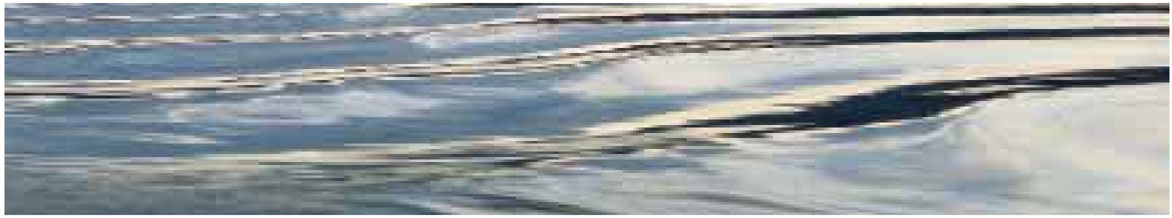
COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

INDUSTRY REPORT

Report 99/14

THE REUSE POTENTIAL OF URBAN STORMWATER AND WASTEWATER

DECEMBER 1999



Grace Mitchell
Russell Mein
Tom McMahon

COOPERATIVE RESEARCH CENTRE FOR
CATCHMENT HYDROLOGY

The Reuse Potential of Urban Stormwater and Wastewater

by

Grace Mitchell, Russell Mein and Tom McMahon

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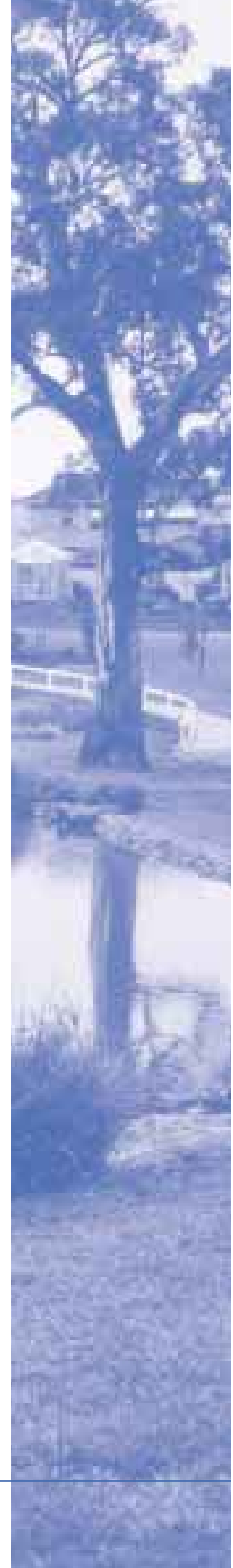

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F o r e w o r d

This Industry Report is one of a series prepared by the Cooperative Research Centre (CRC) for Catchment Hydrology to help provide agencies and consultants in the Australian land and water industry with improved ways of managing catchments. Since we published our first CRC Industry Report in 1997, the response has been overwhelming. It is clear that land and water managers appreciate material written specifically for them.

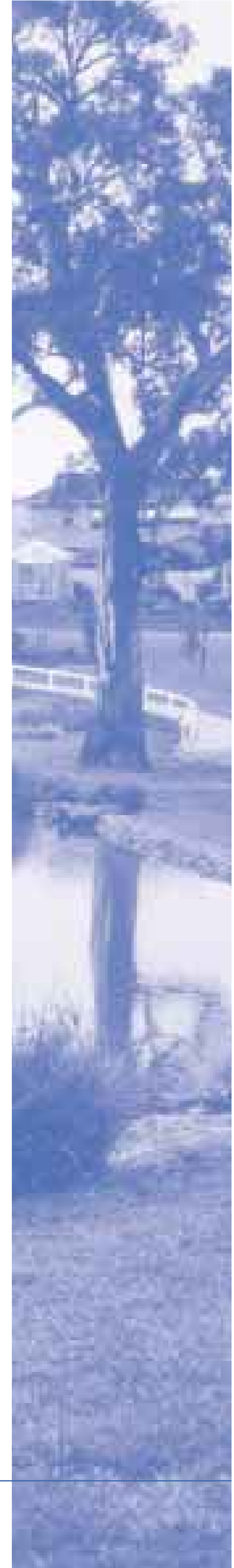
Through this series of reports and other forms of technology transfer, industry is able to benefit from the Centre's high-quality, comprehensive research on salinity, forest hydrology, waterway management, urban hydrology and flood hydrology. Publication of new CRC industry reports is usually accompanied by a series of industry seminars, which further assist in the assimilation of the material.

This particular Report presents key findings from Project C2 in the CRC's urban hydrology research program entitled, 'Design and management procedures for urban waterways and detention basins'.

The CRC welcomes feedback on the work reported here, and is keen to discuss opportunities for further collaboration with industry to expedite the process of getting these research outcomes into practice.

Russell Mein

Director, CRC for Catchment Hydrology



Preface

This report summarises the Cooperative Research Centre (CRC) for Catchment Hydrology's research on stormwater and wastewater reuse in urban areas, part of the CRC's Project C2, 'Design and management procedures for urban waterways and detention basins'. The aim of the project was to provide researchers with detailed information for developing guidelines for more effective management of stormwater infrastructure.

Project C2 has involved a range of studies, including an investigation of litter output and control; a study of flows into and out of a detention basin; monitoring pollution transport through a small urban pond; and investigating water quality and invertebrate populations in different urban streams. This report is concerned with another component of Project C2 - more efficient water use in cities. In particular, it deals with the feasibility of reusing stormwater and wastewater to reduce the demand placed on the potable water supplies in Australian cities.

The report has been written for CRC industry participants, urban water authorities, urban water and environmental consultants and the wider community.

ACKNOWLEDGMENTS

The authors thank the following individuals and organisations that provided information or support to this project:

- ACTEW, Bureau of Meteorology, Melbourne Water, Yarra Valley Water, City West Water and South East Water, each of which provided data
- Kim Pearce, Ross Knee, Gary Newton, Bill Steen and Paul Sheen of EcoWise; Audrey D'Netto, Fred McDonald and David Grinta of ACTEW; John Clark, Richarde Hulanicki, Lorraine Bliss and Melinda Martin of ACT Department of Urban Services
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- Francis Chiew, Hugh Duncan and Sharyn RossRakesh of the CRC for Catchment Hydrology and The University of Melbourne for technical support

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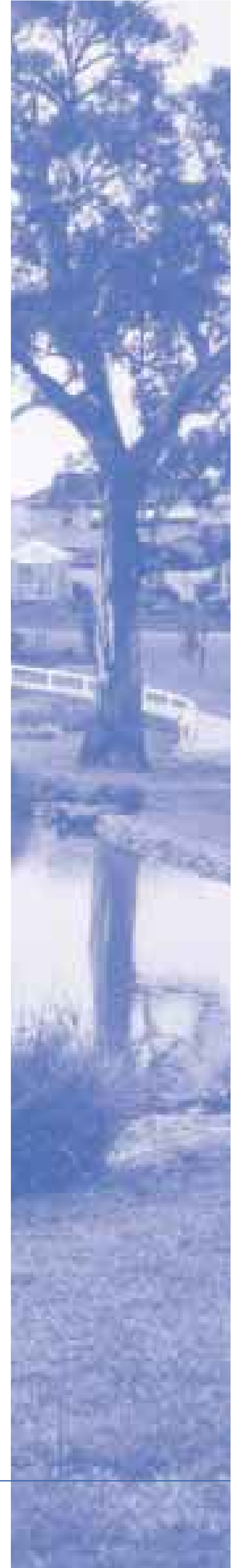


Stormwater runoff captured in a suburban pond can create an attractive water feature

INTRODUCTION

In Australian cities, separate stormwater and wastewater systems are the norm. This report begins with a brief outline of current water reuse levels and guidelines for reuse. It then presents a discussion of the factors that affect reuse potential in practice, showing what planners need to consider in designing reuse schemes.

