

WATER TRANSFORMED

SUSTAINABLE WATER SOLUTIONS FOR CLIMATE CHANGE ADAPTATION

MODULE C: INTEGRATED WATER RESOURCE PLANNING AND MANAGEMENT



This online textbook provides free access to a comprehensive education and training package that brings together the knowledge of how countries, specifically Australia, can adapt to climate change. This resource has been developed through support from the Federal Government's Department of Climate Change's Climate Change Adaptation Professional Skills program.

CHAPTER 7: AUGMENTING TRADITIONAL WATER SUPPLY THROUGH WATER REUSE AND RECYCLING.

*LECTURE 7.2: RESIDENTIAL & COMMERCIAL – WATER REUSE
AND RECYCLING.*

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Augmenting Traditional Water Supply Through Water Reuse and Recycling

Lecture 7.2: Residential & Commercial Buildings – Water Reuse and Recycling

Educational Aim

The aim of this lecture is to highlight the potential for water reuse and recycling in the building sector of cities. The lecture seeks to overview the main ways water can be reused in this sector and seeks to provide an overview of the steps needed to ensure that water is used in ways that ensure human health.

Key Learning Points

1. In Australian capital cities, and many other cities around the world, commercial and residential buildings are responsible for over 70 per cent of all fresh potable water use. Whilst residential buildings use the bulk of this potable water, commercial, retail and office buildings are also significant consumers. *'A moderate sized building of 10,000m² typically consumes over 20,000 litres per day or more than 7 million litres per year – enough to supply 40 average homes.'*¹ Water use for commercial, retail and office buildings can account for 10 per cent of city water consumption.²
2. The potential for water reuse and recycling is significant. To help give a sense of just how significant, consider the fact that over 50 per cent of the water being used for commercial buildings (cooling towers, toilet flushing and gardens/landscape) and residential buildings (toilet flushing, laundry and gardens) does not need to be water of drinking quality.³ There are five strategies to reduce the dependence of buildings on mains water and increase water reuse and recycling.
3. **Strategy #1 – Rainwater Harvesting:** Currently most rain which falls on the world's coastal cities and towns simply flows out to sea without being used. Harvesting and storing rainwater in water tanks enables that water to be re-used in cooling towers, hot water systems, toilets, laundries and for watering gardens and landscapes.⁴ There is increasing demand for harvesting roof-water from larger buildings, such as community halls, schools and commercial premises.⁵ As we showed in Lecture 2.4, a range of businesses such as supermarkets,

¹ Quinn, R., Bannister, P., Munzinger, M. and Bloomfield, C. (2006) *Water Efficiency Guidelines: Office and Public Buildings*, Commonwealth of Australia, Canberra, Australia, p5.

² The Department of Environment, Water, Heritage and the Arts (2007) *Water Efficiency Guide: Office and Public Buildings*, DEWHA, Canberra, Australia.

³ Radcliffe, J. (2004) *Water Recycling in Australia*, Australian Academy of Technological Sciences and Engineering, www.atse.org.au/index.php?sectionid=600, accessed 28 January 2010.

⁴ enHealth (2004) *Guidance on Use of Rainwater Tanks*, Australian Government Department of Health and Ageing, Canberra, [www.health.gov.au/internet/main/publishing.nsf/Content/3D981B51B4FB458DCA256F1900042F6E/\\$File/env_rainwater.pdf](http://www.health.gov.au/internet/main/publishing.nsf/Content/3D981B51B4FB458DCA256F1900042F6E/$File/env_rainwater.pdf).

⁵ Natural Resource Management Ministerial Council, Environment Protection and Heritage Council and National Health and Medical Research Council (2009) *Australian Guidelines for Water Recycling Stormwater Harvesting and Reuse*, National Water Quality Management Strategy Document No 23,

www.ephc.gov.au/sites/default/files/WQ_AGWR_GL_Stormwater_Harvesting_and_Reuse_Final_200907.pdf, accessed 1 May 2010.

shopping centres, mega-stores and factories have significant roof surface area, from which significant rainwater volumes can be harvested to meet much of their water needs.⁶

4. Strategy #2 – Greywater Treatment and Reuse: Greywater is wastewater from showers, baths, spas, hand basins, washing machines, laundry troughs. Importantly, it does not include wastewater from toilets (known as 'blackwater'), and generally excludes kitchen and dishwasher water due to the associated health risks posed by pathogens.⁷ An example of the potential for water savings from greywater reuse is shown by the example of the Mawson Lakes estate development in South Australia. This 3,500 home residential estate was designed so that 80 per cent of used greywater is recycled for toilets and gardening⁸.
5. There are many ways to collect, store and distribute greywater:⁹
 - simple diversion: Simple diversion products can divert greywater to a sub-surface garden irrigation system under the action of gravity. These products consist of a tee junction, rubber socket and valve, and may also include overflow devices. Simple diversion is better suited to residential buildings than to commercial buildings.
 - sedimentation tanks and irrigation fields: Greywater can be stored in a sedimentation tank for several days in order to allow solids to settle to the bottom of the tank. The relatively clean water in the top of the tank can then be transferred to the garden while the sediment at the bottom must be periodically removed.
 - diverter valves, filtration and storage: When greywater cannot reach the garden under the action of gravity, a system may be used that consists of a diverter valve, a small storage cell, a pump and a daily automatic release of the water. Greywater from shower and bath water can be diverted for toilet flushing.
6. Strategy #3 – Blackwater Treatment and Reuse: Blackwater is water from the toilet.¹⁰ Blackwater reuse is much less common than greywater reuse because the permitted uses for treated blackwater are understandably more restricted than those for greywater. Provided that appropriate treatment is undertaken, uses include:¹¹
 - residential garden watering, car washing, and toilet flushing
 - irrigation for urban recreational and open space, and agriculture and horticulture
 - fire protection and fire fighting systems and
 - industrial uses, such as water for cooling towers
7. Strategy #4 – Increasing the Use of Recycled Water through Dual Reticulation: Residential estates can be designed with dual reticulation systems which enable recycled water to be delivered to residential homes for use in toilets and gardening. Dual reticulation enables the

⁶ Chapman, H., Cartwright, T., Tripodi, N. (2008) Guidance Manual for the Design and Installation of Urban Roofwater Harvesting Systems in Australia, 1st ed., Cooperative Research Centre for Water Quality and Treatment, Salisbury, SA, Australia. www.waterquality.crc.org.au/publications/report39_rainwater_tank_manual.pdf.

