# Interim Water Sensitive Urban Design Targets for Greater Adelaide

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Enquires should be addressed to:

Goyder Institute for Water Research
Level 1, Torrens Building
220 Victoria Square, Adelaide, SA, 5000

tel: 08-8110 9994
e-mail: goyder@csiro.au

**Project Team** : University of SA (Project Leader) and CSIRO

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# Executive Summary

## Background to Water Sensitive Urban Design and Targets

Water sensitive urban design (WSUD) is an approach to urban planning and design that integrates the management of the water cycle into the urban development process.

The State Government's *Water for Good* plan aims to transition South Australia to a 'water sensitive State' and ensure that South Australia continues to be acknowledged as a leader in water resources management. It anticipates this being achieved through implementing actions outlined in the plan.

*Water for Good* commits the State Government to introduce WSUD 'targets'. This is seen as a means to ensure compatibility between the intended performance of WSUD systems with WSUD principles and objectives established by State Government. Other governments across Australia have also indentified the value of WSUD targets and implemented a wide variety of voluntary and mandatory targets. Such targets encourage state government agencies, local government, developers and the wider community to adopt WSUD practices in new, renovated and existing developments.

The assessment of potential WSUD targets for Greater Adelaide - the focus of this research report - has been informed by work undertaken through the *'Institutionalising Water Sensitive Urban Design in the Greater Adelaide Region'* project completed in 2009. This project, managed by the (former) Department for Planning and Local Government, involved consideration of both a planning framework and potential WSUD targets, and a set of WSUD technical guidelines (*WSUD Technical Manual – Greater Adelaide Region*) to support the implementation of WSUD in the Greater Adelaide Region.

The WSUD technical guidelines support a 'vision' for WSUD in the Greater Adelaide Region that aims to stabilise and improve the health of the Greater Adelaide Region's coastal waters, and inland watercourses and groundwater systems, while maintaining and enhancing human health and reducing the ecological footprint of the Greater Adelaide Region.

Other aims of implementing WSUD articulated in the WSUD technical guidelines are to:

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

This vision and aims have been taken into account in the development of the WSUD targets recommended in this report.

## Need and purpose of interim targets

The South Australian government aims to secure South Australia's water resources in terms of quality and quantity beyond 2050. The Government's water security plan, *Water for Good*, includes a number of commitments to manage water supplies effectively, including the adoption of WSUD measures. While considerable work on targets has been carried out interstate, climate characteristics significantly affect the performance of WSUD systems. One of the primary purposes for developing interim targets for Adelaide is that they are appropriate for the region and that local data such as climatic information is used.

Through the *'Institutionalising Water Sensitive Urban Design in the Greater Adelaide Region'* project, potential WSUD targets were identified in three main areas:

- Mains water conservation
- Stormwater runoff quality
- Stormwater runoff quantity

*Mains water conservation targets*

Possible mains water conservation targets were developed with the goal of reducing mains water demand by householders in Greater Adelaide. Such targets are a common theme across Australia, particularly in response to dry weather conditions over the previous decade. It was important to consider current water conservation measures in the development of an appropriate mains water conservation target.

*Stormwater runoff quality targets*

Stormwater runoff targets were considered with the goal of improving the quality of stormwater flows from new development. Stormwater quality improvement targets are currently in place in multiple locations across urban and regional Australia. This includes every Australian state capital except Adelaide. In South Australia, stormwater quality improvement targets are enforced by the SA EPA in Mt Gambier, as well as by local governments including City of Onkaparinga and City of Salisbury.

The proposed target will assist towards goal of reducing the amount of suspended solids, nitrogen, and other pollutants that enter Adelaide's coastal waters, which have been identified through the *Adelaide Coastal Waters Study* as impacting on the health of Adelaide's coastal sea-grasses. The quality targets should also support a mitigation of suspended solids, nutrients and other pollutants entering other waterways of the Greater Adelaide region, such as the River Torrens.

*Stormwater quantity targets*

Stormwater quantity targets were considered with a view to managing the flow rate and volume of stormwater runoff from new developments in the Adelaide region. The interim stormwater runoff quantity target aims to minimise in-stream erosion and thus reduce the transport of nutrients and sediment to receiving waters of the Greater Adelaide Region, including Gulf St Vincent for which the

Adelaide Coastal Waters Study final report identifies sediment and other pollutants in runoff as a key factor in the decline of sea grass along Adelaide's coast. The stormwater quantity target is achieved by limiting peak flows to the channel-forming peak flow of the natural catchment (termed the development of a "channel-forming flow management" or "waterway stability management" objective). The target also aims to minimise the change in frequency of disturbance to aquatic ecosystems by managing the volume and frequency of surface runoff resulting from small rainfall events (termed the development of a "frequent flow management" objective).

The stormwater quantity target should result in the detention of stormwater and potentially a reduction in flow peaks and volumes of runoff leaving the site during most storm events. This has potential to support catchment stormwater management objectives, including those relating to flood, the risk of which might otherwise be exacerbated from the deteriorating flow carrying capacity of watercourses due to in-stream erosion. However, it is important that flood management receives due consideration by relevant authorities – this will require appropriate consideration by authorities of the potential impact to, and from, urban development in relation to flood.

## A brief outline of the science behind the choice of interim targets

### Water conservation

The targets were developed with the knowledge that mains water demand has reduced on a per capita basis over the past decade due to drought conditions and the response of the community to state government education campaigns, rebates and restrictions. To explore the potential for further reductions in water use, and provide a basis for setting water conservation targets, a range of scenarios were defined and modelled that simulated the likely impact of different water conservation actions on indoor water demand in new dwellings. In defining the potential for reduced indoor water demand in new dwellings, the modelling considered existing minimum requirements set out for water efficiency in new households across Greater Adelaide. Water demand reduction scenarios for new homes were examined and compared to the expected indoor mains water demand of households with the required minimum water conservation measures. The analysis was conducted for a typical household with 2.4 persons. Estimated indoor mains water use was based on mains water supplied to SA Water domestic users according annual residential water use per connection as reported to the National Water Commission in 2011. Specific in house demand was based on end-use studies conducted in Brisbane and Melbourne. The scenarios explored were:

1. The current case (for Class 1 dwellings)
2. Expanded rainwater harvesting for indoor non-potable demand
3. Third pipe supply for toilet flushing
4. Demand management through uptake of water efficient washing machines and dishwashers.

### Stormwater Runoff Quality

The methodology adopted for developing stormwater runoff quality targets for the Greater Adelaide Region was based on methods used to develop targets for other Australian states and territories in Australia including Queensland and the Northern Territory. This methodology determined the most appropriate ‘footprint’ for a standard WSUD treatment system on an assumed development site based on the balance between the required treatment area (cost) and water quality improvement (benefit). After an analysis of suitable models, the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 4.10 was used for the development of stormwater runoff quality targets. The targets were then assessed by scenario testing, where treatment scenarios were applied to real catchments in the greater Adelaide region to assess the achievability of the adopted target.

### Stormwater Runoff Quantity

The hydrologic indicators used to assess the achievability of the stormwater quantity objectives were the annual volumetric runoff (AVR), the flow duration curve (FDC) and the 1.5 year ARI. The AVR and FDC analyses were used to identify the interim target for the frequent flow objective and the 1.5 year ARI was used to identify the interim target for the channel-forming flow management objective. It was assumed that a peak flow at 1.5 year ARI is adequate as a channel-forming flow of a natural stream in the Greater Adelaide Region.

The interim stormwater runoff quantity target was developed based on a modification of the procedures used for stormwater quantity management in Queensland. The modified procedures included analysis of both volumetric and frequent flow management. The stormwater runoff quantity analysis was carried out using the MUSIC model Version 4.10. It is recommended that the same approach be used by the users of the interim target when demonstrating achievement of the interim targets.

## Proposed interim targets and their application/limitations

### Mains Water Conservation Targets

It is recommended that the *indoor water demand target* for new dwellings be established at ***36 kL/capita/year or 100 litres/person/day.*** Table 1 provides background information on the selection of this target based on the modelling scenarios. This target is effectively supporting the current regime for new Class 1 dwellings and significant renovations in South Australia. Under the Building Code of Australia and the South Australian Housing Code, Class 1 buildings, including building extensions, are required to provide an additional water supply other than the mains reticulated supply. To meet this requirement conditions for rainwater tanks are provided. In addition to this, four-star WELS rated appliances are specified in the Building Code. Exceptions to the requirement for a plumbed rainwater tank are allowed for in buildings that can access another additional water supply, such as dual reticulated water supply systems or water from an approved bore.

Table 1 - Potential mains water savings by water efficiency and alternative sources for indoor demand

| | Household annual indoor mains water use (kL/hh/year) | Household daily indoor mains water use (L/hh/day) | Per capita yearly indoor mains water use (kL/person/year) | Per capita daily indoor mains water use (L/person/day) |
|---|---|---|---|---|
| **Scenario 1 - New dwellings**[1] | 87 | 240 | 36 | 100 |
| **Scenario 2 – Expanded rainwater**[2] | 70 | 190 | 29 | 79 |
| **Scenario 3 – Third pipe**[3] | 84 | 230 | 35 | 96 |

**Notes:**

[1] Indoor mains water use target for new Class 1 dwellings - average household (2.4 persons) with rainwater tank (as per SA Housing Code – 1 kL tank, connected to 50 $m^2$ roof area and plumbed for toilet flushing) and 4 star rated WELS appliances

[2] Example of expanded rainwater harvesting: indoor target for Class 1 dwellings - average household (2.4 persons) with rainwater tank (1 kL tank, connected to 100 $m^2$ roof area and plumbed for all approved indoor uses) and 4 star rated WELS appliances, medium rainfall (Kent Town)

[3] Third pipe: indoor target for class 1 dwellings - average household (2.4 persons) with piped non-potable water for toilet flushing and plumbed for all approved indoor uses) and 4 star rated WELS appliances

A key finding from the water use scenario analysis was that the greatest water savings were achieved through expansion of the minimum rainwater tank requirements (Scenario 2). Rainwater tank yield may be improved by first increasing the number of indoor connections, before increasing connected roof area and tank size. Through consultation with government agencies it was apparent that expansion of the rainwater tank policy required additional research into the economic efficiency of larger tanks, and practical issues such as the effects of coloured roof runoff on clothes washing. Furthermore, an increase in tank size only results in a small increase in rainwater yield, and the mains water reduction is not significant. In light of these issues it is not considered appropriate to expand the existing minimum rainwater tank requirements. There is some scope to increase the use of WELS rated appliances as more products become available and are cost effective to adopt. An alternative water supply (i.e. 'third pipe') to the household such as treated stormwater or wastewater for toilet flushing should also be encouraged. However, it should be noted that while this will contribute to a reduction in drinking-quality water, opportunities to reduce the consumption of mains water may also arise from a third pipe supply being utilised for appropriate outdoor uses, such as for the irrigation of private and public open spaces.

The proposed water saving target was reviewed in relation to schemes in other states aimed at water conservation in new homes, namely: BASIX (New South Wales), 5 Star buildings (Victoria), and the Queensland Development Code Mandatory Part 4.2 (South East Queensland). The review showed the interim target proposed was comparable to the performance being achieved for new dwellings in these regions.

## Stormwater Quality Improvement Targets

The recommended stormwater quality improvement targets are summarised in Table 2, including some commentary on how the achievement of targets may be demonstrated.

Table 2 - Summary of recommended stormwater quality improvement targets

| Pollutant | Recommended target |
|---|---|
| Total suspended solids | 80% reduction in annual load[a] |
| Total phosphorous | 60% reduction in annual load[a] |
| Total nitrogen | 45% reduction in annual load[a] |
| Litter/gross pollutants | 90% reduction in annual load[a] |
| [a] Load reduction may be demonstrated based on modelling procedures which compare proposed catchment design with an equivalent, untreated catchment. TSS, TP, TN and gross pollutant targets are based on, and may be assessed by, modelling in the eWater software MUSIC Version 4.10. Equivalent targets for MUSIC Version 5, released during the period of this research, is provided in Appendix D. | |

The ability of recent residential developments in the Greater Adelaide Region to meet these targets was assessed using the MUSIC model Version 4.10. Developments included a single allotment, a single residential allotment subdivision (1 dwelling into 2), a multi-allotment or 'cluster' development, a high rise development and a greenfield subdivision. It was found that implementation of WSUD was able to achieve the targets in Table 2 in all circumstances, with the exception of the high rise residential scenario, where limited open space was available for treatment systems. It is acknowledged that some developments may not be able to achieve the proposed water quality targets. In such cases, it may be possible to make up for this by implementation of a fee, export offset or export permit trading system. It is understood that the City of Onkaparinga has already applied a pollutant export based fee system onto developments which cannot meet their designated water quality targets. The funds from this are used to assist in the design and implementation of council-led WSUD retrofit projects in areas of need across the local government area.

The development of targets reinforced the need to design WSUD measures appropriately within MUSIC, including the adoption of suitable vegetation and soil parameters that reflect the system design. For this reason, it is highly recommended that guidance is available to clearly identify:

- Suitable design and material characteristics that have been used for WSUD measures in the Adelaide region, including the commercial availability/feasibility of soil media (where relevant).
- Suitable parameters to reflect environmental conditions in Greater Adelaide within the MUSIC model, ideally in the form of MUSIC modelling guidelines for Greater Adelaide.

WSUD targets for oil and grease have also been actively supported by the South Australian EPA that has recommended them be applied to specific developments. At present, due to limitations on demonstrating performance of oil and grease retention, it is recommended that the current arrangements remain for commercial and industrial areas, and that further work explore the feasibility of oil and grease targets for residential areas.

## Stormwater Runoff Quantity Targets

The recommended interim target for achieving both the frequent flow management objective and the channel-forming (or waterway stability management) objective for cluster and multi-residential developments is to:

- Capture runoff equivalent to the volume generated from 5 mm of rainfall on connected impervious areas, for catchments with total impervious area up to 20%.
- Capture runoff equivalent to the volume generated from 10 mm of rainfall on connected impervious areas , for catchments with total impervious area greater than 20%.

The disposal of the captured runoff must be capable of drawing down the captured runoff within a day i.e. 24 hours. Capture of runoff can be achieved in a number of ways and consideration can be given to available storage in rainwater water tanks and surface depression storage. It is strongly recommended that further analysis is undertaken to improve and test the validity and achievability of stormwater quantity interim targets using a local catchment with relevant stream flow data.

At the cluster and development level suitable measures and management systems do exist that can be adapted to meet the water quantity based targets. Such measures include wetlands, ponds, infiltration basins or more local systems such as bioretention basins and raingardens (consideration will however be required as to which may be best suited to the specific locality and development). Using these types of measures it should be possible to implement quantity management systems for developments with 10 or more dwellings. For this reason it is recommended that the quantity targets be applied to cluster and development scales.

It is recognised that there will be instances where quantity targets will not be necessary or applicable. Such instances could include when runoff from a development drains directly (for example via a pipe) to either a stormwater harvesting schemes or large receiving water bodies. Another example where the quantity target may not apply are developments where topography is not favourable for gravity operated systems. It should be noted that stormwater quality and mains water conservation targets will still apply, together with local flood mitigation requirements as specified by the local council.

# Contents

# 1 Introduction

Water sensitive urban design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. The objectives of WSUD in the Greater Adelaide region were first published in the South Australian WSUD technical guidelines and are outlined in Box 1.1 (SA DPLG, 2010).

> ***Box 1.1 – WSUD Objectives***
>
> The overarching objective (or vision) of WSUD in the Greater Adelaide Region is to stabilise and improve the health of the Greater Adelaide Region's coastal waters, inland watercourses and groundwater systems, while maintaining and enhancing human health and reducing the ecological footprint of the Greater Adelaide Region.
>
> Other key objectives of implementing WSUD are to:
>
> - Move towards a natural flow regime (for example, lower flows to reduce erosion of creeks and improve or maintain ecological value);
> - Manage risk in relation to drought, flood, climate change and public health;
> - Protect, enhance, value and conserve water resources;
> - Encourage leading practice in the use and management of water resources so as to increase water efficiency, reduce reliance on imported water and apply at-source reduction of impacts on water quality, flooding, erosion and sedimentation;
> - Raise awareness and catalyse change in the design, construction and management of urban development and urban infrastructure; and
> - Recognise and foster the significant environmental, social and economic benefits that result from sustainable and efficient use of water resources.

The South Australian government has recognised the need to develop targets to implement WSUD in *Water for Good* (SA Office for Water Security, 2010), a plan to guarantee South Australian water resources up to 2050. The plan establishes several actions to manage South Australian water resources. In Part 6, the plan indicates that the South Australian government should "by 2013, develop and implement the best regulatory approach for South Australia to mandate WSUD, dovetailing with the plan for Greater Adelaide" (Action 67). *Water for Good* also proposed to "Introduce targets for WSUD by 2010" (Action 68). This study addresses the Action 68 by developing and recommending interim targets for WSUD in the Greater Adelaide Region, which is also an important step in the accomplishment of Action 67.

For the purposes of interim targets, the Greater Adelaide Region is considered to correspond with the regional boundaries presented in the 30 year Plan for Greater Adelaide (SA DPLG, 2010), as shown in Figure 1-1.

