elements are recommended for development by the appropriate federal, state and local government agencies or water service providers:

1. Further work regarding practical aspects of incorporating integrated water system technologies and managing the associated risks. For example guidance is needed in relation to treating water to acceptable standards to meet technical, health, environmental and safety criteria.
2. Development of educational and training materials to encourage continued participation of residents.
3. Development of guidelines for various aspects of management, including planning, design, construction and operation, to give improved certainty that particular schemes meet legislative requirements and standards.

Suggested research to support these needs and related aspects are described below.

### Suggested research needs

At the request of the Construction Innovation Project Steering Committee, the authors have nominated potential stakeholders or research initiators who could help address some of the issues and knowledge gaps identified by this study.

Knowledge gaps applicable to all scales of development were found in the case-study sites investigated and are described in full in the research report (Diaper et al. 2006). Table 2 summarises knowledge gaps which were identified as high priority or high impact by the authors, together with suggested research initiators.



**Table 2**     *Suggested research needs and initiators*

<b>Suggested research needs</b>	<b>Suggested research initiators</b>
Monitor and assess existing alternative systems and compare their actual performance to predicted performance prior to implementation. Identify reasons for any sub-optimal performance.	Technology developers, universities and research organisations
Quantify additional benefits of alternative systems (such as reduced energy and materials usage, and system resilience and householder wellbeing) by detailed lifecycle costing, analysis and monitoring. Also quantify associated benefits from externalities over LCA.	Australian Greenhouse Office, environment agencies, local and state governments, universities
Understand the impact of greywater (treated or untreated) on the environment.	Technology developers
Improve garden irrigation technologies and practices, including by improved sensing (climate, soil, water use), by understanding the behaviour of users (including plant selection and needs), and by application of efficient autonomous and remotely managed systems.	Technology developers, universities and research organisations
Develop options and design criteria for stormwater harvesting for various residential uses.	Federal environment and water agencies, research organisations (eWater, Water Quality Australia)
Assess the potential impacts of alternative water-servicing approaches on existing infrastructure and transitioning strategies, including how these strategies can be built into longer-term infrastructure masterplans.	Water utilities, local governments
Investigate alternative funding sources and economic incentives and disincentives (such as rebates, headworks charges and planning obstacles) for implementation of alternative water-servicing approaches.	State and local governments, water utilities
Review legislative and planning process impacts on adoption of integrated water-service options with particular focus on how the multi-disciplines necessary to deliver water services can be streamlined.	State and local governments, water utilities and commissions
Conduct social or behavioural research, including what values lead people to consume or conserve water in different ways.	State and local government, water utilities and commissions
Undertake economic analysis of selected water efficient and traditional technologies, as this may help embed new technologies within existing and future urban areas and inform infrastructure planning.	State and local governments, the development industry
Develop technology selection guidance frameworks which account for local conditions and infrastructure.	State government agencies, water utilities and development industries (noting that this should probably be developed on a state-by-state basis)
Develop service models and management frameworks for maintenance of decentralised treatment systems.	State and local government, water utilities and development industry

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# CRC for Construction Innovation participants



# Sustainable subdivisions: Review of technologies for integrated water services



Improved planning and management of water in Australia is essential to ensure reliability of water services and to support the ongoing growth of our cities. *Sustainable subdivisions: Review of technologies for integrated water services* deals with emerging water supply, wastewater treatment and reuse technologies at household, cluster and subdivisional scales.

With its focus on the South East Queensland region, this review includes:

- a discussion of the impact of subdivision design on water use
- a literature review of water management technologies, either in use or under development, which offer alternative approaches to existing water services
- an examination of eight case-study sites outlining the benefits and issues associated with the various technologies in an integrated water system
- suggestions for future projects for understanding and mitigating the barriers to implementation of the water management technologies.

This publication forms part of the *Construction Innovation Sustainable subdivisions* series comprising *Energy-efficient Design* (pictured below) and *Ventilation* (available early 2008).



## Partners in progress

The partners involved in this research:

### Industry



### Government



Queensland Government  
Department of Public Works

### Research



Copies of the industry booklet  
will be available from:



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