⁷ Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

⁸ Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*. Earthscan, London

⁹ Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

¹⁰ Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

¹¹ Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

use of two water supplies – one based on recycled water and the other on drinking quality standard water. An example in Australia is the Aurora Estate.¹² It is a 8,500 lot real estate development, led by VicUrban and Yarra Valley Water, that is incorporating dual reticulation.¹³ The Pimpana-Coomera Scheme in the Gold Coast area is another impressive application of dual reticulation, this time to 150,000 people, which

“incorporates new materials, technologies, standards and practices to reduce the size and capital and maintenance costs of water collection and distribution systems. The scheme will provide overall an 80 per cent reduction in demand for potable water with capital costs only 10 per cent above conventional approaches and lower life cycle costs if headwork costs are incorporated.”¹⁴

8. Strategy #5 – Reusing Heated Water from Light Industry: Water experts are now looking at ways to reuse relatively clean water from light industry, such as from data centres, for heating buildings. For instance, in the Finnish capital of Helsinki, underneath the orthodox Christian landmark Uspenski Cathedral, a data centre, which is full of hundreds of computer servers, emits substantial amounts of heat that is captured and channelled into the city’s district heating network, a system of water-heated pipes that are used to warm 500 homes in the city.
9. There are many benefits of reusing water in residential homes and commercial buildings:
 - Creates greater resilience and water security to ensure water supply even in extreme drought conditions and under tight water restrictions.
 - Reduces use (up to 50 per cent in urban areas) of mains water, which delivers financial savings to the consumer through reduced water demand and reduced trade waste costs,
 - Reduces community infrastructure costs (e.g. dams). A study¹⁵ into the economic viability of rainwater tanks in the central coast and Hunter Valley of NSW shows that the rainwater tanks have delayed, if not eliminated, the need for new water supply head-works infrastructure by 38 and 34 years respectively.
 - Reduces the cost of extending and maintaining stormwater and flood mitigation infrastructure, as water reuse significantly reduces the volumes of water entering the stormwater system.
 - Creates spare capacity in cities’ stormwater systems to help them cope with the risks of climate change-induced flash flooding and extreme weather events by providing cost effective onsite stormwater detention.¹⁶
10. There are many examples of residential water harvesting and reuse schemes in Australia:
 - Michael Mobbs and Helen Armstrong retrofitted an old terrace house in one of the most densely populated suburbs in Sydney to be almost entirely water self sufficient. Through

¹²Bowmer, K. (2004) *Water Innovation: A New Era for Australia*, CI Creations.

¹³Bowmer, K. (2004) *Water Innovation: A New Era for Australia*, CI Creations.

¹⁴Bowmer, K. (2004) *Water Innovation: A New Era for Australia*, CI Creations.

¹⁵ Coombes, P.J., Kuczera, G. and Kalma, J.D. (2000) *Economic benefits arising from use of water sensitive urban development source control measures*, Newcastle City Council and the New South Wales Government Stormwater Trust, www.wsud.org/downloads/Info%20Exchange%20&%20Lit/Coombes%20ECONOMIC%20benefits%20from%20WSUD.pdf, accessed 15 September 2008.

¹⁶ Coombes, P.J., Kuczera, G. and Kalma, J.D. (2000) *Economic benefits arising from use of water sensitive urban development source control measures*, Newcastle City Council and the New South Wales Government Stormwater Trust, www.wsud.org/downloads/Info%20Exchange%20&%20Lit/Coombes%20ECONOMIC%20benefits%20from%20WSUD.pdf, accessed 15 September 2008.

onsite collection of rainwater, as well as onsite waste water treatment, the owners have reduced their already relatively low consumption of mains water to virtually zero. This house does not have a particularly large roof but nevertheless it can still capture enough water in the 8,500 litre tank, located beneath the back deck, to meet the potable water needs of the family of four.¹⁷

- It is also possible to achieve self sufficiency in water for a residential estate. Currumbin Ecovillage¹⁸ is the first self-sufficient Australian residential estate development (unconnected to both the mains water and sewerage systems) which captures, treats and recycles water onsite to meet all its needs in a closed loop water cycle. Water efficiency measures are employed, as well as landscaping techniques such as swales and retention ponds. Over 80 per cent of the water used by households is recycled.

11. There are also some outstanding examples of the potential to reduce mains water usage in commercial/office buildings in Australia. Sixty Leicester Street, Carlton, Victoria¹⁹ or '60L', is a 'green' commercial building that has achieved a 90 per cent mains water reduction²⁰ through the following steps:

- Minimised demand for water is provided through efficient fixtures and fittings, including waterless urinals and low flush volume toilet pans;
- Rainwater is collected to replace 100% of normal mains water consumption whenever possible;
- A three-stage filtration and UV sterilisation water treatment system is installed;
- 100% on-site biological treatment and reuse of grey-water (basins and sinks) and black-water (sewage);
- 100% use of recycled water treated through a separate two-stage filtration and UV sterilisation system to make it suitable for flushing all toilet pans and for use in sub-surface irrigation on the roof garden and other landscape features; and
- Surplus recycled water is discharged via a water feature in the building atrium, with a succession of cascading tanks containing aquatic plants and organisms to provide a third stage of purification.²¹

Brief Background Reading

Next we will discuss how to implement these five strategies for water treatment and reuse in the buildings sector. Our major focus here will be on the first two strategies; namely rainwater harvesting and reuse, and greywater treatment and reuse as these are the most commonly used.

Strategy #1 - Rainwater Harvesting and Reuse

Collecting rainwater for domestic or commercial use is becoming increasingly popular. Rainwater can be used for many applications including: laundry washing machines, toilet flushing, outdoor

¹⁷ Mobbs, M. (1999) *Sustainable House: Living for Our Future*, Choice Books, Sydney, www.sustainablehouse.com.au/, accessed 18 April 2009.

¹⁸ See Currumbin Ecovillage – Sustainability Objectives, theecovillage.com.au/site/index.php/C4/, accessed 18 April 2009.

¹⁹ Case study summarised from 60L Green Building, www.60lgreenbuilding.com/, accessed 20 May 2010.

²⁰ Ibid.

²¹ Ibid.

use, pool/pond/spa top-up, garden irrigation, hot water use²², fire fighting, cooling towers, chillers, and drinking water²³. Allowed uses vary between the states and territories of Australia, but overall most states now allow many uses for rainwater as shown in Table 7.2.1.

Table 7.2.1 *Uses of rainwater allowed in the states and territories of Australia*

| State | Garden Watering | Outdoor Cleaning | Hot water systems | Cooling Towers | Toilets | Shower | Washing Machine | Drinking Water |
|-------|-----------------|------------------|-------------------|----------------|---------|--------|-----------------|----------------|
| ACT | ✓ | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ |
| NSW | ✓ | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ |
| NT | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Qld | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| SA | ✓ | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ |
| Tas | ✓ | ✓ | - | - | - | - | - | ✓ |
| Vic | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| WA | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

✓: Allowed

-: Not specifically allowed, check local regulations with local government and water utility

Source: Australian Rainwater Industry Development Association and Master Plumbers and Mechanical Services Association of Australia (2008)²⁴

While drought is obviously a key motivator in seeking an alternative to mains water, state and territory governments are providing incentives in the form of rebates for the installation of rainwater tanks as outlined in Table 7.2.2

Table 7.2.2 *Major rebates for installation of rainwater tanks and connection to residential properties in states and territories of Australia*

| State | Approval required to obtain rebate | Link to website |
|-------|------------------------------------|--|
| ACT | ACT Government | www.thinkwater.act.gov.au |
| NSW | NSW Department of Environment and | www.environment.nsw.gov.au/rebates/ccfrtw.htm |

²² Jayaratne, A., Sukumaran, N. and Snadden, D. (2006) *Water quality of hot water systems drawn from rainwater tanks in urban environments*. AWA Enviro 06 Conference, May 2006, Melbourne, Australia.