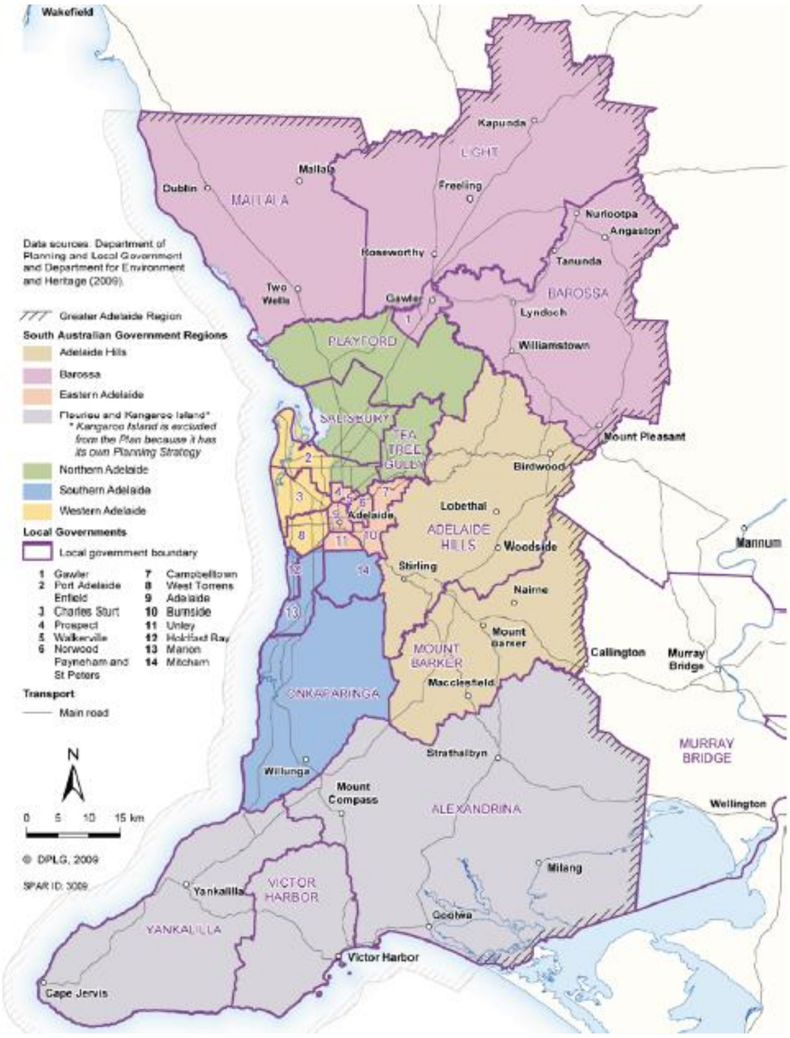


Figure 1-1 – The Greater Adelaide Region (SA DPLG, 2010)

To accomplish the objectives of WSUD, targets are proposed in three main areas:

- Mains water conservation targets (Section 2)
- Stormwater runoff quality targets (Section 3)
- Stormwater runoff quantity targets (Section 4)

## 1.1 The Intention of WSUD Targets

The targets developed in this study align with the WSUD principles that were published in the South Australian WSUD technical guidelines as shown in Box 1.2 (SA DPLG, 2009).

**_Box 1.2 – WSUD Principles_**

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

The guiding principles include to:

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

## 1.2 Stakeholders

Targets for water conservation, stormwater runoff quantity and quality already exist in areas of South Australia, including Mt Gambier in the South East (SA EPA, 2007), as well as in the City of Onkaparinga and the City of Salisbury. It is important that the existing policies, regulations and implementation measures for WSUD already in place in the Greater Adelaide Region are recognised in the implementation of WSUD targets.

In addition to existing local targets, a review of local council development control plans indicated an almost universal requirement for development to consider WSUD and/or WSUD principles in proposed new developments. The wording for these requirements is shown for a selection of councils below:

- City of Norwood, Payneham and St Peters Development Control Plan, p. 23-24

  *"Development should incorporate appropriate measures to minimise the discharge of sediment, suspended solids, organic matter, nutrients, bacteria and litter and other contaminants to the stormwater system and may incorporate systems for treatment or use on site."*

- Adelaide Hills Council Development Control Plan, Page 126

*Development should incorporate stormwater management techniques to contain the quantity, velocity, variability and quality of run-off to as near pre-development levels as practical, by means of but not limited to:*

*(a) directing roof stormwater overflow from rainwater tanks to soakage trenches or to retention/overflow wells or sumps where large roof catchments are involved;*

*(b) utilising grassed swales or natural drainage lines to accommodate the major flows from the land development; and*

*(c) incorporating stormwater systems designed to prevent entry of pollutants such as sediment, pesticides and herbicides, bacteria, animal wastes and oil, grease and waste water from vehicle cleaning processes, air conditioners and fire protection services pipework testing into receiving water.*

Although the importance of WSUD techniques are recognised by a majority of councils in the Greater Adelaide region, only two councils in the Greater Adelaide region were found to have specific WSUD targets in place, of which only one had a written requirement. Communications with local government planning and engineering staff indicated that some local councils were in the process of developing targets, including Yankalilla and Adelaide Hills.

The South Australian Environment Protection Authority (SA EPA) is also a key stakeholder in the development of WSUD targets. The SA EPA implements the Environment Protection Act 1993 (EP Act) to which the Environment Protection (Water Quality) Policy 2003 (WQEPP) is subordinate legislation. Although the WQEPP is under review and scheduled to be revised in 2011, consultation with the SA EPA indicates that WSUD targets are “unlikely to be in conflict with any revised WQEPP” (Pers. comm. SA EPA, see Appendix A). Furthermore, these targets are expected to be of benefit to key priorities in the SA EPA, including the achievement of goals within the current draft of the *Adelaide Coastal Water Quality Improvement Plan* (SA EPA, 2011). WSUD targets will support this by implementing targets for stormwater flow and quality control which will reduce sediment and nutrient loads exported in stormwater runoff from new developments.

The following organisations may also be affected by the implementation of interim WSUD targets (please note that this list is intended to be informative and not necessarily exhaustive):

- South Australian Department of Planning and Local Government (SA DPLG)
- Urban Development Institute of Australia (UDIA)
- Local government entities (and by association, the Local Government Association)
- SA Health
- SA Water
- Department for Water
- Stormwater Management Authority
- The climate change, housing affordability and sustainable neighbourhoods task force (*The 30 year Plan for Greater Adelaide*, pg. 141)

## 1.3 Scope and Assumptions for Water Sensitive Urban Design Targets

### 1.3.1 Project brief

The Department for Water is currently in the process of developing a South Australian Government policy on WSUD which will include interim targets. This project will review current targets from other regions in Australia and assist with the development of appropriate interim water use, urban runoff quantity and runoff quality targets which must be demonstrated by developments in the Greater Adelaide Region. Similar targets are already recommended by the Australian government, implemented to a varying degree by all Australian state and territory governments, and in addition by various local governments. A review of WSUD targets will be conducted including their development methodology, and appropriate targets will be developed based on conditions in the Greater Adelaide Region.

Where possible, recommendations will be consistent with state government agency regulations and initiatives including *Water for Good*, *The 30 Year Plan for Greater Adelaide*, the EPA Water Quality Policy, the Adelaide coastal water quality management plan, and the Adelaide and Mount Lofty Ranges NRM Plan. It is anticipated that further analysis and research will be required to finalise these targets by 2013 and conclude the implementation of WSUD in South Australia in accordance with Action 67 of the *Water for Good* plan.

### 1.3.2 Assumptions and Scope

The development of mains water use conservation, stormwater runoff quality and stormwater runoff quantity targets were carried out with the following scope and assumptions.

- WSUD targets were established using characteristics of the four rainfall zones indicated in the South Australian *Water Sensitive Urban Design Technical Manual* (SA DPLG, 2009). It should be noted that due to the range of conditions that recommended targets will apply to, it is assumed that the targets recommended in this report will be implemented as minimum values, and not take precedence over targets currently and subsequently produced at the local government level where local characteristics and goals may influence targets for water conservation and/or the control of stormwater runoff quality and quantity.
- The WSUD targets in this report were developed for residential development areas (i.e. commercial and industrial areas were excluded). The importance of targets for industrial and commercial land use is recognised by state government as an important issue. However, the variability in commercial and industrial land use and water use precluded the inclusion of this type of development in this short-term research project. The characteristics of industrial and commercial allotments and their water consumption have been included in subsequent research proposed to the Goyder Institute for Water Research. This research will include a review of commercial and industrial land use and water use across the Greater Adelaide Region.

## 1.4 Characteristics of the Greater Adelaide Region

### 1.4.1 Rainfall

The South Australian *Water Sensitive Urban Design Technical Manual* (SA DPLG, 2009) used data from four weather stations to characterise rainfall across the Greater Adelaide region. The stations used were considered representative of the major rainfall zones in the Greater Adelaide region. Figure 1-2 depicts these rainfall zones with coloured dots representing the station used for the analysis in this report, which were:

- Largs Bay (red dot) – 413 mm annual average[1]
- Adelaide Airport (yellow dot) - 450 mm annual average
- Kent Town (orange dot) - 562 mm annual average
- Kersbrook (blue dot) – 868 mm annual average

Data for these sites in Section 2 was extracted from patched point data sets[2]. Due to the requirements of short-timestep data, Sections 3 and 4 used rainfall measurements from the nearest continuously measured rainfall station, as noted in text.

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[1] The Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region used Largs Bay for the lowest rainfall band, however adequate lengths of historical data could not be obtained for this station in Section 2, which uses the nearby Port Adelaide station.

[2] http://www.longpaddock.qld.gov.au/silo/

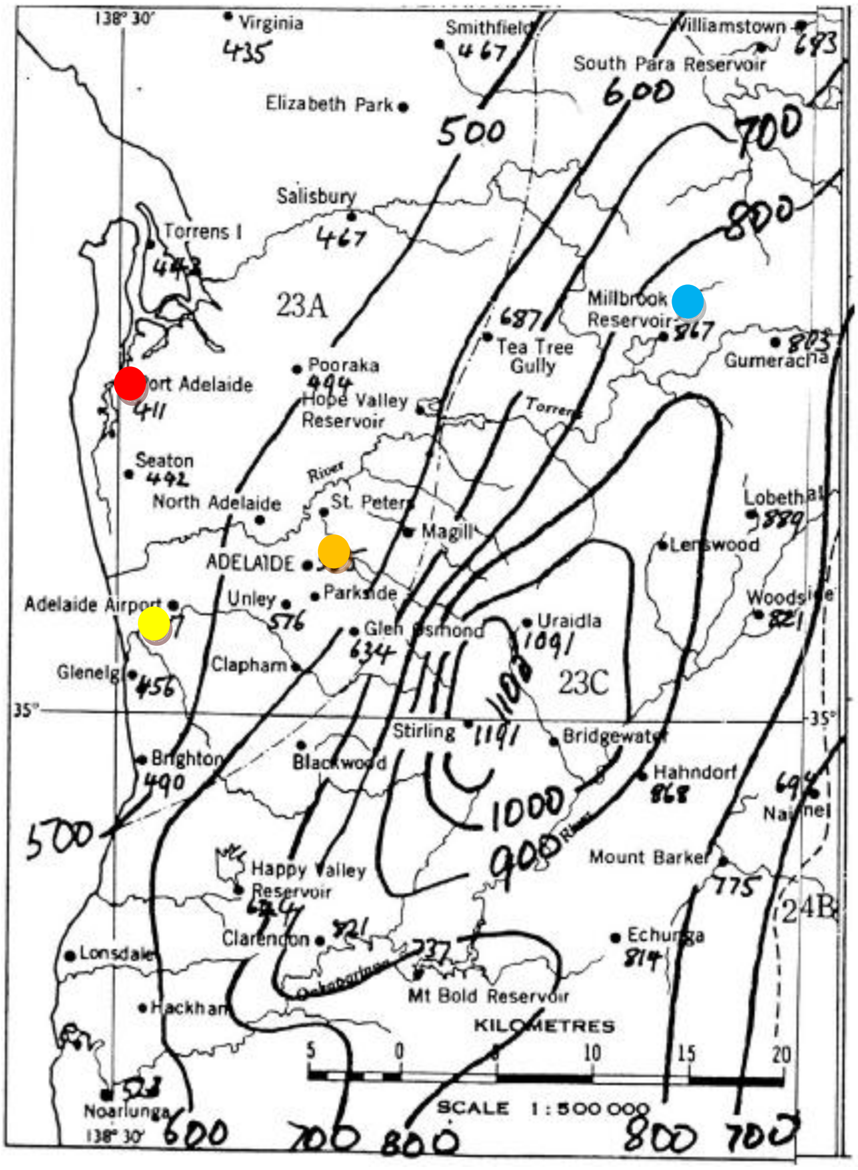


Figure 1-2 - Rainfall Zones in Greater Adelaide (SA DPLG [2009], pp.5 – 39)

Figure 1-3 shows the 29 year annual rainfall for the selected stations and the average annual rainfall over this period. Figure 1-4 plots the average monthly rainfall for each station, which shows that the precipitation pattern for all zones is characterised by dry summers and relatively wet winters. In each case, more than 70% of the rainfall occurs in the six month period between May and October.

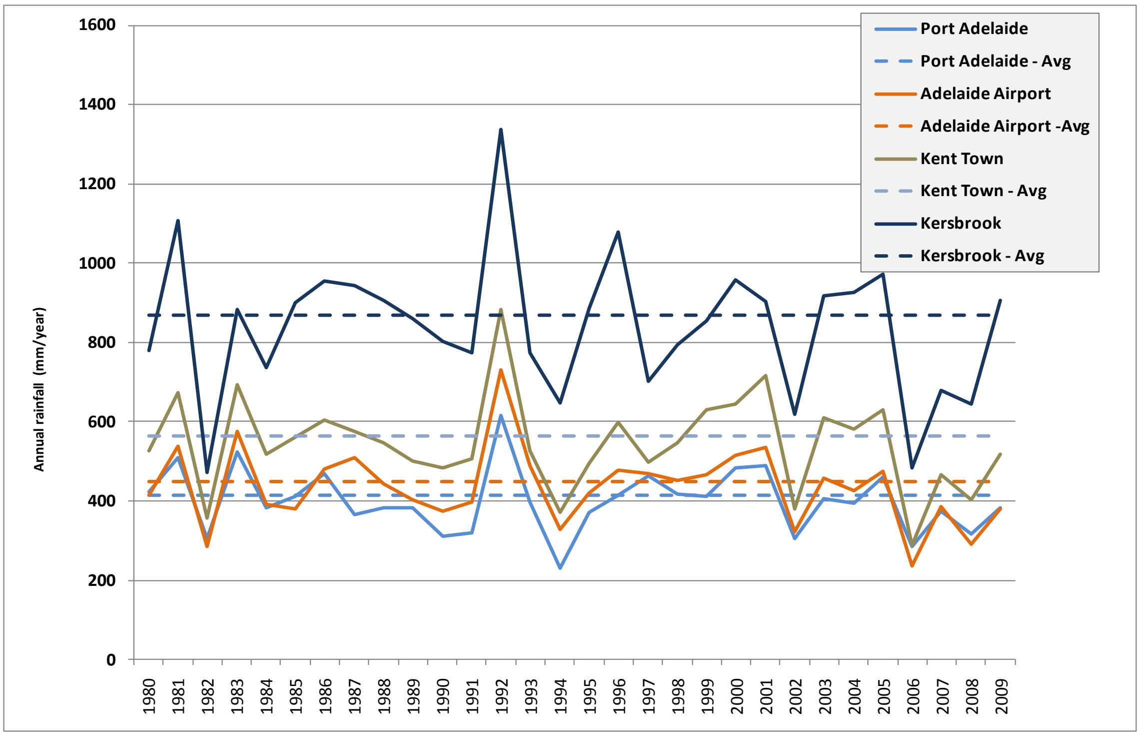


Figure 1-3 - Annual rainfall for the selected weather stations

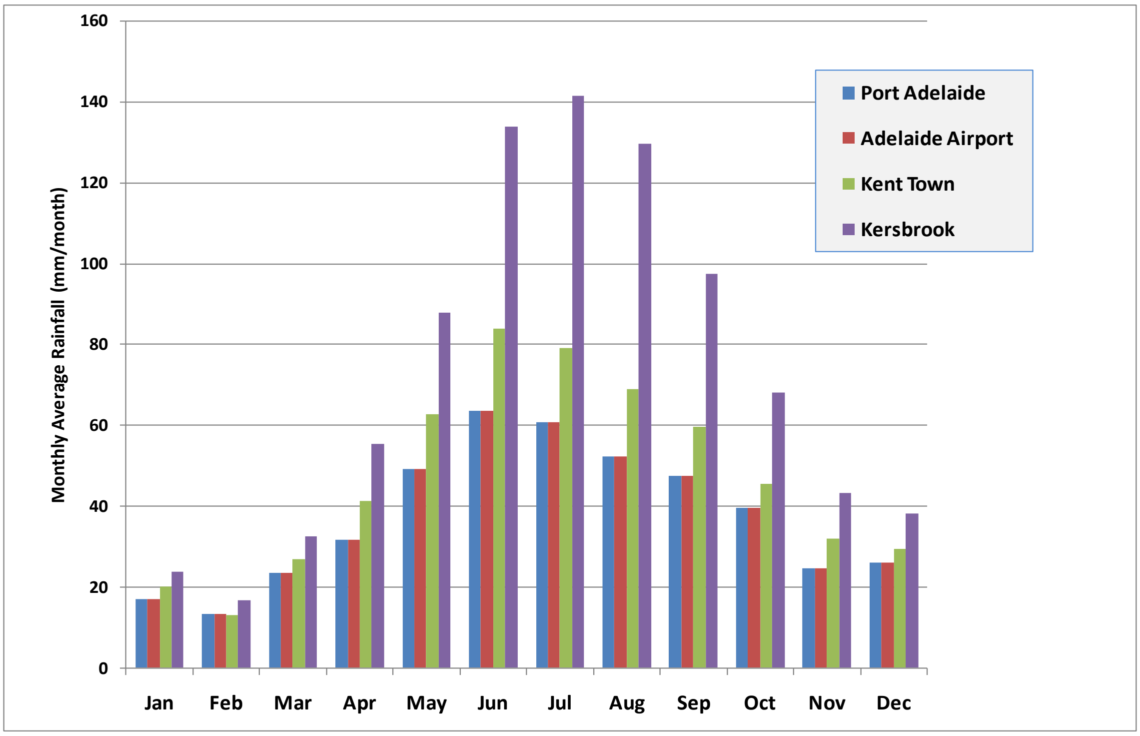


Figure 1-4 - Monthly distribution of rainfall for the selected weather stations

### 1.4.2 Evapotranspiration

Gridded annual evapotranspiration data were acquired from the Australian Bureau of Meteorology based on measured potential evapotranspiration from 1961 to 1990 (BOM, 2007b). Potential evapotranspiration data are illustrated for each of the four zones in Figure 1-5.