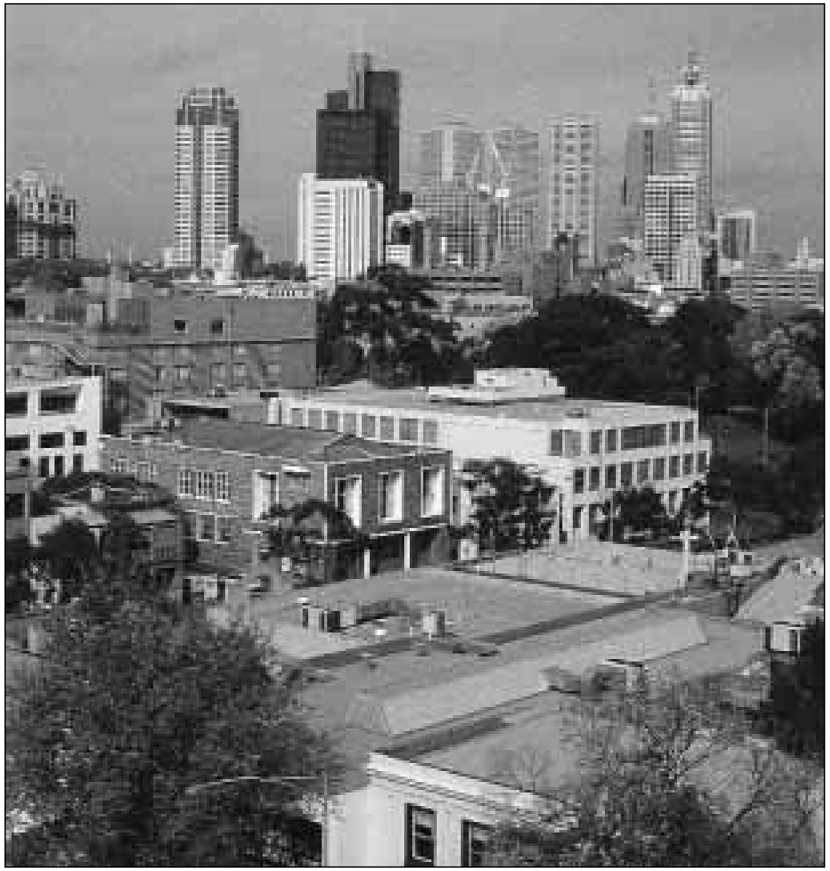
The CRC for Catchment Hydrology has developed a modelling tool ('Aquacycle') to simulate stormwater and wastewater pathways in an urban catchment and identify opportunities for stormwater and wastewater reuse. Test applications discussed in this report show that this model works well.

The report concludes with a discussion of simulation scenarios, in which different reuse schemes are evaluated for their impact on potable water demand, stormwater runoff quantity and wastewater flow. Because the model is generic, it is applicable to any urban catchment.

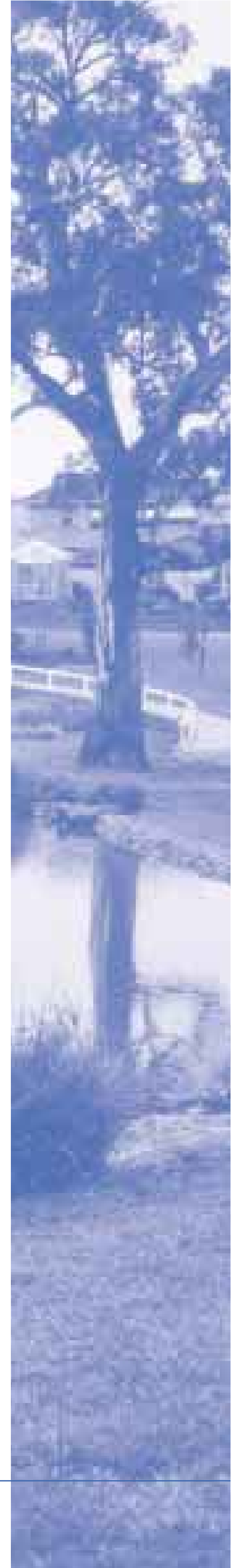
Stormwater flowing from an urban area

REUSE: THE CURRENT PICTURE

Urban areas cover a tiny fraction of Australia's land area, but account for 20% of the water consumed each year. To meet this demand, most Australian towns and cities rely on importing large volumes of high-quality water (after treatment) from surrounding water sources such as rivers, groundwater and dams.



Urban areas such as the central business district of Melbourne are highly modified catchments



Treated wastewater discharging into Port Phillip Bay from the Western Treatment Plant

At the same time, large volumes of stormwater and wastewater are discharged, unused, from towns and cities. Typically, the amount of stormwater and wastewater discharged exceeds the amount of water imported into the area for water supply (Figure 1). About three-quarters of the water imported into urban areas is discharged as wastewater effluent. Wastewater is treated before being discharged to coastal waters or rivers, but the majority of stormwater flows into receiving waters without any quality improvement.

Many supply reservoirs such as this one are used to deliver water to urban areas

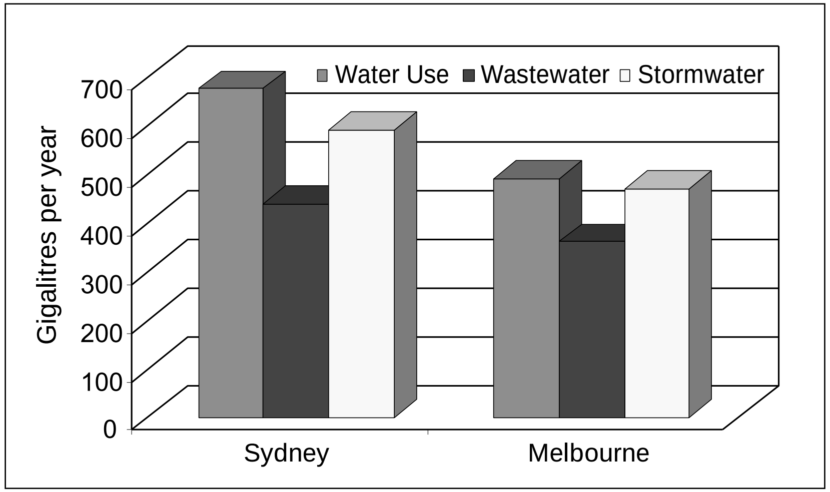


Figure 1: Water supply, stormwater and sewage flows in Melbourne and Sydney

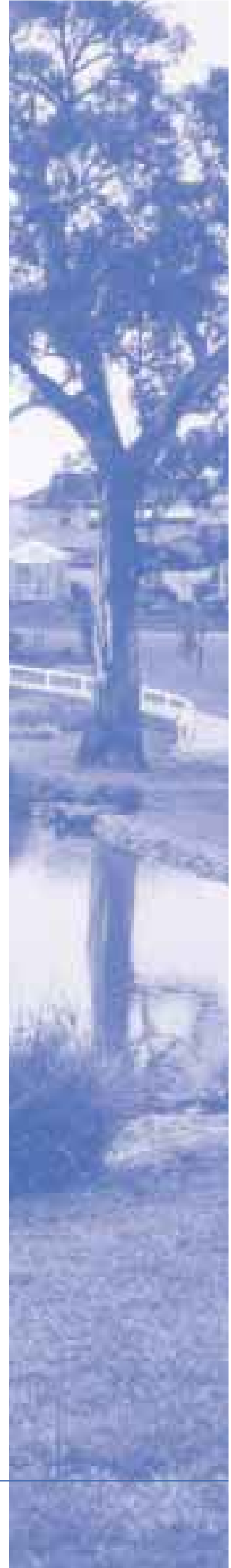
A large amount of infrastructure, from trunk mains to playground water fountains have been constructed

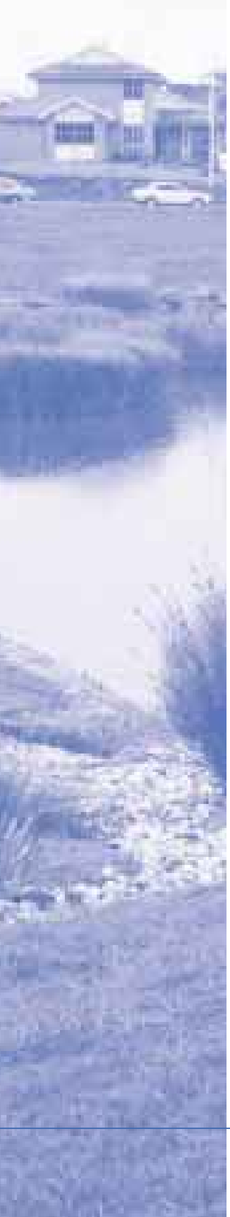
The urban stormwater drainage system includes underground pipes and open channels

Today, Australia's urban water authorities manage water supply, stormwater drainage and wastewater disposal separately. This approach dates back to the 19th century, when authorities found a positive correlation between poor sanitation and high mortality, prompting the development of piped water supply systems and sewers in towns and cities.

Water reticulation pipes were first laid in Sydney in 1844, when about 70 houses were connected to the system. The first sewers were commissioned in 1857, discharging into Sydney Harbour. Some years later, to alleviate the load on the sewerage system, authorities constructed a separate stormwater drainage network. Since then, the construction of urban water infrastructure in all Australian cities has largely been based on this 'separate system' approach.

Today, urban engineers and planners are beginning to evaluate alternatives to traditional water supply and disposal methods, such as the reuse of stormwater





and wastewater. These alternatives appear to offer many benefits. For example, less water is imported into towns and cities, and less stormwater and wastewater are discharged. Thus, stormwater and wastewater are being re-evaluated as resources to be utilised, rather than as waste products for disposal.