²³ Natural Resource Ministerial Management Council, Environment Protection and Heritage Council and Australian Health Ministers' Conference (2006) *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)*, NRMCC, EPHC and AHMC, Canberra; Natural Resource Ministerial Management Council, Environment Protection and Heritage Council and National Health and Medical Research Council (2008) *Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies (Phase 2)*, NRMCC, EPHC and NHMRC, Canberra.

²⁴ Australian Rainwater Industry Development Association and Master Plumbers and Mechanical Services Association of Australia (2008) *Rainwater Tank Design and Installation Handbook*, 2nd ed., ARID, MPMSAA and National Water Commission, p 13, www.nwc.gov.au/resources/documents/RAINWATER_handbooknwc_logo.pdf, accessed 20 May 2010.

| | | |
|-----|---|--|
| | Climate Change | |
| NT | NT Government | www.nt.gov.au/nreta/water/wise |
| QLD | QLD Department of Environment and Resource Management | http://www.derm.qld.gov.au/water/index.html |
| SA | SA Water | www.sawater.com.au/SAWater/YourHome |
| TAS | Hobart City Council | www.hobartcity.com.au/content/InternetWebsite/Environment/Stormwater_and_Waterways/Conservation/Rainwater_Tanks.aspx |
| VIC | Vic Government | www.ourwater.vic.gov.au/programs/owof |
| WA | Water Corporation, WA | www.watercorporation.com.au/ |

Source: based on Australian Rainwater Industry Development Association and Master Plumbers and Mechanical Services Association of Australia (2008)²⁵

The onsite collection and storage of rainwater for domestic or commercial purposes has many benefits as it:

- reduced use (up to 50 per cent in urban areas) of mains water, which not only delivers financial savings to the would be consumer, but also:
 - reduces community infrastructure costs (e.g. dams)
 - provides cost effective onsite storm water detention
 - protects environmental flows in rivers and streams, through stabilised or even reduced demand on catchments.

The two disadvantages of installing rainwater tanks are:

1. *reliability*: factors such as tank size and rainfall will determine the availability of tank water in mid-summer.
2. *financial*: In areas that are serviced by reticulated water not only is there a financial cost involved in system installation and ongoing associated maintenance, but some water suppliers charge a fixed annual fee for provision of service regardless of usage.

There are three broad categories of systems that can be installed to collect rainwater:

1. *above ground tanks*: usually the cheapest option, these can take the form of standard round tanks, or the slimline and modular systems (storage walls) that require less space
2. *underground tanks*: while the catchment potential of these is greater than above ground tanks, the need for excavation generally makes them more expensive. Underground tanks can also capture water through infiltration

²⁵ Australian Rainwater Industry Development Association and Master Plumbers and Mechanical Services Association of Australia (2008) *Rainwater Tank Design and Installation Handbook*, 2nd ed., ARID, MPMSAA and National Water Commission, p 53, www.nwc.gov.au/resources/documents/RAINWATER_handbooknwc_logo.pdf, accessed 20 May2010.

3. *bladders*: these flexible sacs are well suited to sub-floor spaces, requiring as little as 750mm height clearance. Bladder installation is more technically complicated than above or underground tanks, and is ideal in situations with limited space (e.g. renovations).

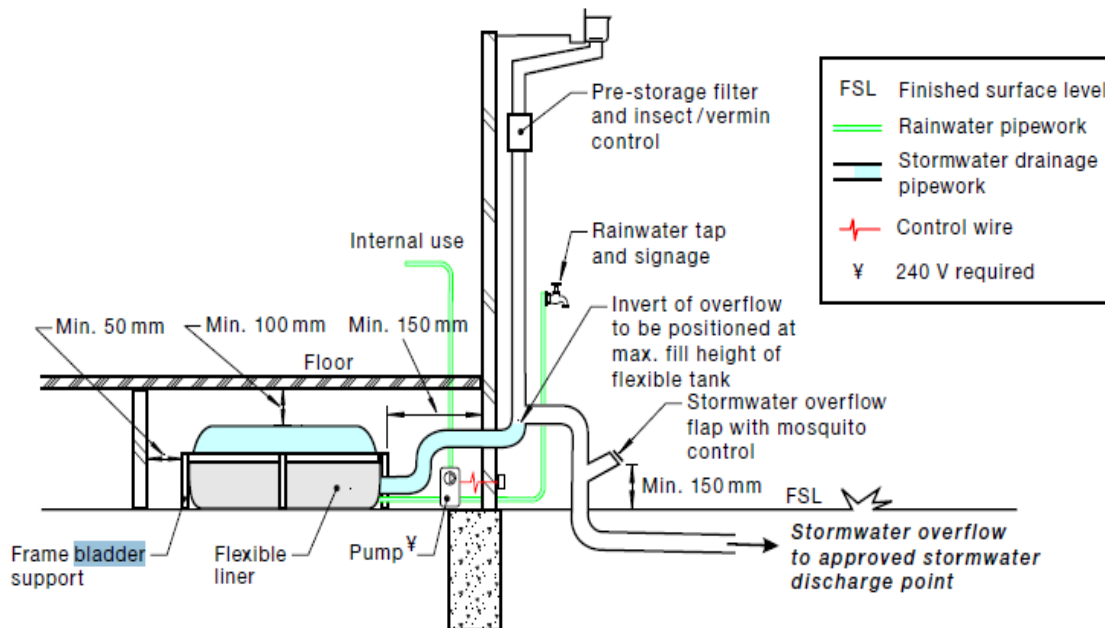


Figure 7.2.2 Flexible rainwater storage device – bladder under floor construction

Source: Australian Rainwater Industry Development Association and Master Plumbers and Mechanical Services Association of Australia (2008)²⁶

The type of system installed will determine the construction material of the tank. Tanks are generally constructed of either:

- *galvanised steel*: limited lifespan due to corrosion, but inexpensive
- *concrete*: longevity, strength, highly customisable due to capacity for onsite construction
- *plastic*: polyethylene are strong, durable, lightweight and coloured

The design and manufacture of potable rainwater tanks can be constructed using the following standards in order to meet or exceed requirements:²⁷

- above-ground tanks made of polyethylene: Australian Standard/New Zealand Standard (AS/NZS) 4766:2006, *Polyethylene Storage Tanks for Water and Chemicals*
- tanks made of other materials: Australian Technical Standard (ATS) 5200.026-2004, *Technical Specification for Plumbing and Drainage Products – Cold Water Storage Tanks*; AS/NZS 1546.1, *On-site Domestic Wastewater Treatment Units – Septic Tanks*; AS 3735-2001, *Concrete Structures Retaining Liquids*

²⁶ Australian Rainwater Industry Development Association and Master Plumbers and Mechanical Services Association of Australia (2008) *Rainwater Tank Design and Installation Handbook*, 2nd ed., ARID, MPMSAA and National Water Commission, p 86, www.nwc.gov.au/resources/documents/RAINWATER_handbooknwc_logo.pdf, accessed 20 May2010.