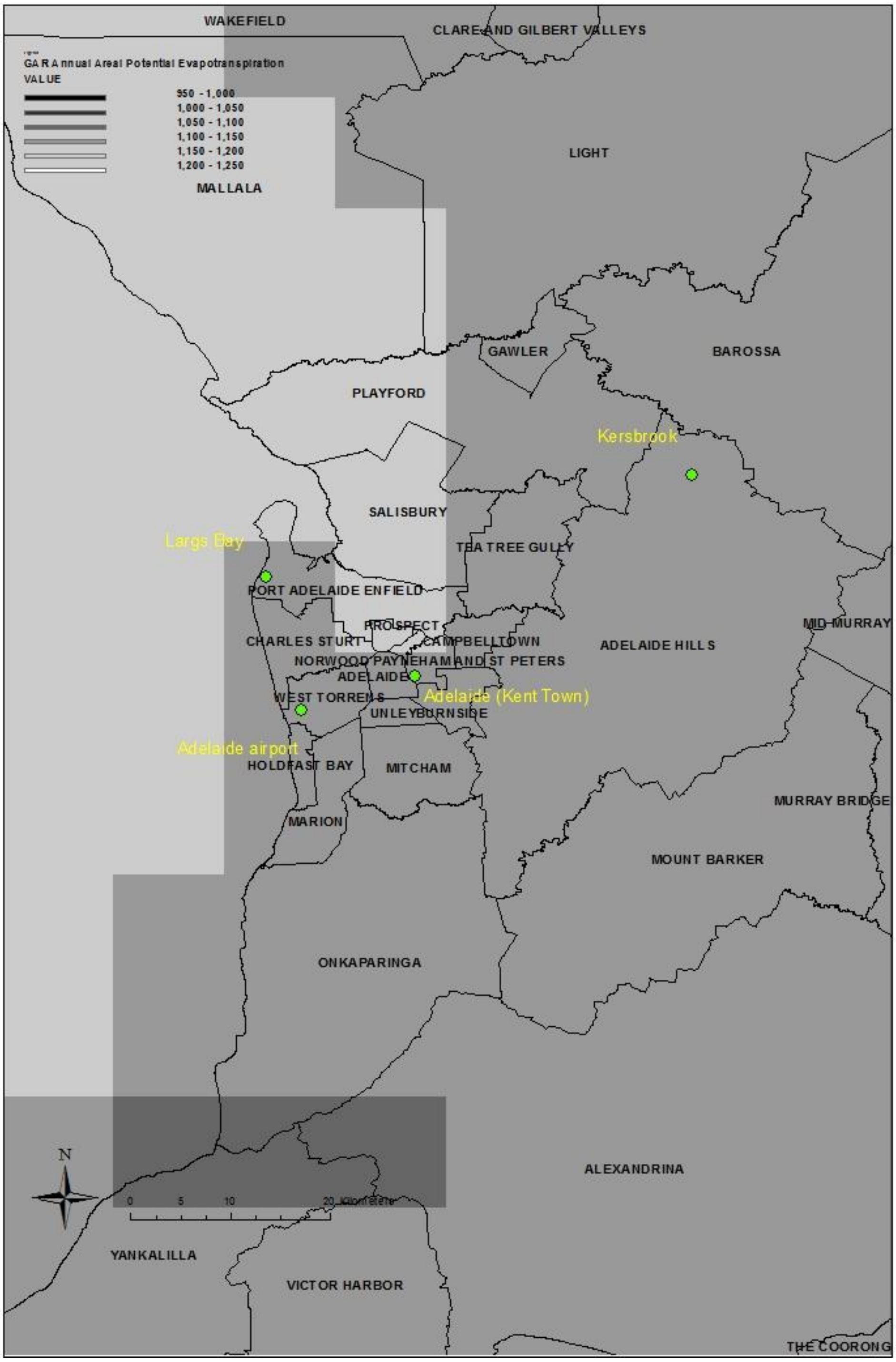


Figure 1-5 – Characteristics of potential evapotranspiration (PET) across the Greater Adelaide Region (adapted from BOM 2007b, 1961-1990)

## 1.5 Structure of Document

The remainder of the document is produced in three main sections (one for each target type). Sections are described as follows:

- Section 2 reviews and reports on the development of mains water consumption targets;
- Section 3 reviews and reports on the development of stormwater quality targets;
- Section 4 reviews and reports on the development of stormwater quantity targets.

Sections 2 to 4 also provide some commentary on the implementation of targets for policymakers. Recommendations for further research based on project findings are also discussed.

## 1.6 References

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# 2 Mains Water Conservation Targets

## 2.1 Introduction

In 2008, the Greater Adelaide region used approximately 163 GL of mains water. In the same period, *Water for Good* estimated that water restrictions and other demand management options had reduced water consumption in Greater Adelaide by 50 GL (Government of SA, 2010). *Water for Good* outlined strategies and actions to enable a sustainable water supply in the face of projected population growth and uncertainty in supply from traditional water sources. The strategies were designed so that water restrictions were not likely to be required more than once in 100 years (Government of SA, 2010). In this section of the report we review existing water conservation measures that have been implemented in South Australia, other Australian states and internationally. Modelling is then undertaken to explore the potential impact of different water conservation approaches in reducing household demand for indoor potable water in new dwellings. Based on this modelling, water conservation targets are proposed for indoor water demand in new dwellings in Greater Adelaide, which take into consideration the existing minimum standards for water conservation in new dwellings, climate variability and targets set in other Australian jurisdictions.

## 2.2 Target Scope and Focus

The interim water targets in this document propose performance based targets for indoor water conservation in new homes. GWA (2006) distinguished performance based targets and prescriptive water conservation targets. In prescriptive measures, such as building codes, there is no need for benchmarks and targets: as long as the dwelling has the prescribed water saving measures then it is considered to be compliant. A performance measure, while suggesting approaches to achieve a target, offers some flexibility in how a water conservation target is achieved. In a performance based approach to water conservation there is the need for benchmarks and targets to assess performance (GWA, 2006).

The interim water conservation targets focus on the residential sector. Non-residential water demand (i.e. commercial and industrial) is more heterogeneous in terms of water demand profiles and there is a paucity of baseline data. This makes it difficult to set a generic water conservation target that is appropriate across non-residential sectors. Non-residential water conservation programs are usually targeted at specific sectors, such as schools or restaurants. In South Australia, as part of the *Water for Good* strategy, all commercial and industrial customers that use in excess of 25 mega-litres per year are required to complete a water efficiency plan that helps to identify potential water conservation initiatives.

The residential water conservation target in this report focuses on indoor demand in new dwellings. New dwellings are considered because there is more opportunity to implement water conservation in new dwellings, through water efficient fittings and/or an alternative water source, relative to existing homes due the cost burden of retrofitting. Existing homes can provide a benchmark to evaluate the performance of water conservation in new homes.

The development of a water conservation target also focuses on water savings for the indoor component of household water demand. Indoor water demand per capita and per household is very similar across Australia (GWA, 2006). Outdoor water demand, which is mostly attributed to garden irrigation, varies considerably between seasons and also annually in response to climate, particularly rainfall. Garden irrigation is influenced by many factors including garden design, irrigation technology, householder behaviour, allotment size, and soil type. The heterogeneity of garden irrigation makes it difficult to develop a generic benchmark for water conservation, in comparison to indoor water use where patterns of demand are more predictable and detailed information for comparative analysis is available from end use studies.

## 2.3 Review of Existing Mains Water Conservation Targets

This section provides some background to the proposal of interim water savings targets for Greater Adelaide. Jeffrey and Geary (2006) provide the following schema for classifying water conservation policy instruments: economic instruments (e.g. rebates, tax credits, pricing), regulatory instruments (e.g. legislation, mandatory water restrictions, mandated standards), technological instruments (e.g. water efficient appliances, design infrastructure to reduce losses and leakage), and education instruments (media campaigns, demonstration sites, targeted engagement with major water users, school programs). These different instruments can be considered as either suasive (education and economic instruments), or obligatory (regulatory and technological). In many cases, the design of a water conservation policy will adopt a combination of approaches to reach the desired level of water savings. This review highlights some of the background to setting of water savings targets in other jurisdictions, how they have been implemented, and any lessons learnt that can be applied in proposing water savings targets for Greater Adelaide.

Before considering in more detail possible approaches for setting water savings targets, it is useful to first define what we mean by water savings. Samani and Skaggs (2008) made the point that "water conservation" will mean different things to different people, but in general it implies an act or policy that results in additional water for consumption without increasing raw supply. Water conservation can be achieved through changes in consumer behaviour that may be prompted by education, water restrictions or increases in price. Water conservation can also be achieved through increased efficiency by technological innovation and/or substitution with an alternative water source. Baumann *et al*. (1984) provides the following definition of water conservation: "Water conservation is any beneficial reduction in water use or in water losses that results in a net increase in social welfare, i.e. the resources used have a lesser value than those saved". For the purposes of the *Goyder Institute Interim WSUD Targets Project* water savings targets can be achieved by any action that reduces demand for municipal (mains) drinking water in an environmentally, socially and economically sustainable manner. The types of actions for saving water are consistent with the framework presented by Grant (2006):

- *Water conservation: doing less with less* – Essentially relates to behavioural changes such as limiting flushing of toilets, restricting washing of cars, taking shorter showers and reducing garden irrigation. The point is made that the acceptability of these changes are culturally dependent, and efficiency practices, discussed below, are more likely to have a higher degree of community acceptance than outright bans.

- *Water efficiency: doing the same (or more) with less* – Efficiency improvements mean the same function can be achieved with less water. Examples include: water efficient appliances, plant selection and landscape design to minimise irrigation requirements, and enhanced pressure or leakage management. This approach is not as sensitive to social acceptability, as it does not require a behavioural change or lifestyle adjustment.
- *Water sufficiency: enough is enough* – Optimisation approach, where similarly to efficiency, there should be no change in function. This option represents the interface between user change and technical innovation. Examples include: use of dual flush toilets, flow regulation, measured approach to garden irrigation and appliance design to minimise water use (e.g. sensors on hand washing taps).
- *Water substitution: replace water with something else* – Technical solutions that replace water in a process; for example, composting toilets, waterless urinals, use of air compressors for cleaning and dry cleaning
- *Water reuse, recycling and harvesting: closing the loop/fit for purpose water use* – This refers to water reuse (reuse with only minimal or no treatment) and water recycling (treatment prior to use). Examples include: rainwater harvesting, direct greywater diversion, and greywater recycling.

### 2.3.1 Rationale for Setting a Water Savings Target

There has been considerable effort over many decades to improve the efficiency of urban water use in a way that continues to provide the goods and services needed by the community while reducing pressure on water resources (Cooley and Gleick, 2009). Although household water demand is responsible for around 10% of South Australia's water consumption (ABS, 2010a) it nevertheless justifies close attention for targeting water efficiencies. In cities such as Adelaide, where untapped, available water sources are limited due to most sources being fully exploited and/or allocated to other uses (irrigated agriculture, environmental flows) new sources of water can have high economic, social and environmental costs. Therefore, strategies that seek to use existing water sources more efficiently can become very attractive. South Australia has traditionally relied on the Murray River for providing much of the urban water supply, but a combination of an extended period of lower than average rainfall, over-allocation and over-use, and growing demand means this resource is under pressure. As such, there is a need to explore alternative water sources and more efficient use of water (Government of South Australia, 2010).

It can be noted that even cities with abundant water sources still invest significantly into improving water efficiency due to the social, economic and environmental benefits (Cooley and Gleick, 2009). These benefits can include: deferment or downsizing capital investment for new infrastructure, reduced energy demand and greenhouse gas emissions for treatment and pumping of water and wastewater, and lower customer water and energy utility bills (the latter particularly where increased efficiency measures are targeted at hot water use).

### 2.3.2 Experiences from Other Jurisdictions - International

#### *California, USA*

The California Department of Water Resources published *Methodologies for Calculating Baseline and Compliance Per Capita Water Use* (California Department of Water Resources, 2011). The methodologies are designed to help urban water retailers meet the legislative requirements of the Californian State *Water Conservation Act 2009*. Before determining their water savings targets retailers need to determine baseline water use. It is recommended that 5 years of water use data is used to determine the baseline for comparing reductions in water use.

The urban retailer is asked to define water savings targets for 2020 and an interim target for 2015 using one of four methods:

- Method 1: Eighty percent of the water suppliers' baseline per capita water use
- Method 2: Per capita daily water use targets estimated using the sum of performance standards applied to indoor residential use, landscaped garden water use, and non-residential water use.
- Method 3: Align with the state hydrologic region target for 2020
- Method 4: A customised approach developed by the California Department of Water Resources, which is presented below.

The urban water use target is set by the following equation:

*Urban water savings target = base daily per capita water use – total savings*

The total savings are broken down into: metering savings, indoor residential savings, non-residential savings and landscape and water loss savings. For this project we will only focus on the method used to calculate potential savings for indoor residential and landscape water use.

Indoor residential savings are estimated based on the uptake of more efficient appliances (toilets, washing machines, showers). The savings are estimated based on the uptake of appliances at certain water use efficiencies, for the mid-point of the target period and end point (in the Californian example, 2020). The landscape irrigation and water loss savings are based on a 21.6% reduction compared to the baseline. The 21.6% reduction was derived from the analysis of 52 water retailers, and is designed to achieve the overall target of 20% specified in the legislation.

### 2.3.3 Experiences from Other Jurisdictions - National

The National Water Initiative (NWI), which has been signed by the members of the Council of Australian Governments, commits all signatories to improve the efficiency of Australia's water use (NWC, 2011). Some of the significant initiatives under the NWI include the Water Efficiency and Labelling Scheme (WELS) and the Smart Approved Water Mark (SAWM) accreditation program.

WELS was legislated through the *Commonwealth Water Efficiency Labelling and Standards Act 2005,* with all states now introducing corresponding legislation to ensure the scheme is consistently applied. WELS requires common water-using household products to be labelled with water efficiency ratings. WELS requires manufactures to provide water efficiency information and star-ratings for the following products: clothes washers, dishwashers, showerheads, taps, toilets, urinals and flow controllers. A database of products that have an accredited WELS star-rating can be found on the internet[3].

Phase 2 of the WELS project is to introduce minimum performance standards for existing WELS products. At present only new toilets have a specified minimum performance standard (an average flush volume of 5.5 litres or less). WELS has made projections on the uptake of water efficient appliances to estimate the potential water and energy savings. These projections also quantify the sustainability and financial benefits from installing water conservation products (Chong *et al.*, 2008).

A related program to WELS is the Smart Approved Water Mark (SAWM) accreditation program[4]. The SAWM program provides accreditation for a range of water conservation products both residential and non-residential. Products in the database include irrigation systems, rainwater harvesting technologies, greywater systems and products to reduce water losses from pools.

Another national initiative is the *Savewater! Alliance* program. This initiative provides an online educational resource for promoting water conservation behaviour and for providing product information and advice on water saving programs[5]. The *Savewater! Alliance* is made up of member water businesses from a number of states.

### 2.3.4 Australian Capital Territory

The *Think water, act water* strategy, released in 2004, focuses on sustainable management of the Australian Capital Territory (ACT) water resources and sets targets for a 12% and 25% reduction in mains water use per person for 2013 and 2023, as well as an increase in the use of reclaimed water from 5% to 20% by 2013 (ACT 2004).

For permanent water conservation, the ACT adopts a daily water target for Canberra as a whole, and breaks down the target on the basis of a per capita, per season and conservation stage. Targets are provided in the range of 220 to 410L per person per day. The targets are shown in Figure 2-1 as a reference to householders. Permanent water conservation measures are currently in place for outdoor water use in the ACT and Queanbeyan (ACTEW 2010b, ACTEW Corporation 2010c). The daily target in Figure 2-1 is the water consumption for all of Canberra divided by the population, to arrive at a target value per person per day (ACT 2004).

Temporary water restrictions which may be implemented to achieve short-term demand reduction in response to drought or emergency requirements are outlined for Stages 1,2, 3 and 4 and aim at achieving 10%, 25%, 35% and 55% annual reduction (ACTEW 2006).

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[3] http://www.environment.gov.au/wels_public/searchPublic.do

[4] http://www.smartwatermark.info/

[5] http://www.savewater.com.au/

| | | Spring | Summer | Autumn | Winter |
|---|---|---|---|---|---|
| PERMANENT WATER CONSERVATION MEASURES | | 290 | 410 | 290 | 220 |
| Stage | 1 | 280 | 390 | 280 | 210 |
| | 2 | 230 | 300 | 230 | 190 |
| | 3 | 200 | 250 | 200 | 180 |
| | 4 | 150 | 150 | 150 | 150 |

**DAILY TARGET** - litres per person

Figure 2-1 - Water saving targets (ACTEW, 2010b)

Tools implemented for achieving strategy outcomes include rebates for the following:

- Dual flush toilets, $100 for a 4-star water efficient toilet suite (ACT government 2011).
- Free Garden assessment and a rebate of $50 upon purchase of garden water saving products (ACT Government 2011).
- Rainwater tanks with internal connection to toilet or washing machine, with a $750 to $1000 rebate available proportional to tank size (2kL to >9kL) (ACT government 2011). Uptake of rainwater tanks is voluntary. Rainwater tank installation does not require approval provided capacity is less than 20kL, maximum height is 3m above ground level, the tank is buried and any part of the tank is located between front boundary and building line of block and clearance criteria are fulfilled (ACTPLA, 2010).