For urban water authorities, the traditional approach of separating water supply and disposal into separate components has generally outlived its usefulness. The restructuring of Australia's water industry has involved more emphasis being placed on higher environmental standards and protection. The wisdom of importing large volumes of high quality water into urban areas, and exporting even larger quantities of stormwater and wastewater out of them, is now being questioned. Consequently, water authorities are seeking a more holistic approach to urban water management.

EXTENT OF REUSE

At present, only a very small proportion of stormwater and wastewater is reused. CSIRO researchers have predicted that the proportion of wastewater reuse will rise by 200% in the period 1994 to 2020. However, this translates to a rise in wastewater reuse from 1% to only 3% of the total output.

The proportion of water supplied from stormwater is also small, although roof runoff collected in domestic tanks is an important source of water throughout Australia. Nationally, about 12% of households use stormwater from rainwater tanks, with the regional rate of use inversely related to the quality of mains water available. One-quarter of Adelaide's households, for instance, use rain tanks for their drinking water.

REUSE PROJECTS IN AUSTRALIA

In Australia, urban stormwater and wastewater utilisation schemes are typically small in scale, and are not integrated into the water supply and disposal system of the surrounding area. Two exceptions to this are outlined below.

Stringybark Grove is a medium-density development of 10 energy- and water-efficient townhouses in Sydney. Along with water-efficient fittings, roof runoff is collected in a communal tank for toilet flushing, garden watering and car washing. Initial figures show that these townhouses typically use 30% less water than traditionally serviced townhouses.

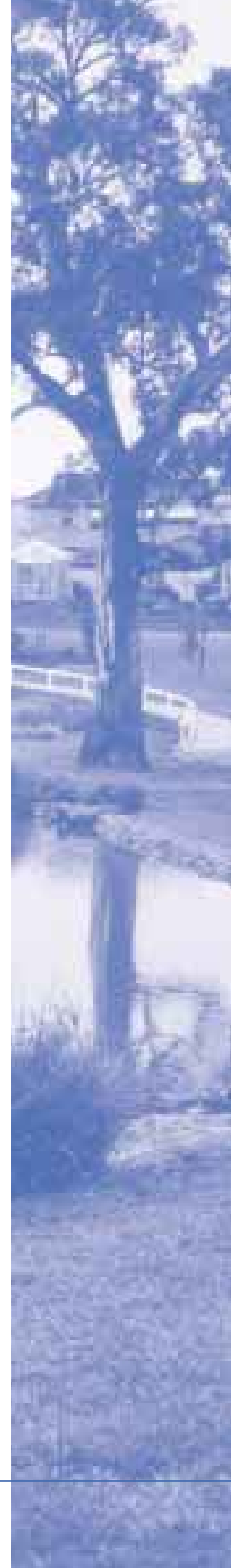
The Southwell Park scheme in Canberra is an example of 'water mining', where wastewater is extracted from the existing sewer system, treated to the required standard and used for irrigation. The water-mining plant has been retro-fitted within a built-up area, taking up little space and providing non-potable water.

Such innovative projects illustrate how Australia and other countries can meet future urban water needs without the need for a dramatic change in technology or infrastructure.

REUSE GUIDELINES

A number of guidelines concerning stormwater and wastewater exist in Australia. The National Health and Medical Research Council (NH&MRC) published guidelines in 1987 for the use of reclaimed water. More recently, the NSW Recycled Water Coordination Committee produced guidelines for urban areas. Other recent guidelines include those from the NH&MRC (1990) and those outlined in the National Water Quality Management Strategy (1996). The NH&MRC also updated the guidelines for supply of Australia's potable water in 1996.

Guidelines are not enforceable standards, and any reuse scheme still requires the approval of local health authorities and local government. Guidelines need to be interpreted on a case-by-case basis, due to the range of possible circumstances and implications. The absence of definite criteria has deterred many potential users, who have been cautious about practical and legal implications. Criteria that are more specific need to be developed to encourage the adoption of reuse practices in urban areas.



FACTORS AFFECTING REUSE POTENTIAL

The feasibility of a reuse scheme in an urban area is site-specific, affected by a range of factors such as:

- climate
- local water demand
- urban layout (e.g. population density, open space and housing type)
- reuse method
- local water quality
- degree of community acceptance
- environmental impact
- cost and standard of existing water supply and disposal systems

This section discusses climate, local water demand, reuse method used and water quality, as well as social, environmental and economic considerations.

CLIMATE

An urban area's prevailing climate influences the temporal pattern of stormwater runoff and water demand. The pattern of rainfall and evaporation and the extent of impervious surface cover determine the volume of stormwater runoff from an urban catchment. Climate also influences the volume and seasonality of urban water demand. An increase in outdoor water use during drier months of the year, for example, causes a seasonal rise in water demand.

To illustrate climate variation between Australian cities, the climates of Canberra and Sydney are compared (Figures 2 and 3).

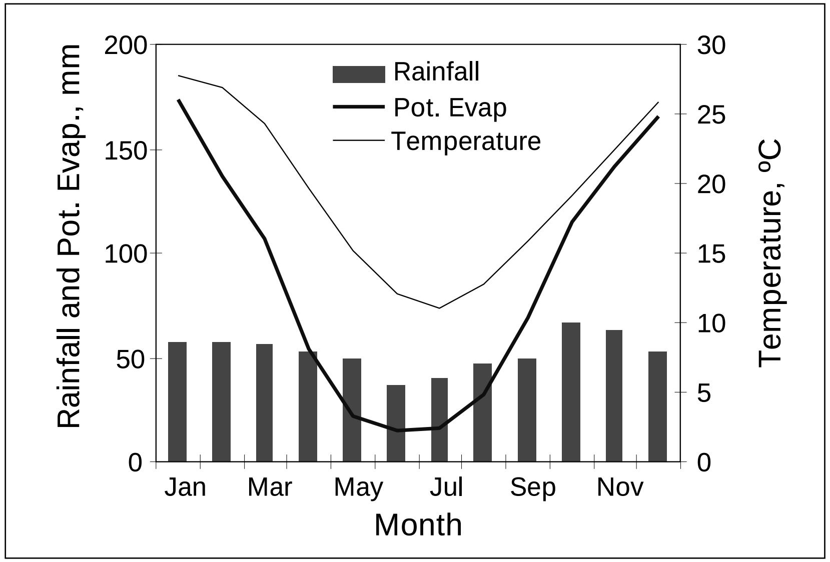


Figure 2: Canberra average monthly climate indicators

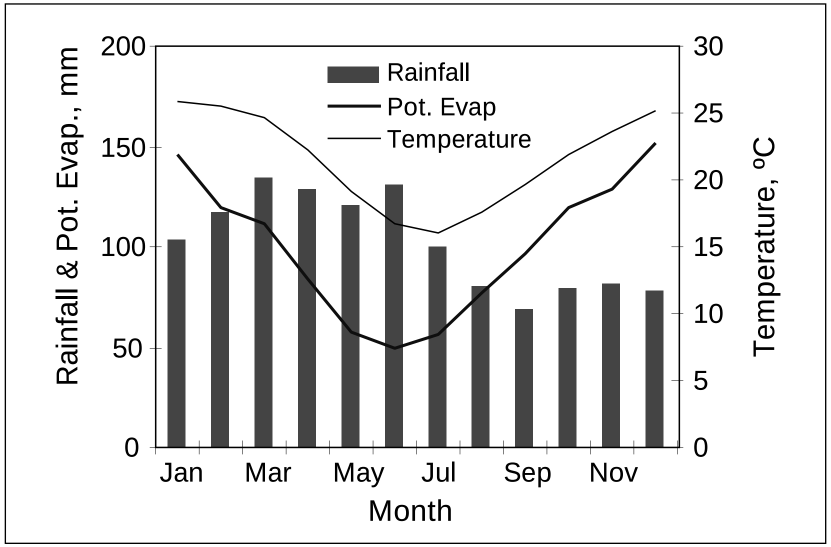


Figure 3: Sydney average monthly climate indicators

The comparison includes historic average monthly rainfall, potential evaporation and maximum temperature records for Canberra and Sydney.

Canberra receives an annual average 630 mm of rainfall, which falls fairly uniformly throughout the year. Sydney receives twice as much rain, falling in a more variable pattern, with most of it falling in late summer and autumn.

While average annual potential evaporation is similar for both cities, Sydney's monthly temperature varies less than Canberra's. In both cities, temperature and potential evaporation rates increase during summer, producing an increased demand for water. This seasonal demand is more pronounced in Canberra.