²⁷ Australian Rainwater Industry Development Association and Master Plumbers and Mechanical Services Association of Australia (2008) *Rainwater Tank Design and Installation Handbook*, 2nd ed., ARID, MPMSAA and National Water Commission, p 13, www.nwc.gov.au/resources/documents/RAINWATER_handbooknwc_logo.pdf, accessed 20 May2010.

- tanks lined with a coating: AS 5200.000, *Technical Specification for Plumbing and Drainage Products*.

The cost of installing a system to collect rainwater varies widely. The key variables are tank size and construction, delivery and installation requirements. Whichever type of system is installed, regular maintenance is essential to mitigate potential health risks²⁸ posed by, for example:

- animal and bird faeces entering tanks via roofs or spouting
- airborne pollutants (in urban environments)²⁹
- contamination from roofing materials, particularly lead.³⁰
- parasites such as *Cryptosporidium* or *Giardia*.

Health risks tend to increase in proportion to the scale of a project. For instance, as opposed to residential systems, rainwater tanks used in non-residential building developments carry risks that include:

- increased risk of pollutants (e.g. bird/animal faeces) due to larger roof areas. Effective mitigation of this may require additional treatments.
- any water quality issues will impact upon larger and potentially sensitive groups
- the scale and complexity of larger projects increases the potential for mixing of potable and non-potable water through cross-connections. This can also be an issue with maintenance by individuals unfamiliar with the project.
- planning, design and maintenance can involve many people and groups and more complexity.³¹

Gutters should drain freely to downpipes – there should not be any ponding of water. Free draining can usually be achieved by installing eaves, gutters and downpipes with a ‘fall’ (downwards grade) of at least 1:500 (0.2%) and by installing box gutters and internal guttering with a fall at least 1:200 (0.5%). In addition, gutters should not be corroded and leaf-protection devices can be installed where needed. Further guidance on roof drainage systems is available in AS/NZS 3500.3, *Plumbing and Drainage – Stormwater Drainage*.³²

Additionally, it is essential that systems be designed to safely overflow into a garden or appropriate drainage system. The use of a first flush diverter is also recommended. As the name suggests, these divert the first flush of water in a rain event from the roof (or other catchment area), which tends to be high in contaminants. Given the potential for contamination of rainwater, it is important that in situations where both rainwater and mains water are used, that they be kept isolated from one another via, for example, a tap or valve. Local council and health authorities can provide specific guidance on this and the above mentioned system maintenance issues.

²⁸ Chapman H, Cartwright T, Hutson R, O’Toole J (2008) *Water Quality and Health Risks from Urban Rainwater Tanks* Cooperative Research Centre for Water Quality and Treatment. Salisbury, SA, Australia.

www.waterquality.crc.org.au/publications/report42_WQ_health_risks_rainwater.pdf

²⁹ Huston, R., Chana, Y.C., Gardner, T., Shaw, G. and Chapman, H. (2009) Characterisation of atmospheric deposition as a source of contaminants in urban rainwater tanks, *Water Research*, vol 43, no 6, pp 1630-1640.

³⁰ Magyar, M.I., Mitchell, V.G., Ladson, A.R. and Diaper, C. (2008) *Lead and other heavy metals: common contaminants of rainwater tanks in Melbourne*, Water Down Under 2008, Adelaide, 15-17 April 2008.

³¹ Cheah, C., Ball, J., Cox, R. and Peirson, W. (2007) *Assessing the quantity and quality of runoff from an urban roof catchment*, Rainwater & Urban Design 2007 Conference, Sydney, 21-23 August 2007.

³² Standards Australia (2010) AS/NZS 3500.3, *Plumbing and Drainage – Stormwater Drainage*. Standards Australia. <http://engineers.ihs.com/document/abstract/EGROJBAAAAAAAAAAAA>

While rainwater systems can eliminate a considerable portion of the demand for mains water, there is some concern about the energy consumption of running rainwater systems. The main argument against the adoption of rainwater systems is that the energy consumption (commonly about 325 kWh/ML and as high as 956 kWh/ML) is comparable or greater than the delivering water via the mains distribution system (260 kWh/ML) but still far less than desalination (4932 kWh/ML). However, the rainwater system energy consumption estimates are for systems that are far from optimal. The next section describes how rainwater systems are conventionally designed, highlighting their shortcomings, and then describes how these systems can be redesigned to consume considerably less energy, as much as 90 per cent. The power consumption and supply efficiency for each configuration is shown in Figure 7.2.3.

Energy Efficiency and Rain Water Tank Systems

This section is largely a summary from the work of Alistair Sproul and Leon Cunio with permission.³³

Conventional system: high pressure system

In a typical conventional rainwater system, water from a tank is pumped at high pressure through about 20-30 m of ½-inch or ¾-inch copper pipe to its end uses in the home – often a toilet, a washing machine or the garden. The output flow rate for such a system may be as low as 20-40 L/min and typically at a pressure of about 15 kPa. A pump drives the water at the tank-end at a pressure of about 250-500 kPa. The electric motor that drives the pump is typically a 240 AC, single phase, of about 25-30 per cent efficiency and consuming about 0.35-1 kW. This setup commonly consumes about 325 kWh/ML but, when servicing restrictive appliances (such as toilet cisterns, low flow shower heads or washing machines), consumption can be as high as 956 kWh/ML.

For a specific example, a 30 m network of ½-inch copper pipe, with an internal roughness value of 0.015 mm, delivering an end use flow rate of 20 L/min at a pressure of 15 kPa, driven at a pressure of 300 kPa at the tank-end by a 400 W, 25 per cent efficient motor/pump system consumes about 330 kWh/ML. Given that a typical home consumes 400 L/day from the appliances considered, the daily energy use for a home is about 0.13 kWh/day. This consumption is a very minor component of a home's total energy consumption (26 kWh/day) but still somewhat larger than the consumption of mains water supply.

The inefficiency in the conventional system is clearly evident from the need to apply 300 kPa of pressure at the tank-end in order to deliver just 15 kPa of pressure at the end use, with the pressure loss across the system being proportional to the energy loss. These losses arise from friction in the pipe network – mostly a result of the small diameter, some from the pipe bends and some from the valve at the end use.

Alternative 1a: low pressure system

³³ Sproul, A.B. (2007) 'Energy Efficient Rain Water Systems', Solar07: the 45th ANZSES Annual Conference, Alice Springs, Australia, October 2007; Cunio, L.N. and Sproul, A.B. (2009) 'Low Energy Pumping Systems for Rainwater Tanks', Solar09: the 47th ANZSES Annual Conference, Townsville, Australia, 29 September-2 October 2009.

The energy consumption can be reduced by simply selecting a larger pipe diameter. Since, for circular pipes, friction decreases with the fifth power of diameter, doubling the diameter to 1-inch would reduce the friction by a factor of 32 ($=2^5$). Assuming that the losses through bends are proportionally smaller and that the valve loss at the end use is about the same as for the conventional system, this alternative system requires that the water is driven at only 30 kPa at the tank-end by a 50 W, 20 per cent efficient motor/pump system and thus consumes about 40 kWh/ML.