Recycled water access requires a licence for non-potable applications in commercial activities, and public space irrigation (ACTEW, 2010a).

### 2.3.5 Victoria

The Victorian Governments *Our Water Our Future* (2004) and *Central Region Sustainable Water Strategy* (2006) shape the policy framework for securing Melbourne's water supply over the next 50 years. This policy framework places primary importance on the role of water conservation, as it has the potential to be cost effective, delay expensive supply augmentations, save energy and is generally supported by the community (City West Water; South East Water; Yarra Valley Water; and Melbourne Water 2007).

The Victorian Government has set the following water conservation targets for the Melbourne region:

- 30% reduction in per capita drinking water consumption by 2015 (reduction is from a 1990s baseline average.
- 30% reduction in residential per capita drinking water consumption by 2015 (reduction is from a 1990s baseline average).

These targets mean that by 2015, metropolitan water consumers will need to reduce total water consumption to 296 litres per person per day and residential water consumption to 174 litres per person per day. The water conservation initiatives implemented in Melbourne have had a considerable impact on levels of water use. The 2008 progress report for *Our Water Our Future* demonstrates that average per capita consumption in Melbourne had fallen by 39 % when compared to the 1990s average (Victorian Government, 2004; DSE, 2008). As shown in Figure 2-2, this exceeds the 2020 target. However, the water demand reduction also includes the impact of water restrictions (Table 2-1). In Melbourne, Stage 3a water restrictions were introduced in April 2007 and reduced to Stage 3 in April 2010. On 1 September 2010, restrictions were eased back to Stage 2 for greater Melbourne (DSE 2011b).

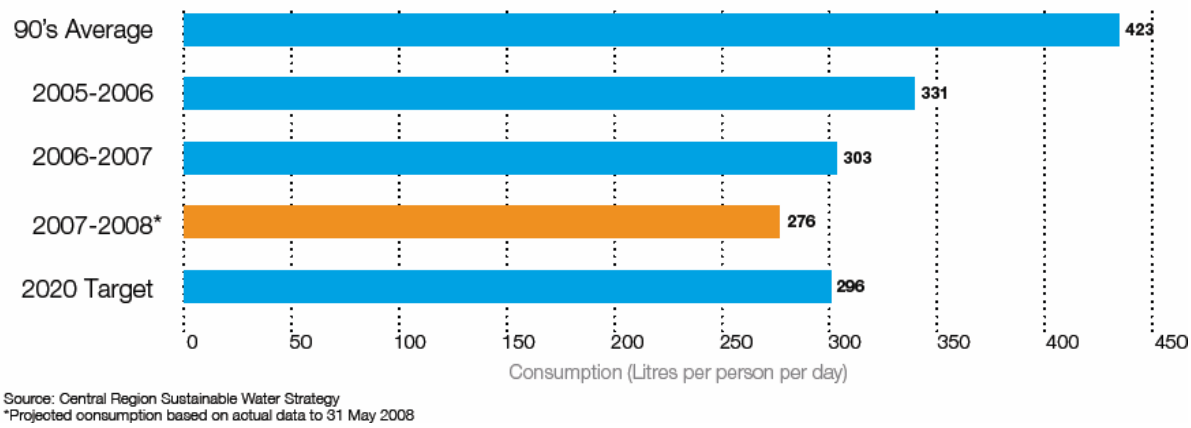


Figure 2-2 - Per capita water consumption in Melbourne (source: Victorian Government, 2008)

Table 2-1 - History of water restrictions in Melbourne

| Level of Restrictions | Time of introduction |
|---|---|
| 1 | 28 Aug 2006 |
| 2 | 1 Nov 2006 |
| 3 | 1 January 2007 |
| 3a | 1 Apr 2007 |
| 3 | 2 Apr 2010 |
| 2 | 1 Sep 2010 |

The level of water restrictions in place across Victoria have also varied in that time period (DSE 2011a). Estimates of average water use for major towns across Victoria during water restrictions in 2009 ranged from 145 to 412 litres per person per day (DSE 2011a), with Melbourne's consumption, estimated as 145 litres per person per day, among the lowest.

Victoria has recently abolished the *Target 155* campaign. This campaign, which ran for more than two years, encouraged Victorians to limit their personal water consumption to 155 litres per person per day. The Target was voluntary and was coupled with water restrictions to reduce water use during an extended period of below average rainfall. The *Target 15*5 campaign was introduced to avoid the introduction of harsh Stage 4 water restrictions in Melbourne (Yarra Valley Water, 2009). It was considered that if daily residential use could be limited to 155 litres per person then the trigger for Stage 4 restrictions (water storages less than 30 percent full) would not be reached. The implementation of Stage 4 restrictions would have significantly impacted on the state economy and community activities. Achievement of the target was encouraged through a range of initiatives including showerhead exchange programs and rebates on water efficient toilets. The *Target 155* campaign included significant mass marketing through print, radio and television advertisements to encourage behavioural change such as shorter showers. In setting *Target 155* water retailers recognised that seasonal climate variations influence demand, so the value of 155 litres per person per day was based on what they considered an achievable average daily per capita demand over a full year.

Siriwardene *et al.* (2011) undertook an analysis to determine how effective *Target 155* was in reducing water consumption. Their analysis included modelling the estimated demand with climate correction based on historical data, and comparing estimated demand with actual demand. This showed that the observed water demand was lower than predicted values (except for extreme heat days), demonstrating that *Target 155* had been effective in reducing demand.

Victoria also has a *5 Star Standard* for residential dwellings, which has the objective of improving energy ratings and water efficiency for all new homes and renovations[6]. The *5 Star Standard* makes it a requirement for all new homes to have water savings measures, such as water saving tapware, flow reducing showerheads and water pressure reduction to 500 kPa at outlets within the home. Proposed new homes are also required to include either a rainwater tank plumbed for toilet flushing or a solar hot water service.

### 2.3.6 Queensland

South East Queensland initiated the *Target 200* program in 2009. This residential water use target was set as the level of water use achievable with permanent water conservation measures in place (without restrictions). The target is based on 200 litres of residential water use per capita a day. Permanent measures for water conservation include limited use of municipal water for general outdoor use, and water efficient equipment such as high pressure cleaners and hoses with trigger nozzle action. Households exceeding 1,200 litres per day are asked to make efficiency improvements and if there is no valid reason for high water use an outdoor water ban can be imposed on these households (QWC, 2011). For a households greater 5 people, excessive water use is deemed to be more than 250 litres per person per day (QWC, 2011). The South East Queensland water supply storages are now at more than 80% of capacity and, with the exception of permanent water conservation measures, there are no water restrictions. Average per capita residential water use is still below the target of 200 litres per person per day, with an average daily residential consumption of 153 litres per person per day recorded for the last monitoring period[7].

The residential *Target 200* is a voluntary target and is based on a regional average over a twelve month period. The Queensland Water Commission website reports on average daily personal consumption for the previous five weeks against the permanent water savings target. An example of this reporting during April/May 2011 is shown in Figure 2-3.

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[6] See http://www.makeyourhomegreen.vic.gov.au/

[7] See http://www.qwc.qld.gov.au/

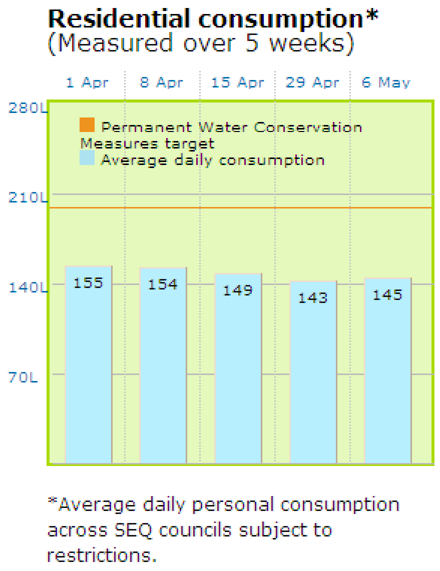


Figure 2-3 – SEQ performance against water savings target for April/May 2011 (from http://www.qwc.qld.gov.au/)

Community consultation was undertaken in developing the water savings target as part of the South East Queensland Water Strategy. It was initially proposed that the permanent water savings target (without restrictions) should be 230 litres per person per day (QWC, 2010). Over a quarter of the submissions (approx. 45) received from residents in the first round of consultation on the proposed strategy regarded the proposed residential consumption target. Of the submissions on water savings targets, 70 percent supported a target lower than 230 litres per person per day. A number of the submissions highlighted the need for water consumption targets to consider impacts on lifestyle, as it was felt that if residents viewed targets as unreasonable or unnecessary they would be less likely to adhere to the voluntary targets (QWC, 2010). The second round of community consultation saw 104 submissions regarding proposed water savings target, with 70 percent of those submissions favouring the revised target of 200 litres or less compared to 230 litres per person per day. Submissions also highlighted the need to continue to invest in water conservation programs and reducing water losses, rather than relying on water restrictions to reduce consumption (QWC, 2010). The submissions to the Queensland Water Commission only represented a relatively small proportion of the total population impacted by the strategy, and as the sample was self-selecting perhaps not that representative of the overall population. An online survey held in March 2010, with 1000 respondents, showed 74 percent were comfortable or very comfortable with a water savings target of 200 litres per person per day (QWC, 2010).

The Queensland Development Code (QDC) MP 4.2 introduces mandatory water savings targets for all new homes. For the Brisbane and Gold Coast City Council areas all new detached homes have water savings targets of 70 kL per year. This saving is from municipal potable water and can be achieved through substitution from one other source, including a rainwater tank, a greywater treatment system or another alternative water source (Queensland Department of Local Government and Planning, 2009).

### 2.3.7 New South Wales

In New South Wales, the *2011-2016 Water Conservation strategy* (Sydney Water 2010) for Greater Sydney sets the following targets for 2015:

- Reduction of Sydney's water needs by 25%;
- Recycling of 70 GL/year for supply of 12% of Sydney Water needs.

These targets assume a long-term average use of 600 GL per year.

Under the Sydney Water *2010-15 Operating License* conditions Sydney Water Corporation is required to achieve "reduction of drinking water usage to equal or less than 329 litres per person per day by 30 June 2011. This figure is the total water use by residential, business, government sectors and water losses, which are capped at 105 ML/day. The license also establishes water conservation requirements to be undertaken by the entity: promotion of water efficiency programs, consideration of such programs in future planning, leak reduction and promotion of production and use of recycled water (Sydney Water 2010). The basis for estimation of the water demand for Sydney is described in Sydney Water (2011).

The demand targets are developed using a demand analysis and forecast model based on an end-use analysis approach and the water consumption on a baseline year. The baseline is the 1991 average water use of 506 litres per person per day (or 426 litres per person per day after climate correction) under a 'do nothing' forecast and the target is equivalent to a 35% reduction by June 2011 (IPART, 2004). Demand projections are developed based on population growth projections adjusted to the water supply area and yearly climate. Temporary water restrictions and water efficiency savings are excluded from the benchmark forecast. Options for water reduction are evaluated and the water savings subtracted from the baseline to determine the water reduction alternatives. Multiple interactions and combinations of options are adopted, with a continuous review of assumptions as data becomes available and sensitivity analysis (high, medium and low savings) is conducted for each option given the uncertainty associated with each option.

Each of the water savings programs are then ranked and evaluated using multi-criteria analysis based on levelised cost, implementation certainty, magnitude of water savings and environmental benefits (Sydney Water, 2008b). The 329 litres per person per day target has been achieved and surpassed with consumption down to 309 litres per person per day (Sydney Water 2010). The yearly average demand per capita is estimated as a 12-month rolling average of total water supplied per day divided by the estimated population and further corrected for climate.

Strategies adopted by Sydney Water to achieve the water savings include initiatives such as leak reduction programs, uptake of recycled water, and water efficiency programs and regulatory measures. Also, regulations have been introduced to mandate water efficiency in new and renovated dwellings in the form of the Building Sustainability Index (BASIX). In New South Wales, every new home development application needs to obtain a BASIX Certificate to obtain approval. The BASIX program is designed to reduce potable water demand and energy use (BASIX, 2004). In 2010, it was estimated that the BASIX program had reduced potable water demand by 6 GL. The application of BASIX is expected to be responsible for a third of water savings achieved over the period 2011 to 2015 (Sydney Water 2010).

Water efficiency programs have also been widely promoted as part of a Sydney Water strategy. Programs offered subsidies for the installation of water efficient appliances (showerheads, toilets, washing machines), rebates on rainwater tanks and free advice on outdoor garden watering, free installation of water saving devices (showerheads, water flow regulators, toilet cistern arrestors) and repair of minor leaks. Savings attributed to these programs were estimated at 3 GL/year in the initial period from July 2006 to June 2009 and levelised at 0.9 GL/yr from July 2009 to July 2010.

The reported water savings attributed to each initiative over the last 15 years are outlined in Table 2-2.

Table 2-2 – Sydney water savings programs (Sydney Water, 2010)

| Initiative | Water saving (GL) | Water saving (% Total) |
|---|---|---|
| **BASIX** | 5.9 | 6 |
| **WELS** | 7.8 | 8 |
| **Recycled water savings** | 10.8 | 11 |
| **Programs' savings**[1] | 71.5 | 73 |
| **Other recycling schemes** | 2 | 2 |
| **Total** | **98** | **100** |

Note: [1] Programs include water efficiency and leak reduction initiatives for residential, business and institutional customers, such as for: (i) residential: WaterFix program (installation and replacement of water efficient devices and leakage repairs), distribution of DIY water saving kits, toilet replacement service, subsidies for water efficient showerheads, toilets, washing machines, advice on outdoor garden watering and rebates for rainwater tanks; (ii) Business, schools and councils: one-to-one partnerships to reduce water consumption and leakage, BizFix (flow regulators and hardware), leak monitoring programs, targeted programs for demand reduction for the NSW top 100 water users in each category (business, schools, councils); and for the distribution network (leak detection and repair, pressure reduction, flow metering).

### 2.3.8 Northern Territory

The Northern Territory (NT) has one of the highest per capita water consumption rates in the country, averaging 380 litres per person per day (NT Government, 2009). The population of 225,900 (ABS, 2009), is small compared to other Australian jurisdictions.

The NT has no mandatory quantitative potable water saving targets, however a 20% reduction on the baseline is considered technically feasible, and has been suggested as an interim target in the NT *WSUD Planning Guide* (McAuley and McManus, 2009). In line with such recommendations, a range of education and voluntary programs for reducing water demand are currently in place across the NT. These include:

- NT Waterwise Central Australia: a range of programs to support water efficiency in the southern region includes the NT Waterwise rebate scheme, NT waterwise schools, gardening tips and fact sheets.
- Alice Springs Water efficiency program,
- Promotion and educational materials relating to WELS, water demand reduction, water efficient products and rebates.
- Advice on rainwater and greywater use, stormwater management for mitigation of run-off pollution generated by particular activities (such as car washing and washdownwater for construction, commercial and industrial activities) is available through the NT Department of Natural Resources, Environment and the Arts and the website for the NT Department of Health and Families (NT Government, 2011).

The *Integrated Natural Resource Management Strategy for the Northern Territory* (currently under review) (Northern Territory Government, 2007a), sets directions for the management of all natural resources in the NT for conservation of biodiversity, sustainable use of natural resources and capacity building at community level. It "identifies and prioritises natural resource management issues across the NT and sets targets to address such issues" (Northern Territory Government, 2007). At a regional level water allocation plans outline the strategy that guides the management of water in declared water control districts (NWC, 2009b). Two NT regional areas currently have water allocation plans, including the Ti Tree and Alice Springs regions. Plans for other regions are currently under development (Northern Territory Government, 2007a; 2009a). The plans reflect the importance of groundwater as the major water supply source for Northern Territorians. Major population centres such as Alice Springs and Tenant Creek rely solely on groundwater, Darwin and Katherine adopt both groundwater and surface water supplies, and the majority of other major settlements are groundwater dependent. Therefore management of environmental flows and recharge of groundwater are the major concerns in water allocation planning.

The *Alice Springs Water Resource Strategy 2006-2015* (Northern Territory Government, 2007b) sets the framework for water resource allocation for the region. The demand estimates for future use were developed using projections based on projected population growth, changes to water use behaviour and impacts due to climate change. This was complemented with a study of demand based on scenarios of low, medium and high growth (Turner *et al.* 2003). The Strategy does not outline steps for a water demand management program, but it acknowledges that a water efficiency program is required for Alice Springs to reduce water consumption. Additional analysis was conducted of strategies for reduction of water consumption through a broad range of options such as water efficiency, source substitution with rainwater and greywater, and effluent reuse for non-potable uses in Alice Springs. A key recommendation from the strategy was the implementation of a water efficiency program (Turner et al, 2007).

### 2.3.9 Tasmania

No water demand targets are in place in Tasmania. Security of water supply is not a concern in the State given its availability of water resources and population size. Instead, major drivers for reform include pollution and wastewater management. Under the National Water Initiative, Tasmania is undergoing a restructure of its water and service provision model. Where water and wastewater provision has previously been the responsibility of 3 bulk water providers and 21 local governments, it has since 2008-2009 been consolidated into three regional water service corporations (TWI 2009).