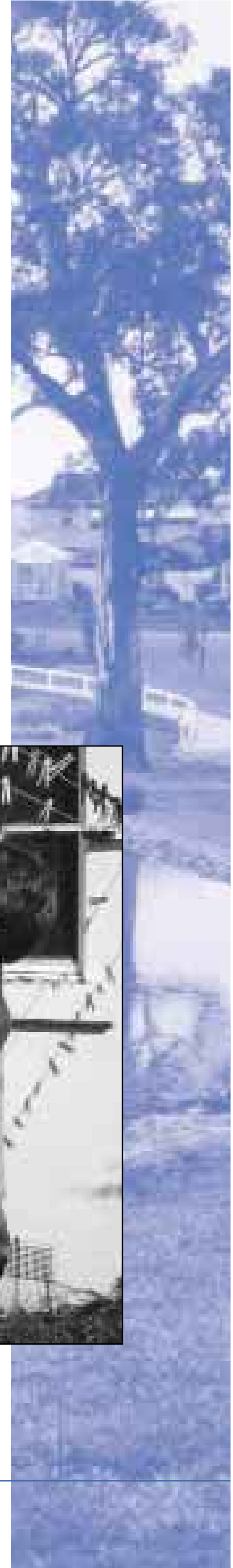
LOCAL WATER DEMAND

A household's total water use is influenced by many factors, the most significant being number of occupants, income per capita, water price and climate. Figure 4 shows the distribution of residential water use among indoor and outdoor applications in Canberra and Sydney. This shows that on average, the two cities vary in the proportion of water used for different household purposes and in the total amount used.

Figure 4: Breakdown of average household water use in Canberra and Sydney

Above: Kitchen water use is a small but important component of domestic consumption

Right: We use water for many different functions, such as washing clothes



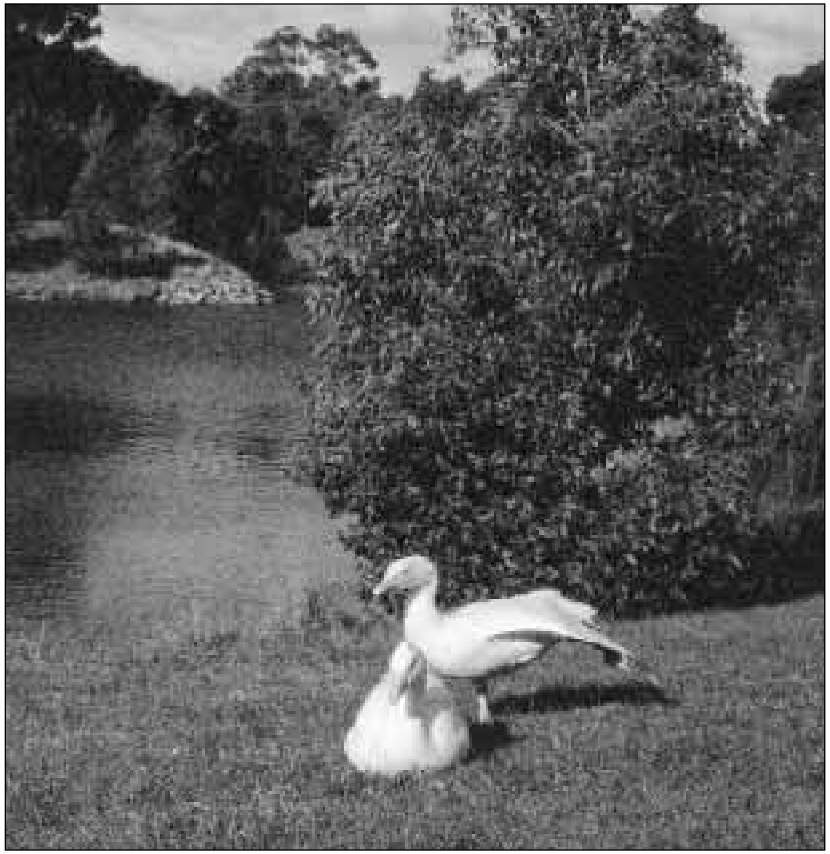
The quantity of outdoor water use is also affected by garden size. Outdoor use generally increases with distance from high-density units in city centres to more spacious suburban blocks. Garden irrigation accounts for some 90% of outdoor water use. The remaining 10% is used for activities such as filling swimming pools and washing cars and paths.

Water for recreation, such as this swimming pool is important to urban dwellerss

In Canberra, garden watering and other outdoor applications account for more than half the average annual household water use (220 kilolitres out of 400 kilolitres). While this rate is high compared to other cities in Australia, the rate of Canberra's indoor water usage is low by national standards. Sydney households are low-volume water users outdoors and average-volume water users indoors. The amount of water applied to gardens in Sydney is 40% of that in Canberra.

REUSE METHOD

Many water reuse methods exist, involving a range of water sources, water applications and spatial scales. A reuse method may represent anything from a small change to the present system, to a more dramatic change - such as the creation of self-sufficient land blocks, in which water supply and disposal occur on site.



Stormwater ponds provide habitat for wildlife

Wetlands play an important role in the ecological cycle

Groundwater bores provide an alternative source of irrigation water

At present, most wastewater use schemes take effluent from large centralised treatment plants in outer urban areas, far from many locations of potential demand for water reuse. In this situation, the cost of installing a dual reticulation network to return treated effluent to the urban area can be prohibitive. A better alternative may be local treatment and subsequent use of wastewater within nearby urban areas, or reuse of wastewater on site. The use of greywater on site for subsurface irrigation has been shown to reduce typical household water use by 30-50% in the city of Brisbane.

Compared to wastewater, stormwater initially appears to be a more suitable resource for urban use, because of its perceived higher quality. However, due to the variable pattern and quality of rainfall, substantial difficulties exist in reusing it. Options for stormwater use include:

- on site rainwater tanks
- community collection and storage for irrigation
- aquifer storage and recovery
- habitat restoration (such as a wetland or stream)

WATER QUALITY

The quality of water from a stormwater or wastewater reuse scheme must meet the requirements appropriate to its use. Authorities need to be aware of the quality of stormwater and wastewater to determine the water’s suitability for particular applications and the level of treatment required to meet these water-quality requirements.

Urban stormwater quality is influenced by many factors, including population density, land use, relative proportion of impervious area, waste-disposal and sanitation practices, soil type, climate and local construction activity. The interaction of these factors contributes to the variable quality of stormwater.

Wastewater quality, on the other hand, is generally affected by the water application from which it is derived. Blackwater is the water discharged from toilets and bidets, while greywater is the water discharged from all other bathroom, kitchen and laundry sources. Wastewater, especially if treated, has a more consistent level of water quality than stormwater, increasing its reliability as a reuse source.

SOCIAL, ENVIRONMENTAL AND ECONOMIC FACTORS

Wastewater and stormwater reuse strategies are difficult to implement effectively. Each strategy must be assessed not only in terms of cost and pricing, but also in terms of ecological responses, environmental impacts, social consequences, technical feasibility and flexibility.

A solution that is appropriate at one site may be inappropriate at another. Any assessment of a water reuse project must weigh up the economic, social and environmental benefits on the one hand, and the disadvantages on the other. The traditional cost/benefit approach fails to account adequately for environmental and social impacts. These impacts can be addressed with alternative assessment methods that take into account the many issues involved in urban water resource management.

CRC 'AQUACYCLE' MODEL

Evaluating the feasibility of stormwater and wastewater reuse schemes in detail has been a complex issue for the water industry. To assist in this process, the CRC for Catchment Hydrology has developed 'Aquacycle', an urban water balance model designed to carry out 'what if?' scenario modelling of traditional and alternative urban water supply and disposal schemes.

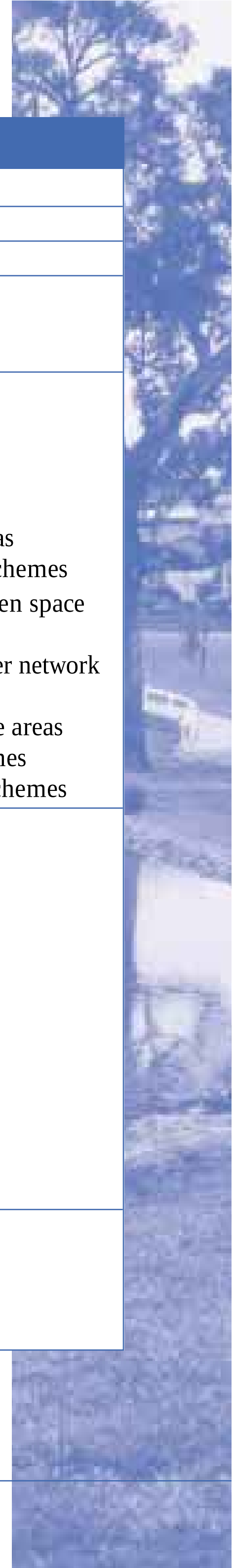
The water balance approach used to develop Aquacycle accounts for the movement of water through both the rainfall-runoff network and the supply-wastewater network, as well as cross-links between the two. Thus, water supply, stormwater drainage and wastewater disposal are integrated into a single framework.