Alternative 1b: low pressure, low flow system

The energy consumption can be further reduced by designing for a lower flow rate at the end use. Reducing the flow rate by half to 10 L/min, which may be acceptable for toilets and washing machines, would further reduce friction losses through the pipe network by about 75 per cent. This system can use a 30 W motor/pump system, which consumes about 25 kWh/ML.

Alternative 2: gravity-fed system

An alternative strategy to reduce energy consumption is to rely on gravity to provide the pressure required at the end use. The rainwater system is usually configured with a small header tank installed on the roof of the home. Water is pumped from ground level directly up to the header tank, which contains a float valve, then water flows from the header tank to the end use under the action of gravity. Using this configuration, the motor only needs to pump against the friction in the first, say, 4 m of the pipe network to move water from ground level, through the float valve and into the header tank. The flow through the remaining 26 m of the pipe plus through the end use valve as well as the delivery of 15 kPa of pressure at the end use is all unpowered. Assuming that water is delivered into the header tank at 20 L/min and 15 kPa, this alternative system requires that the water is driven at only 16 kPa at the tank end by a 30 W, 20 per cent efficient motor/pump system and thus consumes about 22 kWh/ML. While the energy consumption is similar to the low pressure, low flow system, this configuration has the advantage of supplying water at a relatively constant pressure and flow rate.

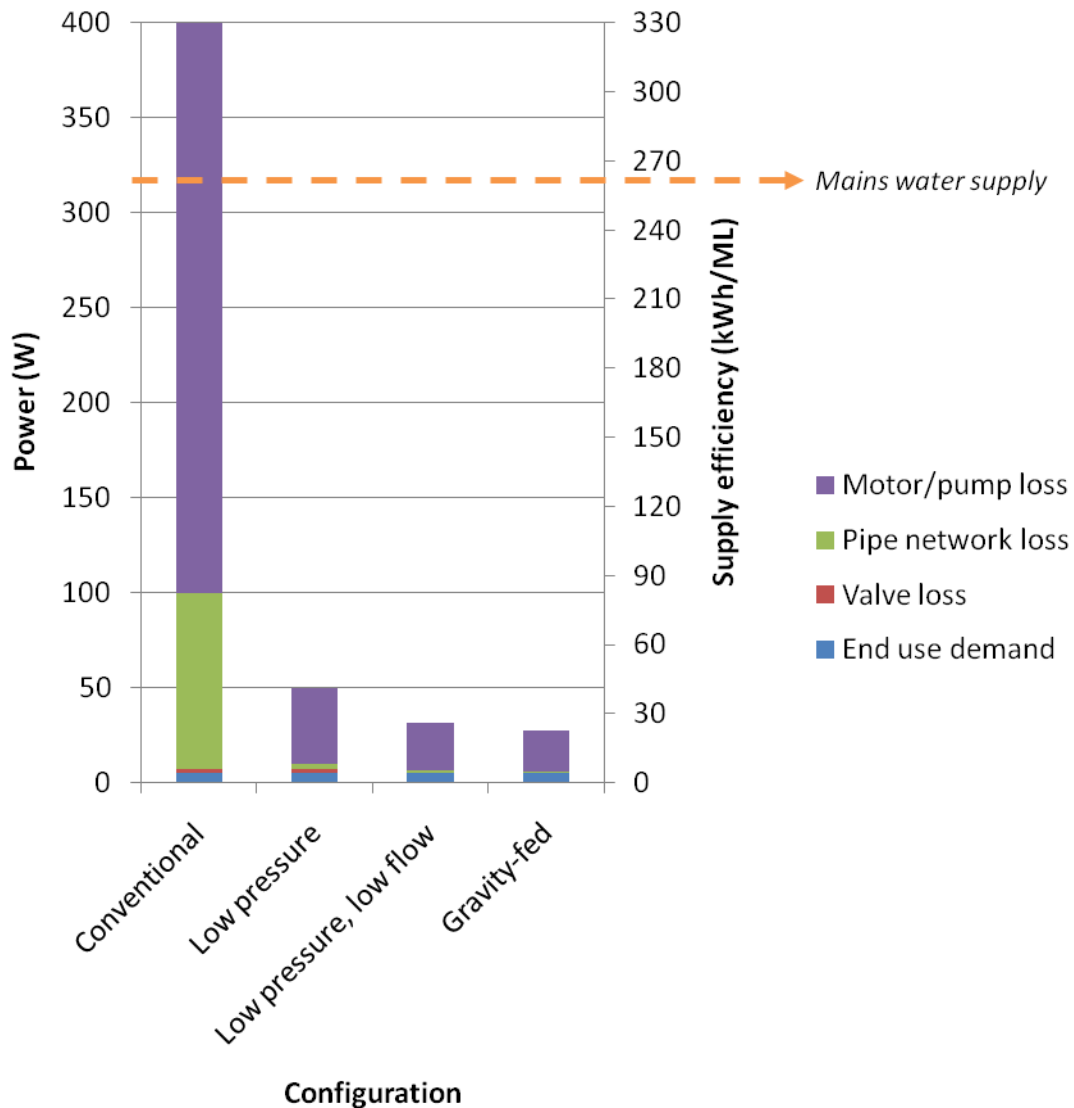


Figure 7.2.3 Breakdown of power consumption and supply efficiency for various rainwater system configurations

Source: based on Sproul, A.B. (2007); Cunio, L.N. and Sproul, A.B. (2009)³⁴.

Alternative power source

For a home that consumes 400 litres/day of rainwater, the energy consumption of both the low pressure system (6 kWh/year) and the gravity-fed system (3 kWh/year) is low enough to be powered by the combination of 5-10 W solar panel, a 10 Ah battery, a small charge controller and a DC pump, all at a capital cost of a few hundred dollars.

Costs

The capital cost of the low pressure system is less than that of the conventional system due to the lower cost of a smaller pump (less than \$100 vs about \$600) and the lower cost of a low pressure

³⁴ Cunio, L.N. and Sproul, A.B. (2009) 'Low Energy Pumping Systems for Rainwater Tanks', Solar09: the 47th ANZSES Annual Conference, Townsville, Australia, 29 September-2 October 2009

polypipes (about \$1/m) as compared to high pressure copper pipes (about \$4/m). The capital cost of the gravity-fed system is about the same as the conventional system due to the savings from a smaller pump and low pressure pipes being offset by the cost and installation of the header tank. For all rainwater systems, the cost a 5000 L ground tank is about \$1000 (compared to around \$3000 a few year ago) plus installation and the running cost of electricity is negligible – less than \$10/year for the conventional system and about \$1/year for the alternative systems.

Assuming a life of 10 years for the rainwater systems, the conventional system and gravity system have a cost of about \$1/kL and the low pressure system has a cost of about \$1.40/kL. By comparison, a 500 ML/day desalination plant, which is planned for Sydney, has a cost of about \$1.80/kL.³⁵

Strategy #2 - Greywater Treatment and Reuse

Wastewater reuse

Wastewater consists of both greywater and blackwater. The amount of wastewater produced in an average home is shown in Table 7.2.3 and a typical wastewater reuse system for a home is shown in Figure 7.2.4.