### 2.3.10 Western Australia

Water allocation in WA is determined based on the amount of water available for a particular resource in an area. The *Western Australia State Water Strategy* (Government of WA, 2007) has the following targets:

- To recycle 20% of treated wastewater by 2012 (and 30% long-term) with a preference for large scale reuse schemes (rather than household scale). The aim is to achieve less than 155 kilolitres per person per year. It also considers the potential for providing water 'fit for purpose' for irrigated horticulture, green space irrigation and industry, the adoption of managed aquifer recharge to increase water availability in groundwater systems and to maintain environmental values.
- To achieve urban water consumption of 155 kilolitres per person per year by 2012 for Perth. This was achieved by 2006 (153 kilolitres per person per year). However, the target was revised to achieve a further reduction of 60 litres per person per day (Target 60), i.e. an additional 10% water reduction, (Water Corporation 2011).

The original targets were developed based on forecasted water demand for a population of 1.8 million in 2030, with consideration of factors such as household size, rainfall patterns, incidence of hot days, watering practices and restrictions, and uptake of water efficient appliances and water wise behaviour (Government of WA, 2007).

The targets were promoted through rebate programs for source substitution (rainwater tanks plumbed into the home, bores), and mandated water efficient fittings and toilets for new homes. In addition, permanent water efficiency measures have been implemented, including restrictions to outdoor irrigation such as a permanent ban on sprinkler use in Winter (1 June to 31 August) for Perth and the WA South West (Water Corporation 2011). After the target 153 kilolitres per person per year was achieved the Government reviewed the target and set a new target of 100 kilolitres per person per year for 2007-2011 (Government of WA, 2007).

### 2.3.11 Benefits and Challenges of Setting Residential Water Conservation Targets

The review has shown there are two main types of water conservation targets implemented in Australian cities. These consist of

- temporary water saving targets as part of a suite of options to deal with a water crisis, where water storages reach critically low levels and;
- permanent water savings targets, which are part of a strategic water supply demand balance planning approach. The permanent targets are designed to be achieved over a number of years, and are likely to be less restrictive than temporary measures to deal with a crisis.

Some of the benefits of setting voluntary water conservation targets include[8]:

- The community responds well, particularly in times of water crisis
- It empowers the community to take action and avoid water restrictions
- It allows flexibility in personal use of water compared to restrictions, which target particular uses
- It is easy to explain compared to a schedule of water restrictions for different activities and household types.
- It provides a focus for recommended water saving actions such as retrofit, and may increase the uptake of these actions
- Targets are media friendly, and enable tracking of performance against the target

Some of the challenges of voluntary water savings targets include:

- The long term effectiveness and ongoing commitment of the community to water savings is not well understood, particularly when a water supply crisis eases
- Actual per capita demand is difficult to calculate, and is influenced by a range of factors including household occupancy, dwelling type and garden size. Therefore, a number of simplifying assumptions are required
- The success of water savings targets is often dependent on an extensive and well-run marketing campaign.

### 2.3.12 South Australian Water Conservation Targets

Water demand management measures are expected to achieve water savings of 50 GL for 2010-2050 or 1.25 GL/year (based on demand with no water restrictions as in 2009) (Government of SA 2010). Water restrictions (Level 2 variable) were introduced on 1 July 2003 for areas supplied by the River Murray and Myponga Reservoir because of low inflows to storage. These were replaced on 26 October 2003 by Permanent Water Conservation Measures (PWCM) when inflows improved, and increased to Level 3 restrictions from 1 July 2007 as the drought worsened and the availability of water from the Murray River was reduced. Level 3 water restrictions were lifted on 30 November 2010 and substituted by *Water Wise Measures* for most of South Australia, with the exception of the Eyre Peninsula, where restrictions were removed on 2 April 2011.

The *Water Wise Measures* cover outdoor water uses (domestic gardens and lawns, washing of cars and boats and outdoor areas, pools and spas, construction sites and recreational facilities) and set conditions for low water use (trigger nozzles, sprinkler use, permits). Under the current scheme hand watering and drip watering times are no longer restricted.

Other demand reduction initiatives include rebates and legislative requirements. For example, the *$H_2$OME Rebate Scheme* was introduced in 2007 and revised in April 2010. It currently applies to

[8] These benefits and challenges are based on personal communications with Kein Gan, Water Conservation Manager for Yarra Valley Water, May 2011.

garden goods, showerheads, dual flush toilets, home water audits and rainwater tanks. Rebates can be claimed by both home owners and tenants. Details of the rebate are shown in Table 2-3.

Table 2-3 - South Australia's $H_2OME$ rainwater tank rebate program

| Rebate ($) | Requirements |
|---|---|
| ≤ $200 | New rainwater tank (minimum 1kL capacity) not connected to household plumbing (i.e. 'stand alone' rainwater tank) |
| $200 | New tank plumbed to either the toilet, all cold water outlets or hot water service. Applied to tank purchases until 30 June 2011. |
| $600 | Plumbing services to connect a rainwater tank to toilet, all cold water laundry outlets or hot water service. Applied to tank purchases until 30 June 2011. |
| Up to $200 | For additional installation measures (automatic rainwater/mains switching or for connecting to two or more of the above-mentioned types of fixtures). Applied to tank purchases until 30 June 2011. |

Since 1 July 2006, the *South Australian Housing Code – Amendment 13*, requires all applications for new houses and relevant extensions/alterations of existing houses of area larger than 50 $m^2$ to include details of how they will meet the water saving requirements (Planning SA, 2006). The water savings requirements can be achieved in any way deemed suitable, including a rainwater tank plumbed into the house.

Water conservation measures caused reduction in potable water demand from 460 litres per person per day in 2003 to 385 litres per person per day in 2010 (Figure 2-4) (ABS 2011). However, it should be noted that this period encompassed a range of water conservation rules and restrictions as follows:

- Prior to 1 July 2003 no water conservation measures were in place;
- From 1 July 2003 to October 2006 Permanent Water Conservation Measures were in place;
- From October to December 2006 Level 2 water restrictions were in place; and
- From 1 January 2007 to 1 Dec 2010 Level 3 water restrictions were introduced.

Level 3 water restrictions were substituted with Water Wise Measures on the 1 December 2010.

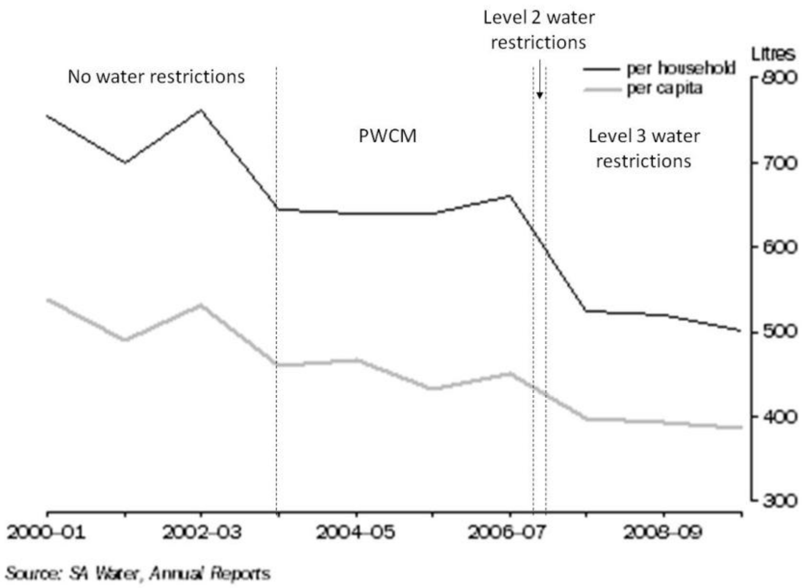


Figure 2-4 - SA daily water consumption (ABS 2011)

### 2.3.13 Impact of South Australian Water Conservation Programs

Permanent water conservation measures were introduced in SA in October 2003. According to the Australian Bureau of Statistics (ABS), this contributed to a reduction in average daily water consumption of 15% in the first year of introduction with approximately 640 litres per household per day achieved. Following the introduction of Level 3 Water restrictions in 2007 water consumption decreased further by 21% to 523 litres per household per day and remained at that level until December 2010 when Level 3 restrictions were lifted (ABS 2011).

The water demand reduction was attributed to the combined penetration of water efficient fittings and appliances in households and of some small behavioural changes in segments of the population. Since 2001 the uptake of water efficient products by South Australian households increased. By 2010, 65% of dwellings had a water-efficient shower-head, 89% had a dual flush toilet and 14% had purchased a water efficient washing machine (ABS 2011). In 2010, household water conservation behaviour uptake was reported as follows: 36% had short showers; 23% turned off taps while brushing teeth,13% checked and fixed leaks; 14% collected greywater, 25% and 11% waited for a full load to use the washing and dishwashing machines. The uptake of rebates for water efficient options between November 2007 and June 2007 in Adelaide was: garden goods – 12,509, showerheads – 5,986, washing machines – 62,245, dual-flush toilets, rainwater tanks – 4,743, and home water audits – 47 (Government of South Australia, 2010).

Mains water was still the major water source for irrigation: adopted in 66% of capital-city households, compared to only 35% in non-metro Adelaide and 45% in households of capital cities in other jurisdictions (ABS 2011). However, there was an increase in mulch use and households that irrigated gardens during cooler times of the day, respectively equivalent to 31% and 20% of all households in Adelaide. Rainwater use in gardens increased from 8% to 15% of households since 2007 (ABS 2011).

### 2.3.14 Regulation of Rainwater Tanks in South Australia

Regulation 83A of the South Australian appendix to the Building Code of Australia (BCA 2006) and the South Australian Housing Code (SAHC) require new Class 1 dwellings and significant renovations in South Australia to have a mandatory alternative water supply together with four-star WELS rated appliances. The performance provisions state that each new dwelling (or renovation with a roof area exceeding 50 $m^2$) must have at least 50 $m^2$ of roof area connected to the rainwater system and 1 kL storage connected to at least a toilet or water heater, or all laundry cold water taps. Exceptions to the requirement for a plumbed rainwater tank are allowed for buildings that can access another additional water supply, such as dual reticulated water supply systems or water from an approved bore.

For a communal plumbed rainwater tank each dwelling needs to contribute a minimum of 50 $m^2$ roof catchment and needs to be have a device (toilet, laundry cold water tap or water heater) plumbed to the tank. The minimum rainwater tank size should be equivalent to the number of dwellings multiplied by 1 kilolitre per dwelling.

### 2.3.15 Rainwater Tanks and Tank Rebates in South Australia

Rebates for rainwater tanks are administered by SA Water and apply to the acquisition of new rainwater tanks for internal household water use and plumbing of existing tanks to internal connections up to a maximum value of $1000. The rebate for plumbed in rainwater tanks ended on 30 June 2011.

In Adelaide 44.6% of all suitable dwellings has had a rainwater tank installed (ABS 2010) (Figure 2-6). There has been virtually no change in the proportion of households with rainwater tanks since 2007 when 44.5% of dwellings had rainwater tanks. Among households that had a tank installed in 2009-2010 the majority (62.2%) claimed the desire to save water as their major driver, 19.8% wanted to save on water costs, 15.9% claimed water restrictions and 16.3% had concerns with mains water quality (ABS 2010). The effectiveness of water rebates was not queried as a driver in the survey, however, rebates for rainwater tanks had been claimed by only 9.2% of households in the 12 months prior to March 2010 (ABS 2010). Despite of the presence of rainwater tanks, the majority of households (65.92%) still used mains water as their main outdoor source (sample size 418,500 households) and only 11.9% of households surveyed claimed to use rainwater tank water as their major source for garden irrigation.

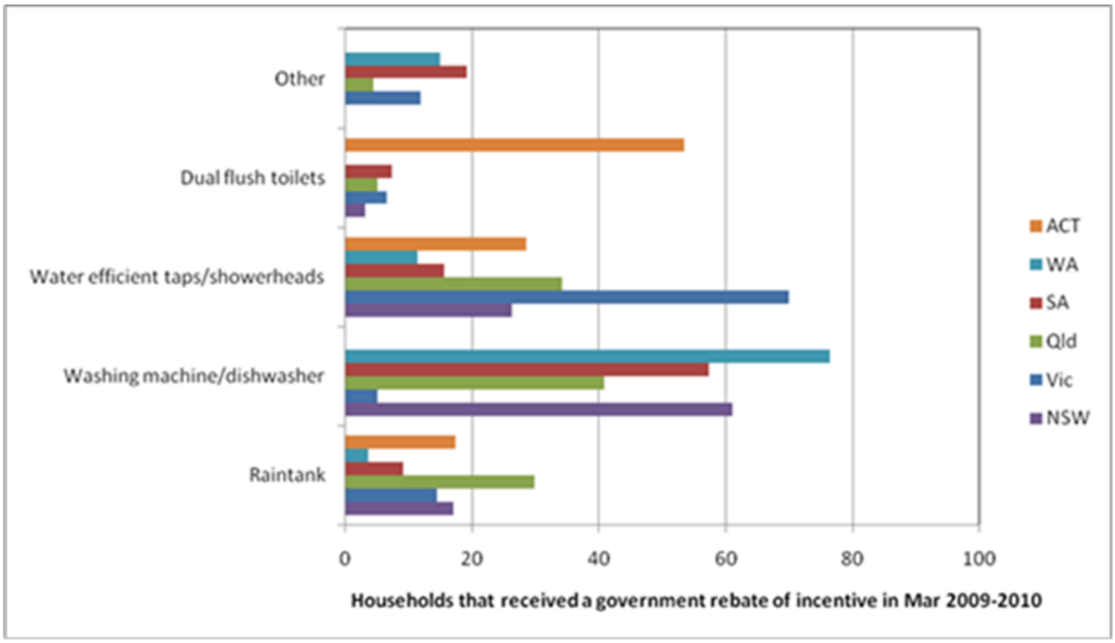


Figure 2-5 - Rebate claims by households across Australia (ABS 2010)


Figure 2-6 – Proportion of suitable households with rainwater tanks in Australian capital cities (ABS, 2010)

### 2.3.16 Greywater Recycling in Adelaide

Greywater use has been reported in 36.3% of households in Adelaide (ABS 2010). By March 2010, 12% of households reported collecting greywater from the bathroom and 13% from the laundry. Only 10% of households reported using greywater for garden irrigation in March 2010, compared with 21% in March 2007 during the water restrictions (ABS 2011). These figures include both non-permanent measures (e.g. direct collection of greywater in buckets) and permanent treatment systems, with the vast majority understood to be via non-permanent measures

### *Regulations for greywater use in Adelaide*

Manual bucketing and direct diversion of greywater is permitted with the Department of Health having developed guidance material for those who wish to apply greywater via such means. Installation of a permanent greywater system requires the approval of (i) Health SA for diversion of greywater in sewered or STED serviced areas, (ii) approval from local government for planning and development of the system and (iii) approval from SA Water for changes to plumbing and drainage (Section 36 of the Sewerage Act) (SA Water 2011, Government of SA 2008a, b). Installation needs to be conducted by a licensed plumber and permanent greywater diversion technologies must be certified by the Watermark program to be retailed and installed in SA. It should be noted that the legislative framework for water and wastewater management in South Australia is changing with the recent introduction of the Water Industry Bill, which supersedes many Acts including the Sewerage Act.

### *Greywater rebates and other schemes*

Rebates for greywater treatment systems are not offered in South Australia. However, South Australian households who purchased and installed a permanent greywater system up to 10 May 2011 were eligible to claim a rebate of up to $500 from the National Rainwater and Greywater initiative (DSEWPC 2011).

According to the ABS (2010), washing machines/dishwashers were the most common type of rebate, claimed by 54.95% of households in the 12 month period prior to March 2010 in South Australia. Rebates for water efficient taps/showerheads and rainwater tanks were claimed by only 15.6% and 9.2% of households, respectively for that same period (ABS 2010). However, the uptake of water efficient toilets was already high, with 89% of Adelaide households equipped with a dual flush toilet in 2010. At this time, 64.5% of households had water efficient showerhead(s) installed.


Figure 2-7 – Proportion of households with dual flush toilets in Australia (ABS, 2010)

## 2.4 Methods to evaluate options to achieve water conservation targets

To make informed investment in options and achieve water conservation targets there is a need to evaluate alternatives on the basis of costs and benefits. Different water conservation strategies incur varying costs and benefits to different parties. Cost and benefits can be categorised as being either direct or external (or indirect) from the points of view of water utilities and consumers.

Direct costs and benefits are those that accrue directly due to either the water utility or the customer. An example of direct costs to the water utility is the capital and operational costs of implementing a water conservation initiative; a customer directly benefits from a water conservation initiative that lowers utility bills. External costs and benefits accrue to a third party or society at large (beyond the utility or consumer). External costs are therefore not adequately captured by the market price in a way which reflects the full cost (or benefit) of the water conservation measure. These include 'intangible' benefits that are not easily measured by conventional means, such as economic cost. Such costs include, for example, the benefit to a catchment from reduced water abstraction or increased landscape amenity from water which has been freed up for irrigation. Consideration of externalities is critical to ensure the evaluation of water conservation takes into account the full social costs and benefits over the lifetime of the initiative.

Traditional evaluation of options for urban management in Australia has focused on direct costs (particularly capital and operation and maintenance costs). The inclusion of broader positive and negative externalities can improve the overall cost-effectiveness of investment decisions in water conservation by ensuring that the complete social costs and benefits are included. Inclusion of externalities can also assist in the development of policy that considers equitable cost-sharing arrangements and an appropriate spatial scale of different water conservation initiatives.

The appropriate method for evaluating water conservation initiatives is dependent on the key criteria that are selected as the basis for the evaluation. There are a suite of evaluation tools available to assess water conservation measures. The following techniques include those that are considered economic tools as well as those that can be used for a broader evaluation that includes externalities:

- Financial evaluation tools – These need to consider both the time value of money and the lifetime of the water conservation initiative. The evaluation should also reflect the stakeholder preferences to bring forward any benefit and delay incurring cost.