The key features of Aquacycle are given in Table 1. Input to the water balance is in the form of precipitation and imported water, which then pass through the system; output is in the form of evapotranspiration, stormwater or wastewater. Aquacycle can 'store' stormwater and wastewater separately, and utilise them as supply sources for non-potable water applications, according to user specifications. Hence, stormwater and wastewater outputs can be re-routed back into the urban water system as water supply sources.

Aquacycle can use several spatial scales (unit block, cluster and catchment) to model a variety of reuse schemes. The unit block - representing a residential house lot or an industrial site - is the smallest scale at which water supply and disposal can be managed. A cluster consists of a number of unit blocks, as well roads and public open spaces, which together represent a neighbourhood. The catchment-scale model is made up of a number of clusters. The clusters contained within the catchment may, or may not, have significantly different characteristics such as residential density, land use, percentage of impervious area and hydrologic response to a rainfall event.

Table 1: Key features of Aquacycle

Item	Description
Temporal scale	Daily time step
Spatial scales	Unit block, cluster and catchment
Surface types	Pervious, roof, paved and road
Input requirements	Site characteristics Indoor water usage profile Daily precipitation and evaporative requirements
Operations: *Unit block-scale*	Indoor and outdoor water use Stormwater runoff Groundwater recharge Wastewater discharge Evapotranspiration from roof, paved and garden areas Unit block-scale, stormwater and wastewater reuse schemes
Cluster-scale	Stormwater runoff from road surfaces and public open space Leakage of the reticulation system Inflow and infiltration of stormwater into the wastewater network Groundwater recharge, storage and baseflow Evapotranspiration from road and public open-space areas Cluster-scale stormwater and wastewater reuse schemes
Catchment-scale	Catchment-scale stormwater and wastewater reuse schemes
Supply and disposal options: *Unit block-scale*	Imported water Rain tank Direct sub-surface greywater irrigation On-site wastewater treatment and reuse
Cluster scale	Imported water Cluster scale stormwater storage and reuse Cluster scale wastewater treatment and reuse Aquifer storage and recovery
Catchment scale	Imported water Catchment scale stormwater storage and reuse Catchment scale wastewater treatment and reuse
Model Output	Stormwater, wastewater, and imported water use Stormwater and wastewater yield Evapotranspiration Storage status Performance of selected reuse options



Because the factors (see previous section) that determine the quantity of stormwater and wastewater available, and the demand for water, can vary significantly, the user is expected to input information about the area being modelled. If this information is not available, the user can make assumptions, and test the sensitivity of results to these assumptions.

AQUACYCLE STRUCTURE

Figure 5 shows the structure of Aquacycle. The configuration of pervious area surface stores and groundwater store is based on AWBM or the Australian Water Balance Model (Boughton 1993), a partial area saturation overland flow model. The use of partial areas divides the catchment into regions that produce runoff (contributing areas) during a rainfall-runoff event, and those that do not. These contributing areas vary within a catchment according to antecedent catchment conditions, allowing for the spatial variability of surface storage in a catchment. The use of the partial area saturation overland flow approach is simple, and provides a good representation of the physical processes occurring in most Australian catchments. This is because daily infiltration capacity is rarely exceeded, and the major source of runoff is from saturated areas.

When one or both pervious surface stores are saturated, excess rainfall is divided into pervious surface runoff, groundwater recharge, and stormwater infiltration into the wastewater system according to the parameters set by the user. The groundwater store then drains according to a simple recession function, creating base flow.

Actual evapotranspiration from pervious areas is calculated as a linear function of soil moisture based on Boughton's simplification of the work of Denmead and Shaw. This is calculated separately for each of the two pervious area storages.

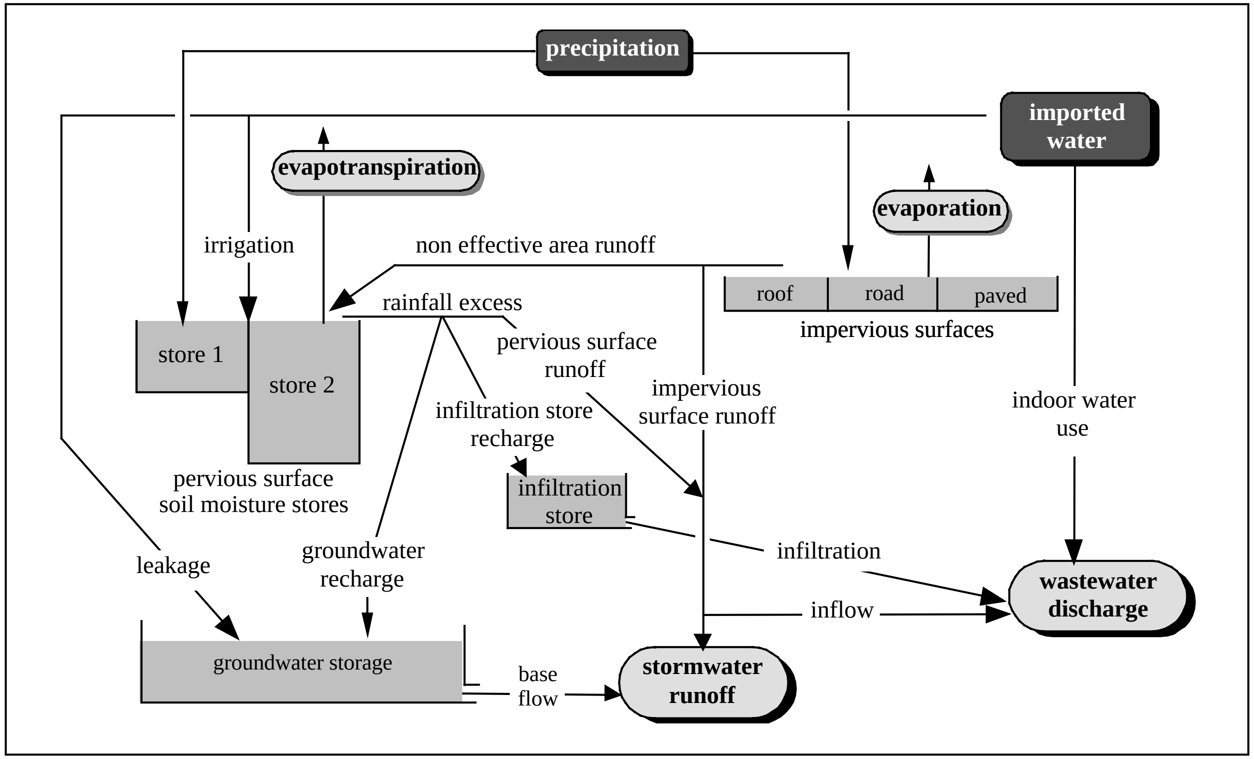


Figure 5: Structure of Aquacycle

Impervious surfaces (roof, paved and road areas) are represented as a single store, which overflows when full. The effective impervious area represents the proportion of impervious surface runoff directly draining into the stormwater drainage system; the rest of the impervious surface runoff drains onto adjacent pervious areas. The water retained in these stores represents the initial loss of rainfall due to interception and depression storage. These impervious surface stores are depleted by evaporation.

Stormwater inflow into the wastewater system is estimated as a proportion of total surface runoff, and enters the wastewater system directly.

Leakage is calculated as a user-specified proportion of the imported water, and is added directly to the groundwater store. Water use is separated into indoor and irrigation components. Indoor consumption is further divided into kitchen, bathroom, laundry and toilet use. The amount of water required for indoor use thus varies with household occupancy, and is specified in an input file. All indoor water use is normally discharged to the wastewater system.

The quantity of irrigation water applied to gardens, parks and sports grounds is influenced by the water requirements of the plants being grown, and the decisions or preferences of the gardener. The decision to irrigate has been formulated as a function of minimum soil wetness. Irrigation water is applied whenever the soil wetness level drops below a ‘trigger’ level specified by the model user. It can be calibrated to fit the observed garden water patterns of the area being simulated.