Table 7.2.3 Approximate amount of wastewater produced per person each day in an average home with WELS 3 Star rated fixtures

| Source | Consumption (litres/person/day) |
|-------------------------|---------------------------------|
| Greywater | |
| Shower | 63 |
| Hand basin | 6 |
| Washing machine | 13 |
| Laundry tap | 2 |
| Other wastewater | |
| Kitchen tap | 12 |
| Dishwasher | 5 |
| Blackwater | |
| Toilet | 20 |

Source: Fane, S. and Reardon, C. (2008)³⁶

³⁵ Ibid.

³⁶ Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

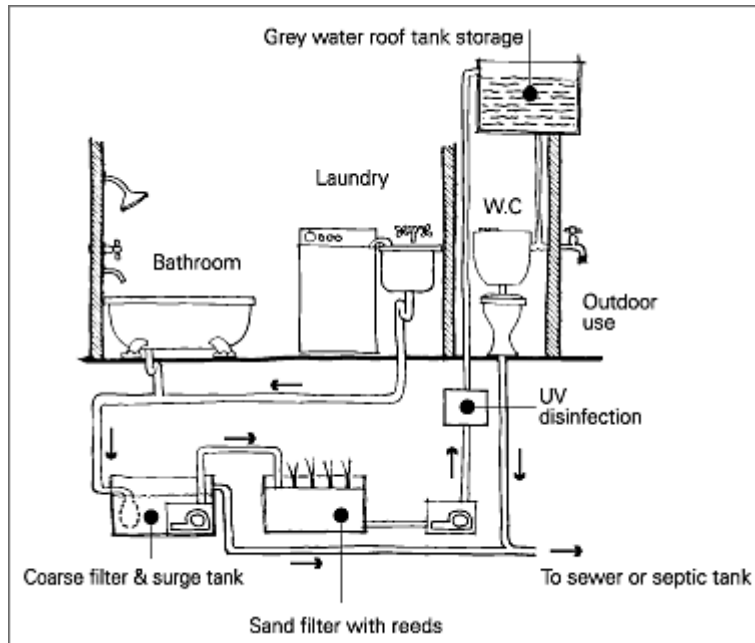


Figure 7.2.4 A typical wastewater reuse system for a home

Source: Fane, S. and Reardon, C. (2008)³⁷

Risks of using wastewater

There are some risks associated with the use of wastewater:³⁸

- Storing wastewater prior to treatment for more than a few hours may produce odour and increase the risk of pathogens spreading, so it is important to minimise storage time.
- Using greywater for clothes washing may cause clothes to discolour due to dissolved organic materials in the water. Discolouration can be avoided by using an activated carbon filter.
- The mains water supply may become contaminated by greywater. Cross-contamination can be minimised by using plumbing controls such as backflow prevention devices.

Greywater reuse

Around the world governments are changing regulations and introducing rebates to encourage the reuse of greywater in toilets or on gardens and landscapes. Half of household water use is for toilet flushing and gardens in Australia. This water does not need to be water of drinking quality. Different types of wastewater produced in a household need to be treated differently before they can be re-used. Greywater is wastewater from non-toilet fixtures such as showers, basins and taps which does not contain human excreta. Greywater from bathrooms and laundry (but not the kitchen) is the easiest to treat for reuse. The average home with WELS 3 Star rated fixtures

³⁷ Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

³⁸ Department of the Environment and Heritage (2006a) cited in Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010; Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

produces about 84 litres/person/day of greywater.³⁹ Most states permit greywater re-use outdoors as well as indoors for toilet flushing and laundry after appropriate treatment.

Using greywater

Greywater can be used for garden watering. Appropriately treated greywater can also be re-used indoors for toilet flushing and clothes washing, both of which are significant consumers of water.⁴⁰ Large-scale treated greywater can be used for a number of applications, although this does vary from state to state, depending on specific state requirements. Some applications for greywater include:⁴¹

- residential garden watering, car washing, toilet flushing and clothes washing
- irrigation for urban recreational and open space, and agriculture and horticulture
- fire protection and fire fighting systems
- industrial uses, including cooling water.

Greywater is thus a valuable resource. Taking advantage of this 'waste product' delivers a range of benefits, including:

- Personal financial savings through reduced water charges
- Community financial benefit through reduced need for infrastructure (e.g. new dams)
- A 'restriction free' supply of water that can be used on gardens
- Reduced demands upon waste infrastructure (i.e. sewage treatment), delivering improved system longevity and efficiency.⁴²

Capturing greywater

There are many ways to collect, store and distribute greywater.⁴³

- Simple diversion: Simple diversion products can divert greywater to a sub-surface garden irrigation system under the action of gravity. These products consist of a tee junction, rubber socket and valve, and may also include overflow devices. Simple diversion is better suited to residential buildings than to commercial buildings.
- Sedimentation tanks and irrigation fields: Greywater can be stored in a sedimentation tank and for a few days in order to allow solids to settle to the bottom of the tank. The relatively clean water in the top of the tank can then be transferred to the garden while the sediment at the bottom must be periodically removed.

³⁹ Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

⁴⁰ Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

⁴¹ Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

⁴² Ibid.

⁴³ Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

- Diverter valves, filtration and storage: There are many systems that can be used when greywater cannot reach the garden under the action of gravity. One such system consists of a diverter valve, a small storage cell, a pump and a daily automatic release of the water. Another system consist of diversion, a storage tank, a pump, a filter, a float switch, an auto-electric controller and a daily automatic release of the water. Greywater from shower and bath water can be diverted for toilet flushing.

Treating greywater

There are several processes available for treating greywater, including sand filtration, aeration, electroflotation, pressure filtration and biological treatment.⁴⁴ Tertiary treatment is generally more costly than secondary treatment.

- Treating greywater for outdoor use: For outdoor use, greywater is usually required to be secondary treated; it is best not to handle primary treated water. Several types of greywater treatment systems available for outdoor water reuse. Currently, the most common type of system is the aerated wastewater treatment system. These systems work by first allowing solids to settle to the bottom of a tank, then aerating the cleaner water in order to assist bacterial breakdown of organic matter. There are also treatment systems that treat all household wastewater (greywater and blackwater) using a combination of plants, animals, fungi, bacteria, algae and other microbes, as well as rocks and other minerals, while using little energy and no chemicals.
- Treating greywater for indoor use: For indoor use, greywater is required to be tertiary treated. The most common process is chlorine disinfection but it is also the most environmentally hazardous. Safer alternatives include ultraviolet disinfection, ozone disinfection and microfiltration. All disinfection systems require regular maintenance. Several packaged on-site greywater treatment systems are available for indoor water reuse. These systems often perform similar processes to those for outdoor water use with an additional disinfection or microfiltration stage and continuously monitor the water quality and system performance. These systems vary considerably variation in their cost, water treatment quality and energy consumption. Homemade systems can also be built with council approval.

Strategy 3 - Blackwater Treatment and Reuse

Blackwater is water from the toilet.⁴⁵ The average home with WELS 3 Star rated fixtures produces about 20 litres/person/day of blackwater.⁴⁶

Using blackwater

⁴⁴ Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010; Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

⁴⁵ Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

⁴⁶ Fane, S. and Reardon, C. (2008) 'Wastewater re-use', in Your Home Technical Manual, 4th ed., Commonwealth of Australia, Australia, www.yourhome.gov.au/technical/fs74.html, accessed 10 May 2010.