- Cost Effectiveness Analysis (CEA) - Used when the benefits of an option are difficult to quantify. The achievement of the target or goal for an option is evaluated against the cost. For water conservation, CEA is expressed as a cost-effectiveness ratio, which is the cost required per unit of water conserved (Aulong *et al.* 2009). Life cycle costing (LCC) is analogous to CEA and calculates the cost of an option over its lifespan. The advantage of the CEA approach is that it takes into account the effectiveness of the water conservation action in relation to the net cost over the action life cycle. As such, CEA can highlight the options that can achieve a target at lowest cost. The limitation of the CEA approach is that it is mostly suitable to the analysis of factors that may be quantified in monetary terms.

- Benefit Cost Analysis (BCA) is a commonly applied evaluation technique that compares the total costs over the lifetime of an option against the societal benefits. BCA provides a framework to bring together economic and environmental dimensions into a common analysis (Kalman *et al.*, 2000). As it is able to incorporate both direct and indirect costs and benefits, BCA offers a more comprehensive evaluation framework than CEA. Where possible costs and benefits are quantified in monetary terms. A limitation of the BCA approach is that it does not consider the reliability of options.

- Least Cost Planning (LCP) and Integrated Resource Planning (IRP) offer a large-scale framework approach for strategic water supply-demand balance planning. These techniques compare demand side measures against supply augmentation to identify the lowest cost option (Beecher, 1995; White and Fane, 2007). IRP is the foundation for the Water Services Association of Australia's *Guide to Demand Management*.

- Multi-criteria Analysis (MCA) is a structured framework that brings together a disparate range of both quantitative and qualitative criteria for the evaluation of water conservation initiatives. The performance of each criteria is standardised to allow aggregation. Usually a weighting is applied in combining factors so that the relative importance of the factors is reflected in the output. MCA however does not follow a Pareto Improvement rule where benefits should exceed costs.

Key references for implementing water conservation programs include:

- Turner, A.J., Willetts, J.R., Fane, S.A., Giurco, D., Kazaglis, A. and White, S. (2008), Guide to Demand Management, prepared for Water Services Association of Australia, Sydney, NSW, Australia

- CUWA (1992). Evaluation of urban water conservation programs: A procedures manual, California Urban Water Agencies.

- AWWA Research Foundation (1997) Guidelines for Implementing an Effective Integrated Resource Planning Process, American Water Works Association, U.S.A.

- Chesnutt, T. W., Fiske, G., Beecher, J. A., and Pekelney, D. M. (2007) Water Efficiency Program for Integrated Water Management, Water Research Foundation (Previously AWWA Research Foundation).

Figure 2-8 depicts the results of an analysis that compares the levelised cost of alternative water sources for major Australian cities, including Adelaide (Marsden Jacob Associates, 2007). The levelised cost represents the cost per kilolitre over the life cycle of the option, and includes capital and operating costs. This shows that while demand management is a cost effective option for reducing drinking water demand, rainwater tanks are relatively costly. This comparison shows the direct costs to the owner, but does not consider the overall community costs, or benefits, such as environmental benefits, landscape effects or the potential for deferment or downsizing of stormwater and water supply infrastructure. Furthermore, the levelised cost does not indicate the reliability of an option, which is relevant for rainwater harvesting compared to other rainfall independent water sources, such as water recycling. George Wilkenfeld and Associates (2008) also compared the levelised cost of different demand management and supply options (Table 2-4). This also showed that water efficiency labelling schemes have a levelised cost well below water supply measures like rainwater tanks.

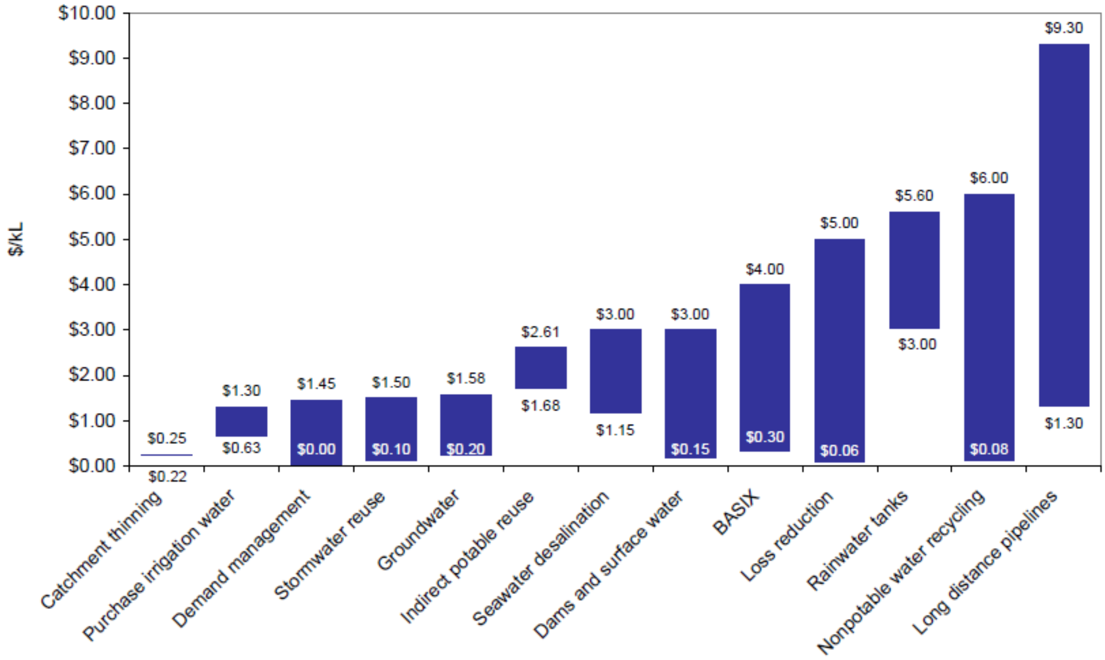


Figure 2-8 - Levelised cost of alternative water sources (Marsden Jacob Associates, 2007)

Table 2-4 - Summary of demand side and supply side option costs (George Wilkenfeld and Associates, 2008)

| | Options | Approx. levelised unit cost ($/kL) |
|---|---|---|
| Demand Reduction Options | Outdoor water efficiency (a) | $0.10 – $0.20 |
| | WELS (programs implemented to date) (a)(b) | $0.13 – $ 0.21 |
| | **WELS measures covered in this RIS (c)(b)** | **$ 0.27 – $0.48** |
| | Shower head programs (shower head exchanges, rebates, and retrofits) (a) | $0.50 – $0.60 |
| | Building regulations (a) | $0.30 – $4.00 |
| | Clothes washer rebates (c) | $2.10 – $2.60 |
| Supply augmentation | Desalination (a) | $1.19 – $2.55 |
| | New storage (a) | $1.26 – $3.58 |
| | New recycling schemes in Sydney (a) | $1.00 – $5.50 |
| | Residential Rainwater Tanks (a) | $3.00 – $4.00 |

Source: (a) ISF (2008). (b) 3.5% to 10.0% discount rates; upper cost estimates. (c) Calculated in this RIS.

## 2.5 Development of Water Conservation Targets for Greater Adelaide

### 2.5.1 Analysis of Options to Achieve a Water Savings Target using the Urban Volume and Quality (UVQ) Model

Options to achieve a water savings target for indoor water use in new dwellings in Greater Adelaide have been modelled using the Urban Volume and Quality (UVQ) model[9]. The UVQ model quantifies urban water and contaminant balances enabling the user to track flow paths and contaminant concentrations through the urban water cycle (Mitchell and Diaper, 2006). UVQ simulates the volume of water flows – and associated contaminant loads – from source to discharge point. A key feature of UVQ is the integration of stormwater, drinking water supply and wastewater systems into a single model that provides a holistic view of urban water flows. The functionality of UVQ has been designed to allow the user to define both conventional and non-conventional urban water supply and wastewater services, and explore the impact of different scenarios on these water flows, contaminant loads and distribution.

In the UVQ model, imported water supplies and rainwater are the major inflows to the urban water cycle while wastewater, stormwater and evaporation are the main outflows. Water sources can be used for indoor and outdoor end-uses. Specific end-uses are: kitchen, bathroom, laundry, toilet, garden irrigation and public open space irrigation.

UVQ operates on a daily time step to calculate water flows and contaminant balances. The model can run from a minimum period of one year up to one hundred years. To account for climate variability at different temporal scales it is best for the simulation period to run over a period of decades.

UVQ has a three-level hierarchy to represent the different spatial scales of an urban area. These are the land block, the neighbourhood study areas. The land block represents a single dwelling or other building type, while a neighbourhood is an aggregation of land blocks that have identical characteristics. Neighbourhoods can be used to describe different land use types making up the study area that will have different characteristics in terms of the physical layouts of pervious and impervious surfaces, water demands and the contaminant profile of end-uses.

In UVQ the rules for satisfying household demand are as follows:

- Lowest quality water source available for the end use is drawn on first (for example, harvested rainwater is used before potable water for garden irrigation).
- Indoor demand is satisfied before outdoor demands (for example, if harvested rainwater is available for toilet flushing and garden irrigation then toilet demand is satisfied first).

The following sections describe the use of UVQ to determine water conservation targets for indoor demand of new dwellings in the Greater Adelaide Region.

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[9] Information on the UVQ model, software and a manual are freely available for download at: http://www.csiro.au/products/UVQ.html

### 2.5.2 The base case

The base case is designed to provide a benchmark value to assess water demand for a new Class 1 dwelling in South Australia, relative to a typical existing dwelling in Greater Adelaide. For the purposes of this analysis, a new Class 1 dwelling is assumed to comply with the current requirements for an alternate water source by having a 1 kL rainwater tank connected to a 50 $m^2$ roof area and fittings with a four star WELS rating. First we present some information on water demand in Adelaide households then define the base case for benchmarking water conservation initiatives.

#### *Residential Water Use in Greater Adelaide*

SA Water provides information to customers on household water bills that provide a range of water consumption for different household sizes and allotment sizes. SA Water develops this information through online phone surveys that gather household characteristics from the customer that are then, with the permission of the customer, compared with water meter readings for that customer (Steven Kotz SA Water , Personal communication, 2011). The information is designed to inform the customer where their water consumption sits on a continuum from low to high for their household type. Table 2-5 shows the ranges of water use for different household types and allotment types in litres per household per day that is presented to customers.

Table 2-5 – Range of daily water use for SA Water customers (litres per household per day)

| | Allotment type | | | |
|---|---|---|---|---|
| No. of household occupants | *No Garden* | *Small ($400m^2$)* | *Medium ($600m^2$)* | *Large ($900m^2$)* |
| 1 | 160 – 195 | 195 - 245 | 215 - 270 | 265 - 330 |
| 2 | 195 – 245 | 245 - 300 | 270 - 335 | 330 - 405 |
| 3 | 245- 305 | 300 - 375 | 335 - 415 | 415 - 510 |
| 4 | 305 – 382 | 380 - 470 | 420- 515 | 515 - 635 |
| 5 | 380 – 475 | 470 - 580 | 520 - 615 | 640 - 790 |

This data was not considered appropriate for use in setting a benchmark value in this project as it is based on a limited survey of selected households, and was collected during a period of relatively low water use (the winter billing period). Also, there was no information on how this data related to the actual distribution of household water demand in Greater Adelaide.

Table 2-6 depicts the average water residential water supplied per connection for major water utilities in Australian cities. In most Australian cities, there has been a marked reduction in residential water use over the last decade. This reduction has been in response to temporary water restrictions, the introduction of permanent water conservation measures and the increased household uptake of water efficient appliances and fittings, such as low-flow showerheads and dual-flush toilets. This shows that for Greater Adelaide around 20% less water was supplied to households in 2009/10 when compared to 2003/04. The differences in household demand between Australian cities are related to a range of factors including: climate, soil type, housing density, temporary and permanent water conservation measures in place, and water price. In considering this data for use in setting a benchmark for strategic water conservation targets there is a need to account for the impact of temporary water restrictions, and the introduction of permanent water conservation measures. For this reason, the base case uses data prior to 2006 when water restrictions were introduced, but covers the period after the introduction of permanent water conservation measures in 2003.

This means that for an average household of 2.4 persons the benchmark is 237 kL per household per year. If placed on a per capita basis, this becomes 99 kilolitres per person per year or 270 litres per person per day. This value combines indoor and outdoor water demand; the following section separates indoor and outdoor demand to derive an indoor water demand benchmark.

Table 2-6 Average annual residential water supplied per connection for major Australian utilities (National Water Commission, 2011, Table 3.1.3)

| Utility | 2003-04 | 2004-05 | 2005-06 | 2006-07 | 2007-08 | 2008-09 | 2009-10 |
|---|---|---|---|---|---|---|---|
| **Sydney Water** | 224 | 211 | 203 | 199 | 182 | 198 | 205 |
| **WC – Perth** | 285 | 277 | 268 | 281 | 268 | 277 | 276 |
| **Yarra Valley Water** | 204 | 193 | 198 | 178 | 157 | 151 | 144 |
| **South East Water** | 186 | 184 | 187 | 167 | 152 | 143 | 141 |
| **SA Water – Adelaide** | 245 | 235 | 233 | 235 | 194 | 190 | 191 |
| **Brisbane** | 258 | 264 | 185 | 153 | 128 | 133 | 143 |
| **City West Water** | 188 | 187 | 183 | 163 | 149 | 146 | 140 |
| **Gold Coast** | 198 | 244 | 200 | 183 | 149 | 166 | 182 |
| **Hunter Water** | 208 | 197 | 205 | 195 | 177 | 180 | 184 |
| **ACTEW** | 248 | 240 | 261 | 240 | 195 | 201 | 199 |

### *Indoor water use*

Figure 2-9 shows the breakdown of residential water use in Adelaide presented by the *Water for Good* plan (Government of South Australia, 2010). This shows that there has been a change in water use since the introduction of permanent water conservation measures in 2003, and the imposition of temporary water restrictions to deal with lower than average inflows to catchments. The major change is the reduction in outdoor watering. However, indoor water use has also declined with the widespread uptake of water-efficient appliances such as low-flow showerheads and dual-flush toilets. For the value of 237 kL /year residential water demand, which is based on data prior to the introduction of water restrictions (discussed in previous section), it is assumed that 60% of this demand was for indoor purposes (based on the data provided in Figure 2-9). Table 2-7 summarises the total demand and subsequent assumed indoor water demand of existing housing in South Australia. This figure is considered appropriate because the assumed indoor water use for South

Australia (162 litres per person per day) is within 10% of the indoor water demand measured in the end use study conducted for Melbourne presented in Figure 2-10.

For the purposes of UVQ modelling, the total indoor water use was disaggregated to kitchen, laundry, bathroom and toilet uses. Due to the absence of end use studies in South Australian households to determine indoor water use, disaggregation was undertaken based on the data from end use studies by Roberts (2005) and Willis *et al.* (2009), presented in Figure 2-10. The breakdown of indoor water use adopted for UVQ modelling in this study is illustrated in Figure 2-11.