AQUACYCLE PERFORMANCE

Aquacycle has been tested using data collected from within Canberra’s Woden Valley region. While the model performed well in this catchment, it needs to be tested on catchments with different climates, land use, drainage

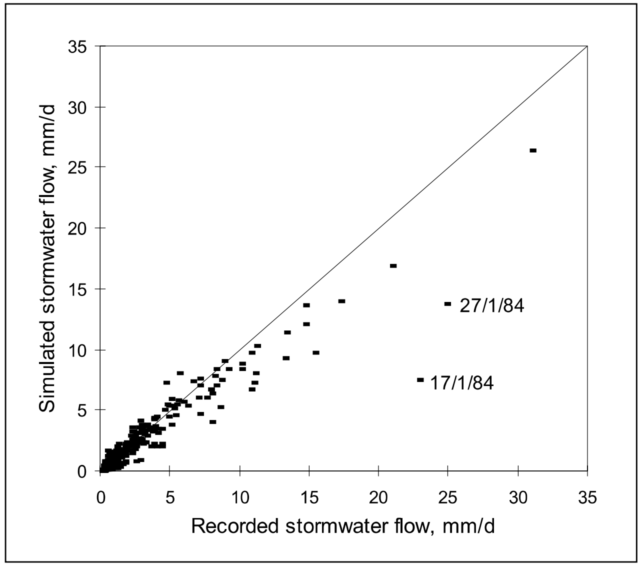


Figure 6:
Daily simulated stormwater flows plotted against recorded storm-water flows for Yarralumla Creek at Curtin (Woden Valley, Canberra) during the model validation period

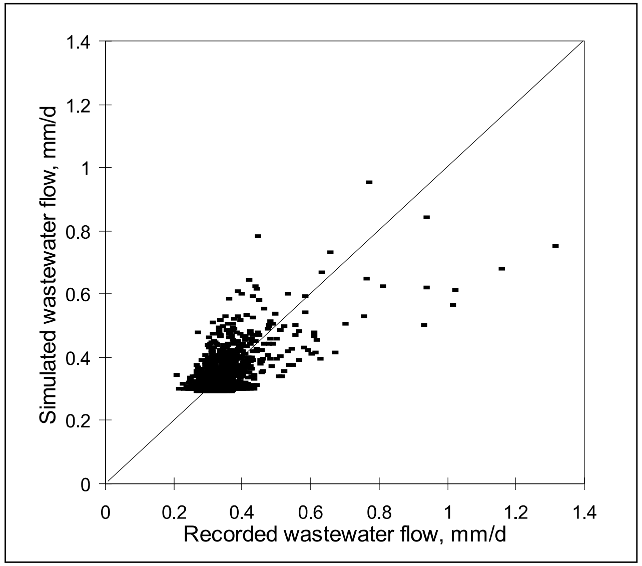
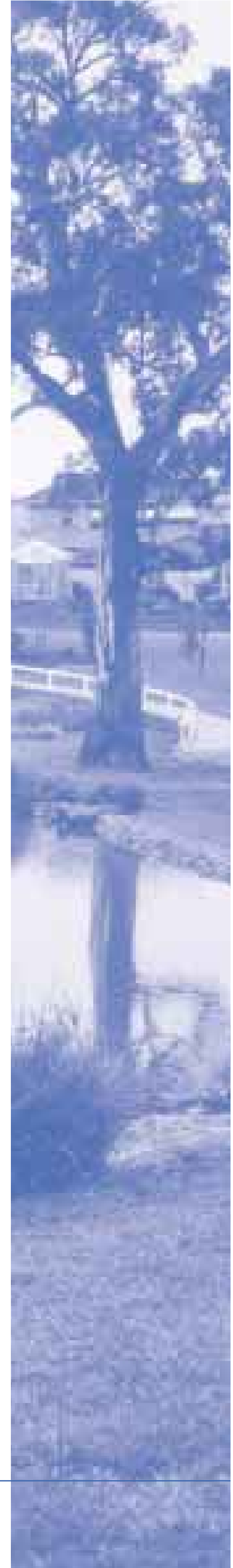


Figure 7:
Daily simulated wastewater flows plotted against recorded waste-water flows at Woden Woolshed (Woden Valley, Canberra) during the model validation period



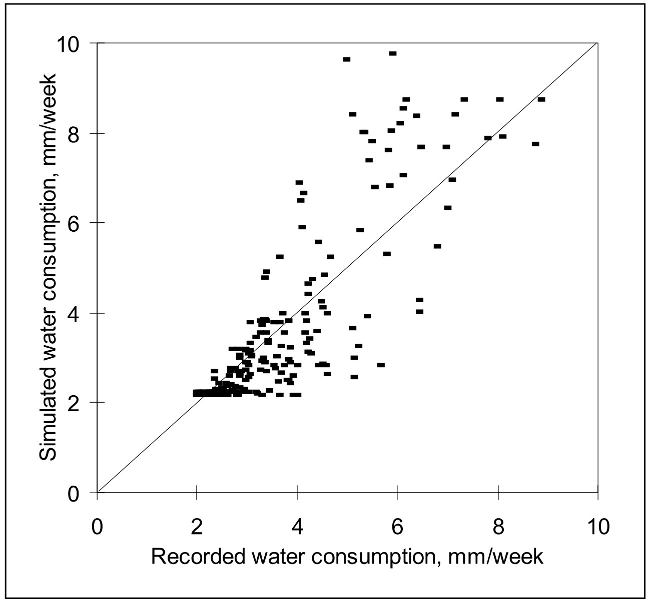


Figure 8: Simulated weekly water consumption plotted against recorded water consumption for the Woden Valley (Canberra) during the validation period

methods and topography. Figures 6, 7 and 8 illustrate Aquacycle's performance in simulating water consumption, stormwater runoff and wastewater discharge within the Woden Valley region of Canberra.

AQUACYCLE LIMITATIONS

At present, Aquacycle cannot predict water quality. The range of stormwater and wastewater reuse options available in the model have been selected on the basis of water quality requirements - for example, a user can select untreated greywater as a source for direct subsurface irrigation, but not for drinking water.

There is no flow routing within Aquacycle. It was developed to assess the total quantity of water moving through the urban water cycle, rather than estimate peak flow or produce an event hydrograph. In most urban catchments, surface runoff would flow out of the catchment in a matter of hours. Therefore, there is no need for flow routing when using a daily time step.

Several urban hydrological processes are not included in Aquacycle, such as imported water application to impervious surfaces, wastewater overflow, stormwater pipe infiltration and leakage, and wastewater pipe leakage. These processes are omitted because they represent minor pathways of water flow within the total urban water cycle or cannot be quantified for the purposes of modelling.

AQUACYCLE AVAILABILITY

The Aquacycle software and accompanying user manual is available from the CRC for Catchment Hydrology (users will be requested to sign an agreement with the CRC for the use of the Aquacycle software and manual). The software is written in the Microsoft Visual Basic™ program for Windows™ as a stand-alone computer application, and may be run in Windows 95. It is assumed that the user is familiar with the operation of standard Windows features, such as pull-down menus.

Before installing Aquacycle, the user should ensure the following minimum hardware and software requirements are satisfied:

- 1.44 Mb (megabyte) floppy-disk drive
- at least 32 Mb of Random Access Memory (RAM)
- hard disk with 50 Mb of available disk space for installation and result simulation
- Windows-compatible pointing device

Further information on Aquacycle and user requirements can be obtained via the CRC website at www.catchment.crc.org.au

AQUACYCLE SIMULATIONS

This section presents a series of alternative stormwater and wastewater reuse simulations in the form of case studies. These illustrate the 'what if?' modelling capabilities of Aquacycle, and the effect that reuse can have on the supply and disposal requirements of a typical urban area. Of the four scenarios presented, two consider reuse at the household scale, while the other two consider reuse at the catchment scale.

HOUSEHOLD-SCALE REUSE

As discussed, the prevailing climate conditions and local demand for water varies, depending on the location of a reuse scheme. The effect of these two factors on the performance of a rain tank is illustrated in the following comparison of the performance of a household rain tank in Canberra (Scenario 1) and Sydney (Scenario 2).

The residential block simulated here has a total area of 980 square metres (sq.m.), with a roof plan area of 210 sq.m. and a paved area of 40 sq.m.; the remaining 730 sq.m. is garden. The house is occupied by three people (the average occupancy rate), who maintain the garden to an average standard. Traditionally, the household would meet its water requirements through imported water, with disposal of stormwater and wastewater via the appropriate drainage networks.

For stormwater reuse, a 10-kilolitre rain tank has been installed for storage of roof runoff. Any overflow from the rain tank is directed into the stormwater drainage network. The rain tank water is used for household uses, and any deficit in supply of tank water is met by imported water.

VARIATION IN RAIN TANK PERFORMANCE (CANBERRA AND SYDNEY)

In Canberra (Scenario 1), the demand water is, on average, three times greater than the supply of roof runoff (Figure 9). This means that a rain tank of any size would not meet the demand for toilet flush and garden irrigation water. Thus, the performance of a rain tank in Canberra is limited by demand exceeding supply. The 10-kilolitre tank provided 30% of the household demand for water, with nearly all available roof runoff being used (87% - see Table 2). The installation of the rain tank resulted in 30% less water being imported into the house block, and 66% less stormwater runoff from the house block.