The permitted uses for treated blackwater are more restricted than those for greywater. Provided that appropriate treatment is undertaken, uses include:⁴⁷

- residential garden watering, car washing, toilet flushing and clothes washing
- ornamental water features
- irrigation for urban recreational and open space, and agriculture and horticulture
- fire protection and fire fighting systems
- industrial uses, including cooling water
- sub-surface irrigation of landscapes.

Treating blackwater

Blackwater requires biological or chemical treatment and disinfection before being used. Treating blackwater to a certain class is generally more costly than treating greywater to that class. Until recently, treating blackwater for residential or small commercial buildings was difficult due to space limitations and the risk of treatment failure.⁴⁸ New innovations in advanced membrane and other treatment technologies may provide opportunities for low cost and safe blackwater use. Some new products include:⁴⁹

- *“wastewater recycling units, which act on raw sewage and separate gross solids and fine solids through continuous deflection separation, followed by submerged aerated filters, a fine sand filter, UV disinfection and chlorine addition. Sewage [blackwater] is transformed into water up to Class A standard.*
- *those that can treat a range of effluents, including greywater, sewage and other wastewaters, using flat sheet membrane panels (that are aerated) within an activated sludge treatment tank. Screening and de-gritting must occur prior to use of the unit. These units produce water to a standard for toilet flushing, wash-down and irrigation*
- *using a simulated soil matrix (worm farm) to break down sewage and household organic waste, or an on-site, in-ground tank containing a fully aerobic, humic biological filtration matrix, which also incorporates extensive vermicultural (worm) activity for the accelerated decomposition of organics. The cleaned water from these biological filtration matrix systems can then be re-used on site, or the effluent can be exported to a pressurised reticulation network.”⁵⁰*

Regulations and standards

Most states and territories have specific guidelines for recycling wastewater. Regulation of recycled water at the state government level, as of 2009, is shown in Table 7.2.4. Most

⁴⁷ Corr, K., Adams I. and Boynton D. (2009) ‘Water use and sustainable commercial buildings’, Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

⁴⁸ Hyder Consulting (2005) cited in Corr, K., Adams I. and Boynton D. (2009) ‘Water use and sustainable commercial buildings’, Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

⁴⁹ Corr, K., Adams I. and Boynton D. (2009) ‘Water use and sustainable commercial buildings’, Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

⁵⁰ Corr, K., Adams I. and Boynton D. (2009) ‘Water use and sustainable commercial buildings’, Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

regulations and initiatives relate to residential dwellings. However, future regulations will probably apply to public, commercial and industrial buildings.⁵¹

Table 7.2.4 *Water conservation initiatives implemented by state and territory governments*

| State | Allowing greywater | Recycled water scheme for buildings |
|-------|--------------------|-------------------------------------|
| ACT | ✓ | ✓ |
| NSW | ✓ | ✓ |
| NT | ✓ | ✓ |
| Qld | ✓ | ✓ |
| SA | ✓ | |
| Tas | ✓ | |
| Vic | ✓ | |
| WA | ✓ | |

✓: Allowed

Source: Corr, K., Adams I. and Boynton D. (2009)⁵²

The primary standard related to onsite domestic wastewater systems is AS/NZS 1547:2000.⁵³ This standard covers primary and secondary treatment of domestic waste, blackwater and greywater, as well as land application and absorption systems.

Strategy 4 - Increasing the Use of Recycled Water through Dual Reticulation

Residential estates can be designed with dual reticulation systems which enable recycled water to be delivered to residential homes for use in toilets and gardening. Dual reticulation enables the use of two water supplies – one based on recycled water and the other on drinking quality standard water. Mawson Lakes is a fully planned and integrated mixed use development which reduces the amount of potable water used in by supplying recycled water through dual reticulation. This will additionally reduce the impact on nearby receiving water bodies through minimised stormwater and wastewater discharge.⁵⁴ Another example in Australia is the Aurora Estate.⁵⁵ This six star Victorian housing development is reducing mains water supply by 45 percent through capturing, treating and reticulating wastewater onsite through a separate reticulation system for non-potable uses. It also uses rain gardens (planted bioretention basins) and drought tolerant plants and grasses to reduce the impact of the development on nearby

⁵¹ Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

⁵² Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

⁵³ Corr, K., Adams I. and Boynton D. (2009) 'Water use and sustainable commercial buildings', Your Building, Australia, www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584, accessed 10 May 2010.

⁵⁴ Ball, R. (2008) *Mawson Lakes Development*, Your Development, Australia. Available at <http://yourdevelopment.org/casestudy/view/id/6>, accessed 15 September 2008

⁵⁵ Bowmer, K. (2004) *Water Innovation: A New Era for Australia*, CI Creations.

waterways and promotes water use efficiency.⁵⁶ It is a 8,500 lot real estate development, led by VicUrban and Yarra Valley Water.⁵⁷ As discussed in the key learning points, The Pimpana-Coomera Scheme in the Gold Coast area is another impressive application of dual reticulation to homes and businesses.⁵⁸

The Water Services Association of Australia's publication entitled "*Dual Water Supply Systems*"⁵⁹ covers the design and construction of dual supply systems for servicing new developments that provide both drinking water and non-drinking water via reticulation. The supplement contains detailed advice relating to:

- *differentiation of drinking water and non-drinking water pipe systems via colour coding and other markings*
- *design considerations for dual supply systems, including system configuration, sizing of mains, pressure, main depths, fittings and flushing points*
- *construction and installation of property services*
- *standard drawings for prevention of cross-connections between drinking and non-drinking water supply systems.*⁶⁰

Strategy 5 – Reuse Heated Water in Buildings from Light Industry – Datacentres.

As discussed in the key learning points, water experts are now looking at ways to reuse relatively clean water from light industry, such as reusing water previously used to cool data centres, to heat buildings or be used in hot water systems. IBM has gone a step further and developed a new on-chip water-cooling system, which

*“consists of a network of microfluidic capillaries inside a heat sink, which is attached to the surface of each chip in the computer cluster... The micro-fluidic capillaries allow water to be piped to within microns of the semiconductor material itself. By having water flow so close to each chip, heat can be removed more efficiently... The water is heated to 60 °C is then passed through a heat exchanger to provide heated water that is delivered elsewhere.”*⁶¹

This technology will be used to cool datacenters efficiently and enable the heated water to be reused elsewhere in the datacentre building or buildings nearby.

Further Reading

ACF, NCC and EV (2007) *The economics of rainwater tanks and alternative water supply options*, A report prepared for Australian Conservation Foundation, Nature Conservation Council (NSW)

⁵⁶ Baldwin, C. (2008) *Aurora*, Your Development, Australia. Available at: <http://yourdevelopment.org/casestudy/view/id/13>, accessed 15 September 2008.

⁵⁷ Bowmer, K. (2004) *Water Innovation: A New Era for Australia*, CI Creations.

⁵⁸ Bowmer, K. (2004) *Water Innovation: A New Era for Australia*, CI Creations.