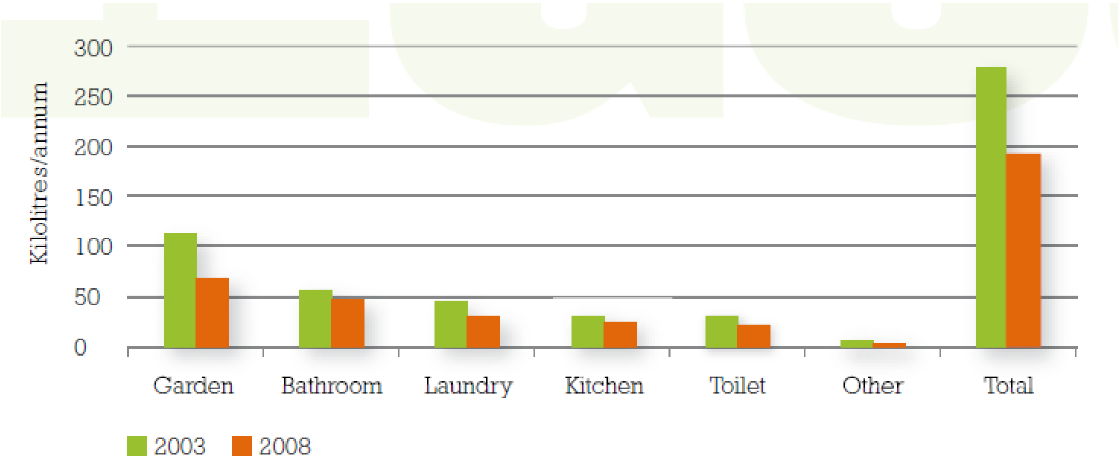


Figure 2-9 - Breakdown of household water use in Adelaide - pre and post restrictions (Government of South Australia, 2010, p. 38)

Table 2-7 - Assumed indoor demand for the base case of greater Adelaide (average household size of 2.4 persons)

| | Household annual (kL/household/year) | Per capita a year (kL/person/year) | Household daily (L/household/day) | Per capita daily (L/person/day) |
|---|---|---|---|---|
| Total water demand | 237 | 99 | 650 | 270 |
| Indoor water demand | 142 | 59 | 390 | 162 |

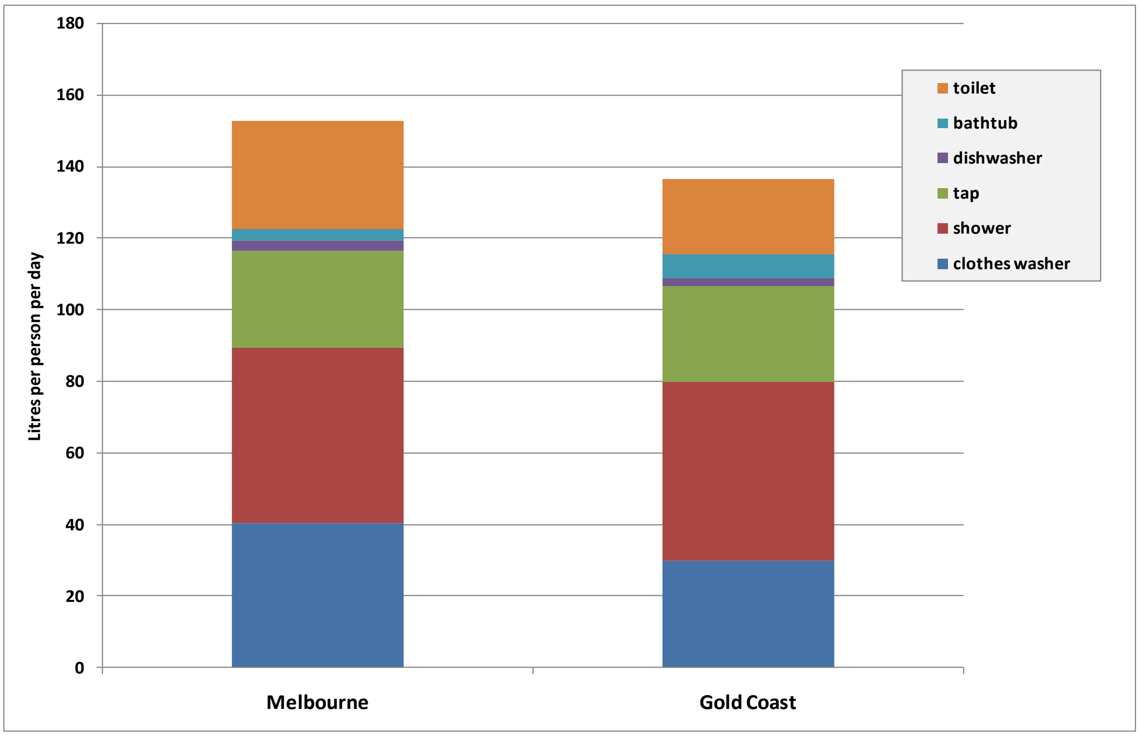


Figure 2-10 - Breakdown of indoor water use – Australian End Use Studies (adapted from Roberts [2005] and Willis *et al.* [2009])

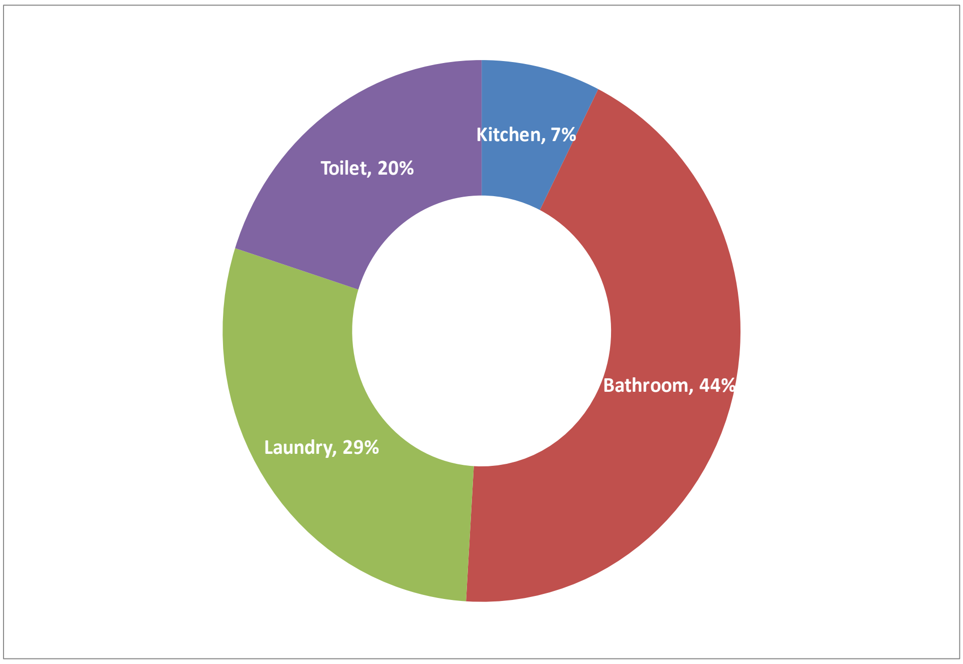


Figure 2-11 - Breakdown of indoor water use used in UVQ modelling for this study (based on Australian end use studies i.e. Roberts [2005] and Willis *et al.* [2009])

In presenting the data in Figure 2-10, Willis *et al.* (2009) makes the point that water consumption will vary significantly between regions, due to influences such as water restrictions and climate. Stewart *et al.* (2005) demonstrated that there were economies of scale for dishwasher and washing machine water consumption, with an increase in household size being correlated with a decline in per capita consumption for those appliances. Athuraylia *et al.* (2008) showed that, based on a Melbourne study, as household size decreases there is a marked increase in per capita water consumption. However, this analysis does not consider the economies of scale in deriving targets as the target is focussed on options that can be implemented in new dwellings where the household composition is not known.

### Hot water demand

The options for water conservation include the supply of harvested rainwater for all approved indoor uses, which includes hot water demand. The factors influencing household hot water demand include: appliance flow rate, occupancy rate, household composition, installed appliances and the temperature of mains water.

Hot water demand characteristics are summarised in Table 2-8. The split between hot and cold water for taps, baths and showers, assumes a cold water temperature of 18°C, hot water temperature of 60°C and desired end use temperature of 36°C. Appliances such as front loading washing machines and dishwashers now often only connect to cold water supply as they have internal water heating units. Therefore, we have assumed the dishwasher component of kitchen water use, 7 litres per day, does not require external water heating. While, for the laundry it is assumed that 60% of the washing machines are either used exclusively on cold water cycles or are front loaders with an internal water heating unit. This approximately aligns with the finding of George Wilkenfeld and Associates (2008) which reported that washing machines use 12% hot water on average across all cycles.

Table 2-8 - Indoor demand for hot and cold water (hh = household)

| End use | Overall indoor demand (L/hh/day) | Estimated cold water proportion (L/hh/day) | Estimated hot water proportion (L/hh/day) |
|---|---|---|---|
| Toilet | 78 | 78 | 0 |
| Kitchen | 27 | 18 | 9 |
| Laundry | 113 | 96 | 17 |
| Bathroom | 172 | 98 | 74 |

### 2.5.3 Climate

Rainfall records adopted in this Section of the report consisted of 29 years of daily rainfall data extracted from patch point data as described in Section 1.4.1.

### 2.5.4 Allotment characteristics

The allotment characteristics scenarios consider two main residential development types – separate residential dwellings, and medium density dwellings. In the Adelaide Statistical Division, around 80% of households reside in separate houses, with the remainder of households living in higher density dwellings such as flats, units or townhouses (ABS, 2010b). The average floor area of new Adelaide houses is around 200 $m^2$ and for medium density dwellings 150 $m^2$. These floor areas have been used to estimate the potential roof catchment for rainwater harvesting.

## 2.6 Scenario Results

The following section presents the results of the scenario analysis in the UVQ model, which shows, for different scenario options, the potential substitution of potable water that can be achieved. The following scenarios were examined:

- Scenario 1 – Base case
- Scenario 2 – Rainwater tanks
- Scenario 3 – Demand management
- Scenario 4 – Municipal third pipe scheme

### 2.6.1 Scenario 1 - Base Case

The base case in Greater Adelaide is based on Regulation 83A that specifies the minimum requirements for a rainwater tank in a new dwelling, which are: a connected roof area of $50m^2$ and a 1 kL tank size. For the base case we have also assumed an average household size of 2.4 persons located in the medium rain fall zone (Kent Town). Appliances and fittings are assumed to have a four star WELS rating. This scenario otherwise uses conventional centralised services for water supply. Demand was determined based on placing the demand profiles in Table 2-7 (Page 36).

The results of UVQ Modelling for this base case showed the yield from a rainwater tank would be 11 kL per household per year. This corresponds to an indoor water demand of 87 kL per household per year.

### 2.6.2 Scenario 2 – Expanded Rainwater Tanks

The expanded rainwater tanks scenario explores the expansion of rainwater harvesting to satisfy indoor demand from the following approved uses: toilet flushing, laundry and hot water demand. The scenarios explore potential yield considering:

- Rainfall zones
- Different storage sizes (1, 2, 5, 10 and 20 kL tanks); and
- Effective roof area (50, 100, 150 and 200 $m^2$)
- Water usage characteristics

In general, the yield of rainwater tanks (and associated reliability of supply) varies with the rainwater tank holding capacity and the roof catchment area. This is illustrated in **Appendix B** (Figure B 1 to Figure B 12) for three representative rainfall zones (Port Adelaide, Kent Town and Kersbrook). These rainfall zones were selected to represent low, medium and high rainfall areas of Adelaide residential areas. The figures show how climatic zones, rain tank storage capacity, water demand and roof area impact on the reliability of water supply. It was assumed that the rainwater tank was plumbed for indoor non-potable uses (toilet flushing, hot water and laundry). Therefore, the results in Figure B 1 to Figure B 12 represent the use of harvested rainwater for all approved indoor uses.

Around 57% of homes in South Australia are considered suitable for a rainwater tanks, and 44% of households have a rainwater tank, which seems to indicate there is a limited scope for additional water conservation through rainwater tanks. However, in South Australia only 7.3% of households used rainwater as a source for toilet flushing, while 12% of South Australian households used rainwater as a source for clothes washing (ABS, 2011). However, in Adelaide the proportion of households using rainwater for clothes washing fell to 2% (ABS 2011). This indicates that rainwater for plumbed indoor uses is more common in areas remote from reticulated services. Therefore, the use of harvested rainwater for toilet flushing, hot water services, and the laundry represents significant potential for reduction in drinking water use, which is explored in this section.

To further examine the relative impact of the key characteristics that affect the yield from rainwater tanks we further compare water yield and subsequent indoor mains water demand for the low and medium rainfall zone in Table 2-9 to

Table 2-11.

Table 2-9 - Rainwater use for a 2.4 person household with 4 star WELS appliance, and rainwater tank plumbed for toilet flushing only. Figures indicate tank yield, kL/hh/year and (Indoor mains demand, kL/hh/year)

| | **Connected Roof Area** | | |
|---|---|---|---|
| **Tank size** | 50 $m^2$ | 100 $m^2$ | 200 $m^2$ |
| | **PORT ADELAIDE** | | |
| **1 kL** | 10 (88) | 11 (87) | 12 (86) |
| **2 kL** | 11 (87) | 12 (86) | 13 (85) |
| **5 kL** | 13 (85) | 13 (85) | 13 (85) |
| | **KENT TOWN** | | |
| **1 kL** | 11 (87) | 12 (86) | 12 (86) |
| **2 kL** | 12 (86) | 13 (85) | 13 (85) |
| **5 kL** | 13 (85) | 13 (85) | 13 (85) |

Table 2-10 - Rainwater use for a 2.4 person household with 4 star WELS appliance, and rainwater tank plumbed for toilet flushing and cold water tap in laundry. Figures indicate tank yield, kL/hh/year and (Indoor mains demand, kL/hh/year)

| | **Connected Roof Area** | | |
|---|---|---|---|
| **Tank size** | 50 $m^2$ | 100 $m^2$ | 200 $m^2$ |
| | **PORT ADELAIDE** | | |
| **1 kL** | 13 (85) | 19 (79) | 23 (75) |
| **2 kL** | 14 (84) | 22 (76) | 26 (72) |
| **5 kL** | 14 (84) | 25 (73) | 30 (68) |
| | **KENT TOWN** | | |
| **1 kL** | 16 (82) | 21 (77) | 24 (74) |
| **2 kL** | 18 (80) | 24 (74) | 27 (71) |
| **5 kL** | 19 (79) | 27 (71) | 30 (68) |

Table 2-11 - Rainwater use for a 2.4 person household with 4 star WELS appliance, and rainwater tank plumbed for toilet flushing, cold water tap in laundry and hot water. Figures indicate tank yield, kL/hh/year and (Indoor mains demand, kL/hh/year)

| | **Connected Roof Area** | | |
|---|---|---|---|
| **Tank size** | 50 $m^2$ | 100 $m^2$ | 200 $m^2$ |
| | **PORT ADELAIDE** | | |
| **1 kL** | 14 (84) | 23 (75) | 32 (66) |
| **2 kL** | 14 (84) | 26 (72) | 38 (60) |
| **5 kL** | 14 (84) | 27 (71) | 45 (53) |
| | **KENT TOWN** | | |
| **1 kL** | 18 (80) | 28 (70) | 36 (62) |
| **2 kL** | 19 (79) | 32 (66) | 41 (57) |
| **5 kL** | 19 (79) | 36 (62) | 48 (50) |

The results indicate that where rainwater tanks are used only for toilet flushing, neither the connected roof area nor the tank size have significant impact on annual yield. However, as indicated in Appendix B, where a tank is connected to toilet, laundry cold water tap and hot water, the connected roof area has a generally larger impact than tank size on annual rainwater tank yield. The data in Appendix B also shows that yield across Greater Adelaide varies based on rainfall patterns. Households in relatively low annual rainfall areas (around 400 mm per year) are estimated to have 25% less yield from their rainwater system plumbed for indoor non-potable demand compared to households located in moderate rainfall zones (560 mm a year). The analysis also shows that as roof area increases rainfall collection efficiency increases and tank size becomes a more significant influence on rainwater yield and reliability of supply.

### 2.6.3 Scenario 3 - Third Pipe Scheme

The municipal third pipe scheme scenario explores the impact of a third pipe supplying non-potable quality water for toilet flushing. The source of the third pipe scheme is not considered in this scenario. Existing schemes in Adelaide include sourcing non-potable water from both stormwater and recycled wastewater. It is assumed in the scenario that a third pipe system is always able to meet indoor non-potable demand. The analysis found that indoor water use could be 230 kL per household per day (96 L per person per day) with the availability of a third pipe water source.

While outdoor demand is not explicitly considered in the interim water conservation targets for Greater Adelaide, a reticulated non-potable rainfall independent water source would provide a reliable source to replace potable water used for garden irrigation.  It should be noted that while there is an improvement in indoor mains water demand, the greatest benefit of a third pipe supply is achieved by reductions in outdoor mains water use.  Although outdoor water use options were not examined the adoption of Smart Watermark approved irrigation products should be encouraged.

### 2.6.4 Scenario 4 - Demand Management for Class 2 Dwellings

The demand management scenario was based on the uptake of water efficient appliances with no rainwater tanks. Class 2 dwellings consist of multiple dwellings on a single property, where mandatory rainwater tanks may not be feasible. As such, this case was examined to explore the water savings opportunities for Class 2 dwellings. Appliance water efficiency was based on information contained on the Australian Government's Water Efficiency Labelling and Standards (WELS) scheme (http://www.waterrating.gov.au/). The water efficiency assumptions for each appliance are:

- *Toilet* – Full flush = 4.6 litres, half flush = 3.15 litres, average flush volume = 3.5 litres (WELS rating 4), total flushes = 3.6 flushes per person a day.
- *Washing machine* (8 kilogram capacity) – Average volume per wash = 70 litres (WELS rating 4), total wash loads = 6.4 loads per week for the average household.
- *Dishwasher* – Average volume per wash = 14 litres (WELS rating 4).
- *Shower* – Flow rate = 8 litres per minute (WELS rating 3).
- Taps (bathroom, kitchen and laundry sinks) – Flow rate = 7.5 litres per minute (WELS rating 4).

The impact of the uptake was estimated using data from the residential end use study undertaken by Roberts (2005), where the average frequency and flow rate of appliances was reported.

Washing machines need to meet the minimum performance standards specified in *AS/NZS 2040: 2005 Performance of household electrical appliances – clothes washing machines*. The WELS rating bands for washing machines are normalised to 1.0 star rating for a machine that uses 30 litres per kilogram of capacity. Each 30% reduction in litres per kilogram earns an additional star (George Wilkenfeld and Associates, 2008). Washing models registered to the latest standard (AS/NZS 2040: 2005) are on average more efficient that those registered under the preceding standard (AS/NZS 2040: 2000) (George Wilkenfeld and Associates, 2008). Both top loaders and front loaders have, on average, reduced water consumption by 13% from the 2000 standard to the 2005 standard. There has been a shift toward customers purchasing more efficient washing machines in recent years, with a related shift to front loaders from top loaders (Figure 2-12) (George Wilkenfeld and Associates, 2008). Given the natural replacement rates for existing washing machines, and the potential introduction of guidelines for appliances in new dwellings, there is the potential for further household uptake of water efficient washing machines, which will substantially reduce indoor water demand.