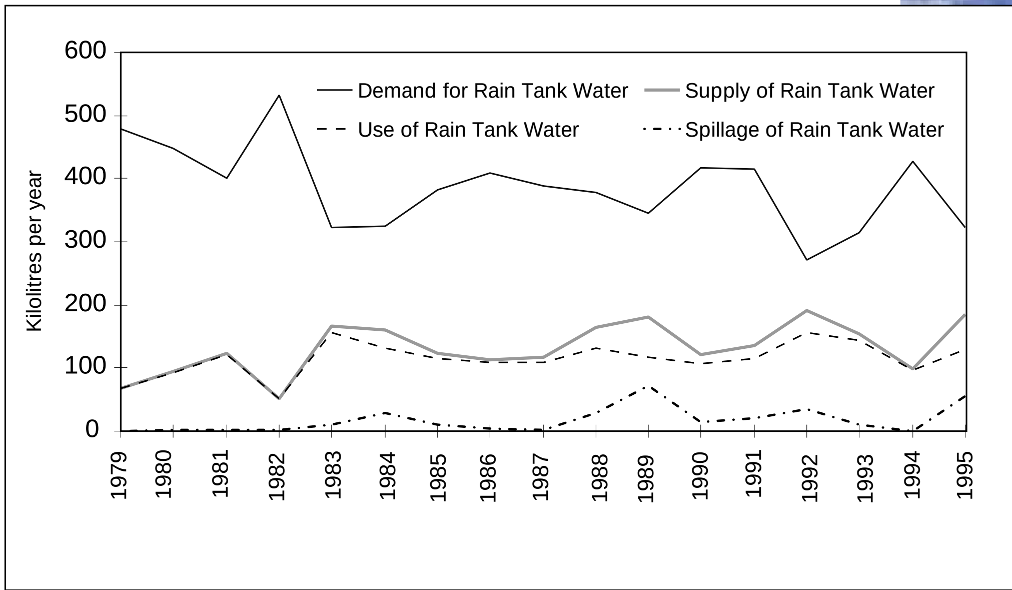


Figure 9: Annual rain tank performance for Canberra (Scenario 1)

Performance measure	Canberra (Scenario 1)	Sydney (Scenario 2)
Reduction in imported water	30%	48%
Reduction in stormwater runoff	66%	35%
Proportion of roof runoff used	87%	64%

Table 2: Annual average rain tank performance (10-kilolitre capacity)

In Scenario 1, the disparity between the relatively constant supply of roof runoff and the highly seasonal demand for garden irrigation did not affect the rain tank's performance. In other words, the rain tank system did not exhibit a seasonal pattern of spillage in winter months and supply deficit in summer months. This is because the rain tank's performance was not limited by the storage capacity, but by the demand for water exceeding the supply of roof runoff.

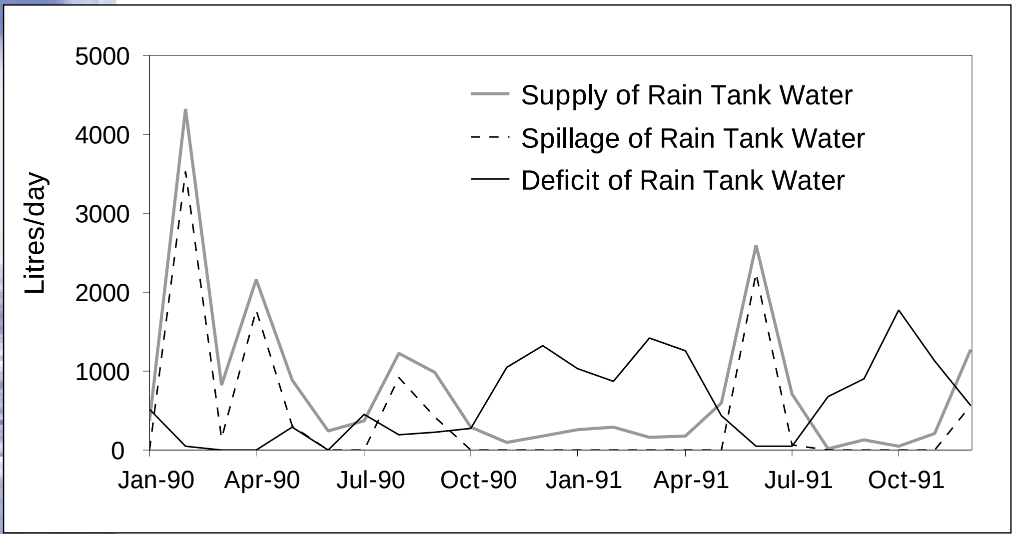


Figure 10: Sydney monthly rain tank performance for 1990-91 (Scenario 2)

In Sydney (Scenario 2), the disparity between annual water demand and annual supply of roof runoff was not as great as in Canberra. In four out of the 20 years of the simulation, supply actually exceeded the demand for toilet flush and garden irrigation water. Even so, only 47% of the demand for toilet flush and garden irrigation water was met by the rain tank system, and about 33% of the roof runoff was spilled from the rain tank. From year to year, the proportion of demand met by the rain tank varied from one-quarter to three-quarters.

The rain tank system in Scenario 2 is characterised by long periods dominated by either deficit of supply or spillage from the rain tank (Figure 10). Compared to the Canberra site, a higher proportion of the demand for toilet flush and garden irrigation water was met at the Sydney site, and there was a greater reduction in the importation of water. In contrast, the rain tank installation had a much smaller impact on the amount of stormwater runoff from the Sydney house than the Canberra one (35% and 66%, respectively - see Table 2).

CATCHMENT-SCALE REUSE

To illustrate the impact of stormwater and wastewater utilisation on the water supply and disposal requirements of a typical residential urban catchment, two catchment-scale reuse scenarios have been simulated using Aquacycle. Both scenarios are based in the Curtin catchment (Woden Valley, Canberra).

In Scenario 3, rain tanks were installed in all domestic residences within the Curtin catchment, and large stormwater storages were constructed within the two commercial precincts. Stormwater was used for toilet flushing and garden irrigation in domestic residences, and also used for open-space irrigation in the two commercial precincts. The rain tank sizes ranged from

4 to 15 kilolitres, depending on the combination of roof area, garden area and household occupancy in each suburb. The large stormwater storage located within the commercial precinct of Mawson had a capacity of 1,500 kilolitres, while the storage in Phillip had a capacity of 12,500 kilolitres. To improve water quality, the first flush of roof runoff was diverted into the wastewater system, rather than being allowed to flow into the rain tank.

Stormwater runoff captured in a suburban pond can create an attractive water feature.

In Scenario 4, wastewater treatment plants were installed within each suburb of the Curtin catchment. The treated effluent was then used for residential toilet flushing and irrigation, as well as public open-space irrigation. Each treatment plant contained a storage tank, which retained the effluent until it was required. The capacity of these tanks ranged from 500 to 1,000 kilolitres. If the storage capacity at the treatment plant was exceeded, the unused effluent was returned to the wastewater system and was available for use by downstream urban clusters.

PERFORMANCE OF CATCHMENT-SCALE SCENARIOS

The impact of Scenarios 3 and 4 on the annual water balance is presented in Figure 11. Stormwater reuse (Scenario 3) resulted in a 14% reduction in the quantity of water imported into the catchment, and a 16% decrease in the output of stormwater. The additional load on the wastewater from the first flush of roof runoff was counteracted by decreased illegal inflow of stormwater, resulting in little change in the wastewater output. (When the total amount of stormwater runoff is reduced, due in this case to the installation of rain tanks, the amount of stormwater inflow will decrease).