⁵⁹ Water Services Association of Australia (2005) *Dual Water Supply Systems First Edition Version 1.2 A Supplement to the Water Supply Code of Australia* at https://www.wsaa.asn.au/NationalCodes/Documents/SUP_WSA03-2002%20V1.2%20DWSS.pdf accessed 1 May 2010

⁶⁰ Ibid.

⁶¹ Graham-Rowe (2010) *Computer Clusters That Heat Houses: A novel water-cooling system makes it more efficient for computers to heat buildings*. Technology Review, MIT at <http://www.technologyreview.com/computing/22917/page1/> accessed 20 May 2010.

and Environment Victoria. Available at:

http://www.acfonline.org.au/uploads/res/res_rainwater_tanks.pdf accessed 18 May 2010.

Grant, T. and Hallmann, M. (2003) 'Urban Domestic Rainwater Tanks: Life Cycle Assessment', *Water*, August, p22-27. Available at:

http://www.wsud.org/downloads/Info%20Exchange%20&%20Lit/Water%20August%202003_grant.pdf accessed 18 May 2010.

Dupont, P. (2008) 7.3: *Rainwater*, Commonwealth of Australia. Available at:

<http://www.yourhome.gov.au/technical/fs73.html>, accessed 18 May 2010.

WBM Oceanics Australia (2006) *Rainwater Tank Modelling Investigation: South East Queensland Regional Water Supply Strategy*, Australia. Available at:

[http://www.qwc.qld.gov.au/myfiles/uploads/SEQWS/supporting%20docs/Rainwater%20tank%20modelling%20\(Jan%202006\).pdf](http://www.qwc.qld.gov.au/myfiles/uploads/SEQWS/supporting%20docs/Rainwater%20tank%20modelling%20(Jan%202006).pdf), accessed 18 May 2010.

Standards Australia (2008) *Rainwater Tank Design and Installation Handbook*.

http://www.nwc.gov.au/resources/documents/RAINWATER_handbooknwc_logo.pdf accessed 18 May 2010.

enHealth (2004). *Guidance on Use of Rainwater Tanks*. Australian Government Department of Health and Ageing, Canberra.

[http://www.health.gov.au/internet/main/publishing.nsf/Content/3D981B51B4FB458DCA256F1900042F6E/\\$File/env_rainwater.pdf](http://www.health.gov.au/internet/main/publishing.nsf/Content/3D981B51B4FB458DCA256F1900042F6E/$File/env_rainwater.pdf) accessed 18 May 2010.

Chapman H, Cartwright T, Hutson R, O'Toole J (2008) *Water Quality and Health Risks from Urban Rainwater Tanks* Cooperative Research Centre for Water Quality and Treatment Salisbury, SA, Australia. www.waterquality.crc.org.au/publications/report42_WQ_health_risks_rainwater.pdf accessed 18 May 2010.

Chapman H, Cartwright T, Tripodi N (2008) *Guidance Manual for the Design and Installation of Urban Roofwater Harvesting Systems in Australia (Edition 1)* Cooperative Research Centre for Water Quality and Treatment Salisbury, SA, Australia.

www.waterquality.crc.org.au/publications/report39_rainwater_tank_manual.pdf accessed 18 May 2010.

ACT Government (2006) Australian Capital Territory. *Rainwater tanks guidelines for residential properties in Canberra*. Australian Capital Territory Government, Canberra, ACT, Australia.

www.actpla.act.gov.au/_data/assets/pdf_file/0003/3378/tanks.pdf accessed 18 May 2010.

NSW Health (2007) *Guideline. Rainwater Tanks Where a Public Water Supply is Available - Use of space*. New South Wales Health, North Sydney, NSW, Australia.

www.health.nsw.gov.au/policies/gl/2007/pdf/GL2007_009.pdf accessed 18 May 2010.

Sydney Water (2003) *Guidelines for rainwater tanks on residential properties. Plumbing requirements. Information for rainwater tank suppliers and plumbers*. Sydney Water, Sydney, NSW, Australia.

www.sydneywater.com.au/Publications/FactSheets/RainwaterTanksGuidelines.pdf accessed 18 May 2010.

Northern Territory DHCS N (2006) *Information Bulletin No. 7. Environmental Health.*

Requirements for the Use of Rainwater Tank. Department of Health and Community Services, Northern Territory, Darwin, NT, Australia.

www.nt.gov.au/powerwater/news/publications/save/water/save_water_alternative_water_sources.htm accessed 18 May 2010.

Queensland Qld Health (Accessed 2008) Queensland Health policy 'Managing the Use of Rainwater Tanks'. www.health.qld.gov.au/ph/documents/ehu/30632.pdf accessed 18 May 2010.

US EPA (United States Environmental Protection Agency) (2006) *Ultraviolet Disinfection Guidance Manual*, EPA report 815-R-06-007.

MJA (2007) The cost-effectiveness of rainwater tanks in urban Australia. Marsden Jacob Associates for the National Water Commission, Canberra.

DEUS (2007) *NSW Guidelines for Greywater Reuse in Sewered, Single Household Residential Premises*. Department of Energy, Utilities and Sustainability. NSW Government, Sydney, NSW, Australia.

Water Services Association of Australia (2005) *Dual Water Supply Systems First Edition Version 1.2 A Supplement to the Water Supply Code of Australia* at https://www.wsa.asn.au/NationalCodes/Documents/SUP_WSA03-2002%20V1.2%20DWSS.pdf accessed 1 May 2010.

Graham-Rowe (2010) *Computer Clusters That Heat Houses: A novel water-cooling system makes it more efficient for computers to heat buildings*. Technology Review, MIT at <http://www.technologyreview.com/computing/22917/page1/> accessed 20 May 2010.

Other Useful Links

Biolytix (2006) '*Biolytix delivers the best service*'. Biolytix, Australia. Available at <http://www.biolytix.com/detail.php?ID=57> accessed 18 May 2010..

Fane, S. and Reardon, C. (2005) '2.3 Wastewater re-use' in *Your Home Technical Manual*, 3rd edn, Commonwealth of Australia. Available at <http://www.yourhome.gov.au/technical/fs23.htm> Accessed 25 March 2008.

NSW Health Department (2001) *Septic tank and collection well accreditation guideline*, New South Wales State Government, Australia. Available at http://www.health.nsw.gov.au/public-health/ehb/general/wastewater/septic_guideline.pdf accessed 18 May 2010.

Public and Environmental Health Service (1995) *Waste control systems: standard for the construction, installation and operation of septic tank systems in South Australia*, South Australian Health Commission, Australia. Available at <http://www.dh.sa.gov.au/pehs/publications/Septic-tank-book.pdf> accessed 18 May 2010.

Public and Environmental Health Service (1998) *Waste control systems: standard for the construction, installation and operation of septic tank systems in South Australia: supplement A – aerobic sand filters*, South Australian Health Commission, Australia. Available at <http://www.dh.sa.gov.au/pehs/publications/Supplement-A.pdf> accessed 18 May 2010.

The Department of Environment, Water, Heritage and the Arts (DEWHA) (2007) *Water Efficiency Guide: Office and Public Buildings*. DEWHA. Available at <http://www.environment.gov.au/settlements/publications/government/water-efficiency-guide.html> accessed 18 May 2010.