Analysis of the simulation results for Scenario 3 showed that roof tanks provided 30% of the demand for toilet and garden irrigation water over the 17-year simulation period. The relationship between roof size, garden size, occupancy and rainfall meant that rain tanks could not meet the observed

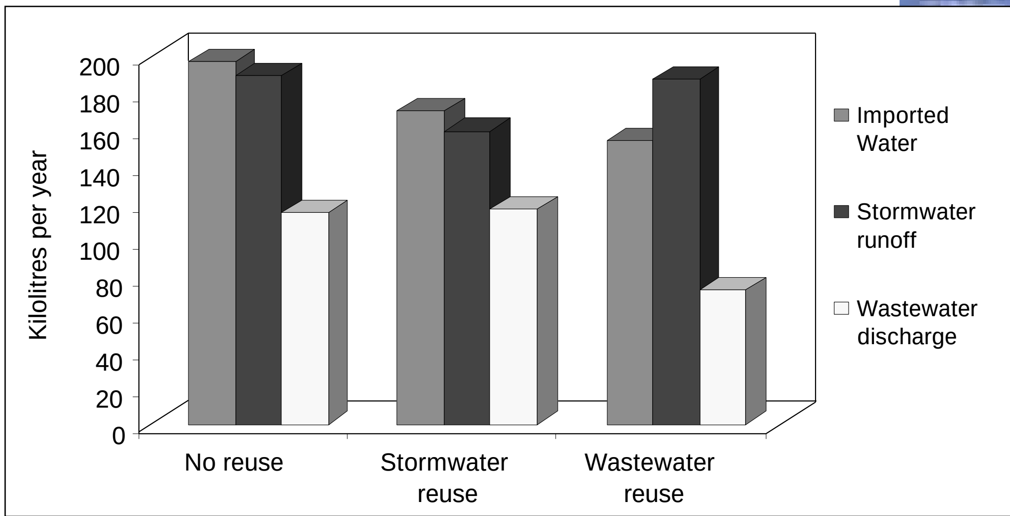


Figure 11: The impact of reuse on the water balance of a Canberra catchment

demand for water. On a suburb-by-suburb basis, the percentage of demand met by the rain tanks ranged from 12% to 44%.

Wastewater reuse (Scenario 4) resulted in a 22% decrease in the quantity of water imported into the Curtin catchment, and a 37% decrease in the output of wastewater, compared to a traditional water supply and disposal set-up. At the catchment scale, the wastewater treatment plants provided 46% of the demand for residential toilet flushing and irrigation, and public open-space irrigation. On a suburb-by-suburb basis, the percentage of wastewater supply used by the scheme ranged from 28 to 71%. This range was due to a combination of factors, such as the size of the area irrigated and domestic toilet-water demand within a suburb, as well as the suburb's position within the catchment. The further down the wastewater drainage network a suburb is positioned, the greater the available supply of wastewater due to the greater 'upstream' area contributing to the wastewater treatment plant.

Both scenarios had a significant impact on the supply and disposal of water in the Curtin catchment. The utilisation of wastewater at the community scale (Scenario 4) would have the greatest effect on the import and export of water to and from the catchment, but this approach would require considerably more infrastructure than would be needed for Scenario 3.

Neither scheme was able to meet all of the irrigation and residential toilet water requirements. In Scenario 3, insufficient supply of roof runoff was the limiting factor in the scheme's performance. In Scenario 4, the annual supply of wastewater exceeded demand. However, due to the mismatch between the temporal pattern of supply and demand, much of the wastewater was not utilised. Significantly larger storages would be required to meet the demand for wastewater.

CONCLUSION

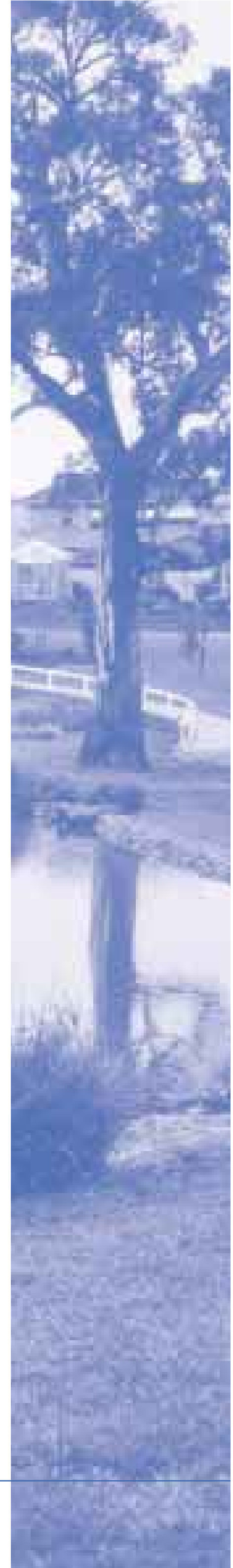
Importing large volumes of potable water into urban areas, and exporting even larger quantities of stormwater and wastewater out of them, has been questioned in the last few years. Alternatives to these traditional methods of water supply and disposal, such as the use of stormwater and wastewater, are receiving increasing attention. These alternatives appear to offer many benefits, including reducing the volume of potable water imported into an urban area, and reducing the volume of stormwater and wastewater discharged.

A range of factors - including regional climate, local water demands and the method of reuse - determine the effectiveness of a stormwater and wastewater reuse scheme in replacing imported potable water. This report has explored the impact of climate, local water demand and reuse method.

The CRC's Aquacycle is a generic model that can be applied to any urban area. The model is designed for 'what-if?' scenario modelling of alternative urban water supply and disposal schemes. The model works over a range of spatial scales - unit block, cluster and catchment. Aquacycle can 'store' stormwater and wastewater, and utilise it as a supply source according to user specifications. Aquacycle, at present, cannot predict water quality.

Simulation results from Aquacycle show that stormwater and wastewater reuse can significantly reduce both the quantity of imported water, and the volume of stormwater and wastewater discharged from an urban catchment. For example, a 10-kilolitre rain tank installed in a Sydney house block could halve the requirement for imported water, and reduce stormwater runoff from the block by 35%. In another example, if wastewater treatment plants were installed within each suburb of a Canberra catchment and the effluent used for residential toilet flushing and irrigation, this could reduce the amount of water imported into the catchment by 22%, and reduce the wastewater output by 37%.

The utilisation of stormwater and wastewater as an urban water resource rather than a waste product offers an alternative to the present approach to water supply and disposal. Such alternatives hold the key to lessening environmental impacts while maintaining a high level of service to those living in towns and cities.



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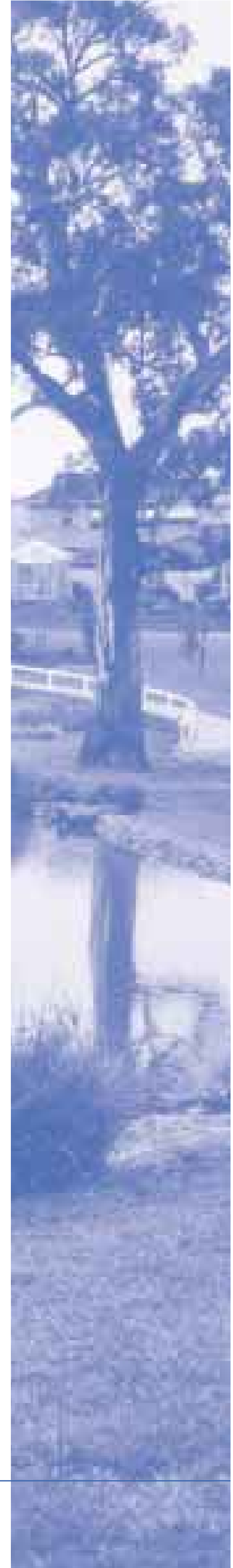

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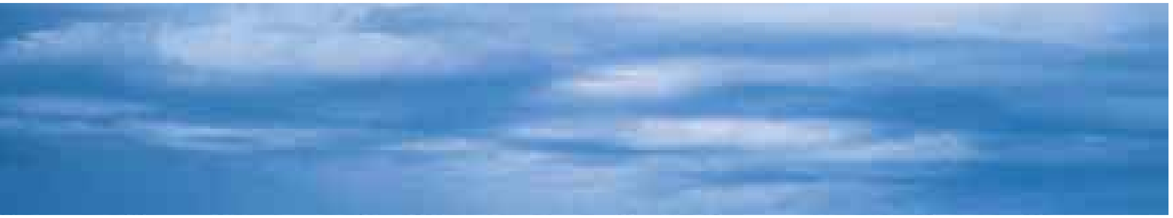

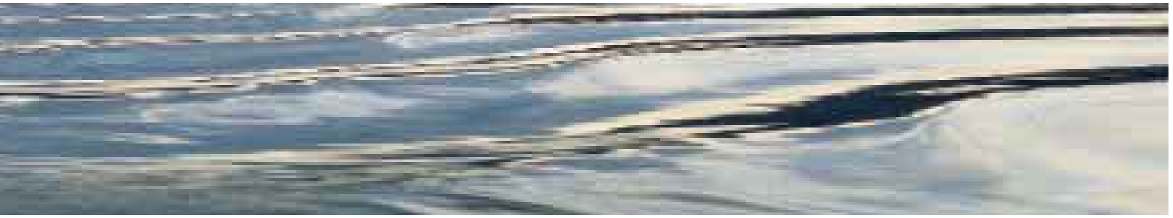

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- Brisbane City Council
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- CSIRO Land and Water
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- Department of Natural Resources, Qld
- Department of Natural Resources and Environment, Vic
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