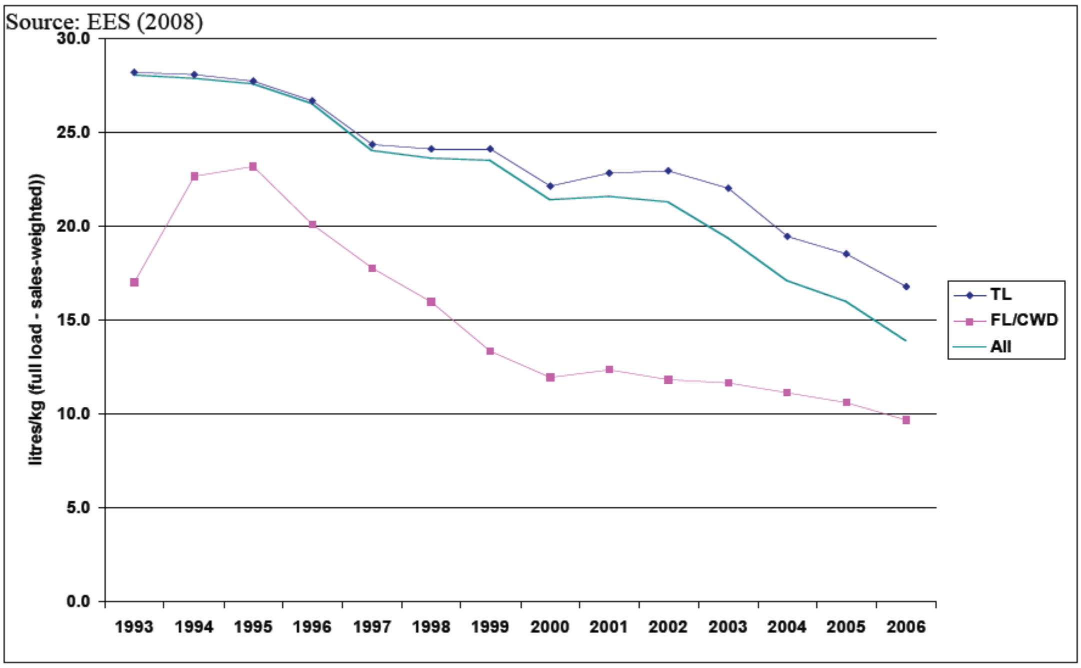


Figure 2-12 - Sales weighted average litres per kg, clothes washers sold in Australia (George Wilkenfeld and Associates, 2008)

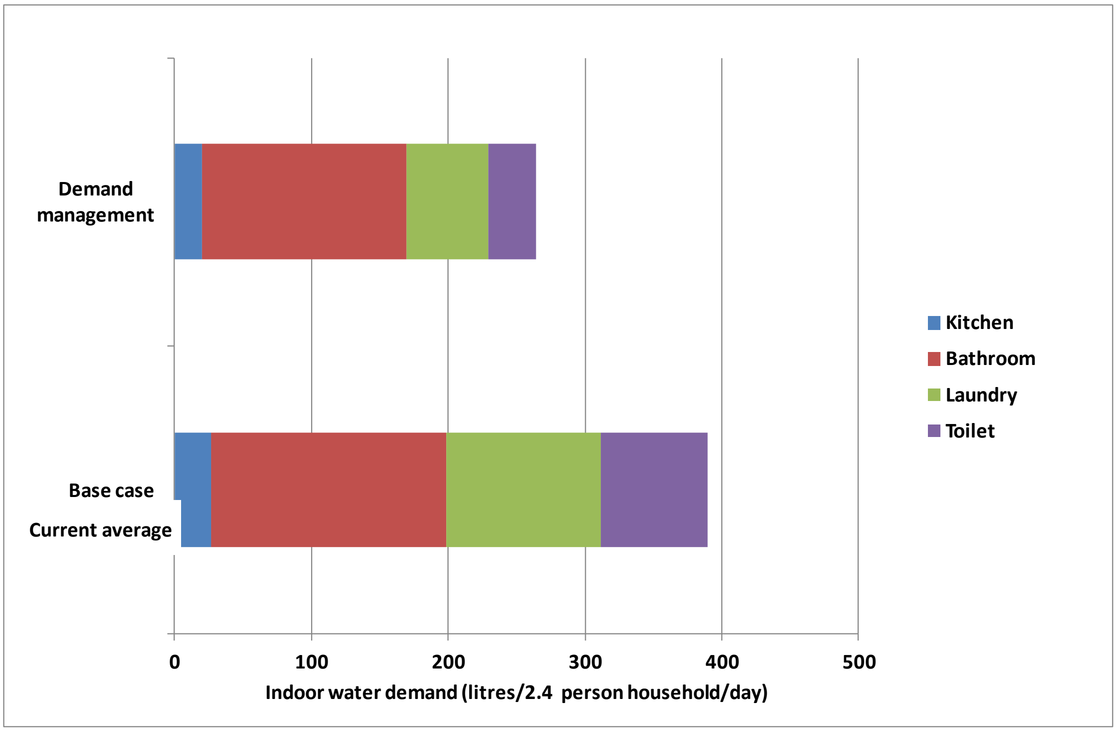


Figure 2-13 – Indoor water demand for a typical household (2.4 persons) – base case and demand management scenarios (litres/hh/day)

Figure 2-13 compares indoor water use between the South Australian average water use between 2003 to 2006 (390 L per household per day as outlined in Section 2.5.2) and Scenario 3. This shows that 126 L of water are saved each day for each 2.4 person household under the demand management scenario assumptions. The laundry (washing machine) is responsible for the greatest water savings. The scenario does not model changes in garden watering as the focus is on the impact of the uptake of water efficient appliances rather than behavioural changes, such as less watering or changes in garden design.

## 2.7 Scenario Overview

The scenarios presented in the previous sections demonstrate the potential level of water conservation for indoor water demand that could be achieved using different approaches for an average household size. The purpose of the scenario analysis was to demonstrate options to achieve an interim water savings target.

The consideration of the scenarios needs to be done in light of a number of caveats:

- There was limited data available in terms of baseline water demand.
- The development of the interim water conservation targets has not undertaken a full cost benefit of different options. As such, there is no relative cost per unit of water saved or comparison against supply side initiatives. This is required to guide any investment strategies in implementing a water conservation program.
- There are a range of variables that determine the suitability of different water conservation options for different household types, including: dwelling type, allotment area, household size
- New Class 1 dwellings in Adelaide under the Building Code of Australia are assumed to be those that require WELS rated appliances with a minimum of four stars. New dwellings also require a minimum 1 KL rainwater tank, connected to a 50 $m^2$ roof area and plumbed for toilet flushing in accordance with the South Australian Housing Code. Exceptions to the requirement for a plumbed rainwater tank are buildings that can access a different additional water supply, such as dual reticulated water supply systems or water from an approved bore.
- The best outcome in terms of reduction would come from a combination of options (demand management and an alternative water source). However, the potable water reductions for each option are first presented independently.

Some of the key findings from the scenarios were:

- Rainwater tanks are prevalent in Adelaide separate dwellings, however, there is a potential to realise additional reductions in indoor demand, particularly if rainwater tanks are plumbed for indoor uses such as laundry, hot water services and toilet flushing. The present mandatory standard of 50 $m^2$ connected roof area is the limiting factor for yield from rainwater systems in Adelaide.
- Demand management through the uptake of water efficient appliances and permanent water conservation has resulted in a significant reduction in per capita residential water use in Adelaide compared to 2003 water use. The demand management option in the analysis presented focuses mostly on the potential reductions that could be achieved through more widespread uptake of the most water efficient washing machines. The sales weighted

average for washing machines sold in Australia in 2006 showed most were rated between 2.5 to 3 stars according to the WELS scheme. A shift from a 3 star rated machine to a 5 star clothes washer could save around 8 kL a year for an 8 kg machine used three times a week

- The demand management scenario explored moving to 5 star WELS rated toilets and tap fixtures, however there is only a relatively minor difference in water reductions between the current BCA standards (4 star rated fixtures) and use of 5 star rated WELS appliances. For example moving from a 4 star rated WELS dual flush toilet, using an average of 3.5 litres per flush, to 5 star rated WELS toilet, using an average of 3 litres per flush, is likely to save an average size household around 1.5 kL a year. This assumes 3.6 flushes per person a day for an average household size of 2.4 people.
- Adelaide has a number of residential developments serviced by a dual pipe system that supplies both potable and non-potable water to the home. These developments include Mawson Lakes, recognised as pioneers in utilising non-potable water sources for indoor and outdoor water demand. This option for reducing potable water demand is likely to be only applicable for new residential areas due to the difficulty and cost associated with retrofitting existing properties with a ‘third pipe’. Demand management should still apply to the use of recycled water as there is significant cost and energy required to provide this resource to households.

## 2.8 Water Conservation Targets and Recommendations

Adelaide households over the last 10 years have significantly reduced per capita residential water demand. Some of this reduction has been through temporary measures such as water restrictions, but many of the actions taken to reduce water demand are more enduring, such as permanent water conservation, uptake of water efficient appliances and alternative water sources. In addition to these actions that have locked in reduced per capita residential water demand there has been behavioural changes in water use. These behavioural changes have been motivated by ongoing education campaigns, particularly during the period of water restrictions, which have made householders more conscious of the need to conserve water through measures such as shorter showers. In addition, new dwellings in Adelaide need to meet the minimum standards under the Building Code of South Australia for water efficient appliances and use of an alternative water supply, such as rainwater, in Class 1 Dwellings. This means targets for water conservation need to consider the existing context in identifying the potential for reductions in drinking water use.

Under the *South Australian Housing Code*, there is minimum requirement for all new Class 1 dwellings to have (in the absence of a secondary reticulated supply or access to bore water) a 1 kL rainwater tank, connected to a 50 $m^2$ roof area and plumbed to either the toilet, water heater or all indoor laundry taps. Modelling showed that for the moderate rainfall zone and average household size the potential average reduction in potable demand was 16 kL a year when the rainwater tank was plumbed for toilet flushing. This potential reduction could be significantly improved through increasing the minimum connected roof area to 100 $m^2$ and plumbing the rainwater tank to all approved indoor uses, with modelling indicating the potential substitution of potable water demand could be doubled to 32 kL a year.

The *Building Code of Australia (BCA)* specifies that all Class 1 Dwellings have the minimum water efficiency measures:

- All tap fittings (other than bath outlets and garden taps) to be a minimum 4-star WELS rated
- All showerheads to be a minimum 3-star WELS rated
- All toilets to be a minimum dual-flush minimum 4-star WELS rated

Table 2-12 shows the potential reductions in indoor mains water use for new dwellings in the Greater Adelaide Region, with a combination of both demand management and substitution with a non-potable water source. The results showed that a new dwelling could achieve, or are already achieving a reduction of between 32% and 47% in indoor demand compared to the 2003-2006 average, which was used to benchmark the performance of water conservation initiatives. The rainwater harvesting scenarios have used simulation results from the low rainfall zone for Greater Adelaide. So potable substitution with rainwater would be higher in moderate and higher rainfall zones, under the assumptions of the scenarios modelled. It should be noted that the estimated substitution is based on the mean of the annual performance of rainwater tanks simulated using a 29 year climate history. Therefore, the yield from the rainwater system, and hence potable substitution, would vary annually.

Table 2-12 - Potential mains water savings by water efficiency and alternative sources for indoor demand

| | ***Household annual indoor mains water use (kL/hh/year)*** | ***Household daily indoor mains water use (L/hh/day)*** | ***Per capita yearly indoor mains water use (kL/person/year)*** | ***Per capita daily indoor mains water use (L/person/day)*** |
|---|---|---|---|---|
| **Scenario 1 - New dwellings**[1] | 87 | 240 | 36 | 100 |
| **Scenario 2 – Expanded rainwater**[2] | 70 | 190 | 29 | 79 |
| **Scenario 3 – Third pipe**[3] | 84 | 230 | 35 | 96 |

**Notes:**
[1] Indoor mains water use target for new Class 1 dwellings – assuming average household (2.4 persons) with rainwater tank (as per SA Housing Code – 1 kL tank, connected to 50 $m^2$ roof area and plumbed for toilet flushing) and 4 star rated WELS appliances
[2] Example of expanded rainwater harvesting: indoor target for Class 1 dwellings - average household (2.4 persons) with rainwater tank (1 kL tank, connected to 100 $m^2$ roof area and plumbed for all approved indoor uses) and 4 star rated WELS appliances, medium rainfall (Kent Town)
[3] Third pipe: indoor target for class 1 dwellings - average household (2.4 persons) with piped non-potable water for toilet flushing and plumbed for all approved indoor uses) and 4 star rated WELS appliances

Based on the results in Table 2-12, this project proposes the following target for *indoor water demand* for new dwellings based on the current requirements established by the Building Code of Australia and the South Australian Housing Code: ***36 kL per person per year or 100 litres per person per day.*** A performance based target enables flexibility for how the target is achieved depending on the household characteristics, dwelling type and development context.

## 2.9 Comparison of water conservation target with other jurisdictions and end use studies

Analysis of water savings attributable to the BASIX in NSW found that 87% of houses relied on a rainwater tank to achieve the BASIX target of up to a 40% reduction in water use compared to the benchmark value (Sydney Water, 2008a) (see Appendix D for a discussion on BASIX). The benchmark used for BASIX is based on 2002/03 average water use data of 90 kL per person per year, compared to the benchmark used in this study of 99 kL per person per year. The benchmark assumes 76% of total household water demand goes to indoor uses, and the remainder to outdoor uses. This means the BASIX baseline indoor demand can be assumed to be 68 kL per person per year, which is higher than the baseline of used for this study. It is unclear if the 40% reduction attributed to BASIX applies equally to both indoor and outdoor demand, but if it did this would mean that BASIX homes are achieving indoor demand of 40 kL per person per year, comparable to the 36 kL per person per year recommended in this study.

The Victorian 5 star building standard requires all Class 1 dwellings to have flow rates to showers and taps of between 7.5 and 9.0 litres per minute, which is equivalent to WELS 3 star rated tapware. Furthermore, the house needs to have either a solar hot water system or a rainwater tank with a minimum storage capacity of 2 kL that is connected to 50 $m^2$ roof and plumbed for toilet flushing. Analysis by GWA (2006) estimated that an average household (2.67 persons) living in a 5 star rated home uses 166 kL per year compared to 202 kL per year for a home that has not implemented the 5 star standards. This equates to 62 kL per person per year, and assuming 60% of demand is indoor as in the case of this study, this equates to an indoor component of 37 kL per person per year.

Under the Queensland Development Code Mandatory Part 4.2, all new Class 1 dwellings are now required to save 70 kL of mains water per year compared to the benchmark of all existing homes. The most common approved way to achieve this target is through a 5 kL rainwater tank connected to at least 100 $m^2$ of roof area and plumbed for toilet flushing and cold water laundry tap. Chong *et al.* (2011) have undertaken analysis to determine the savings in mains water being delivered by mandated rainwater tanks. Their analysis for the Gold Coast shows that a household with a mandated rainwater tank reduced their consumption by 88 kL per household per year compared to average water consumption over the same period. Across the 172 households studied in the Gold Coast local government area in 2010 the mean water use for households with mandated rainwater tanks was 45 kL per person per year, while average consumption for all households was 70 kL per person per year. This represented in mains water savings of 33% (Chong *et al.*, 2011). The values recorded include indoor and outdoor water demand. Beal and Stewart (2011) reported that, for Gold Coast households in 2010, 15% of water demand was for garden irrigation (summer and winter average). Adjusting for outdoor demand, households with mandated rainwater tanks reduced their indoor demand for mains water to around 106 litres per capita day or 38 kL per person per year.

The VicUrban Ecologically Sustainable Development Guide uses a benchmark of 260 litres per person per day, which includes indoor and outdoor water use. Points towards ESD certification are available for conservation measures that reduce demand. VicUrban recommends the following performance standards for residential water conservation:

- 4 points - Reduce consumption to 75% of benchmark (195 L per person per day)

- 8 points - Reduce consumption to 50% of benchmark (130 L per person per day)

Table 2-13 lists some Australian end use studies that have reported on indoor water demand. Indoor demand is influenced household composition, dwelling type, appliances and householder behaviour. These end use studies provide a benchmark to compare a target of 40 kL per person per year indoor demand in new dwellings for Greater Adelaide.

Table 2-13 – Summary of Australian end use studies (Note these studies are based on existing, not new housing)

| City and end use study | Reported indoor demand (kL/person/year) | Reported outdoor demand (kL/person/year) | Total demand (kL/person/year) |
|---|---|---|---|
| Perth (2008/09) – Water Corporation (2010) | 56 | 46 | 102 |
| Gold Coast (2008) – Willis et al. (2009) | 49 | 7 | 56 |
| Melbourne (2004) – Roberts (2005) | 55 | 21 | 76 |

## 2.10 Comment on Implementation of Water Conservation Targets

The implementation of any water conservation target needs to undertake a full cost benefit analysis, which considers the net cost (or benefit), both direct and indirect, associated with implementation. *Water for Good* defines the parameters that need to be considered in taking decisions on supply augmentation or demand management. Those relevant for water conservation implementation include:

- Consumer efficiency
- Demand factors – population and economic growth
- Climate change scenarios
- Environmental requirements
- Cost effectiveness
- Standards of services

Investment in water conservation programs needs to consider the following:

- The uptake of water efficient appliances that can be attributed to any rebate or other scheme
- The marginal cost benefits of water conservation, particularly for potable water supply
- The total cost of any water conservation initiative to both individual households and the Government
- Consumer preferences and acceptance of water conservation measures
- Equity of measures across different socio-economic groups
- The broader impacts of water conservation on hydrological balance, such as rainwater harvesting, in reducing stormwater discharge and reduced energy demand for water supply and end use.

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# 3 Stormwater Runoff Quality Improvement Targets

## 3.1 Introduction

Urban stormwater contains a variety of pollutants that contribute to the degradation of receiving waters such as streams and wetlands and coastal waters (Duncan, 2005). In response to this, Australian state and local jurisdictions have begun to establish varying degrees of control on stormwater runoff quality. In this section, existing methods for stormwater quality management are reviewed and targets are proposed for the Greater Adelaide Region.

## 3.2 Review of Existing Stormwater Runoff Quality Improvement Targets

During the 1990s, the Agricultural & Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australian and New Zealand Environment & Conservation Council (ANZECC) developed the National Water Quality Management Strategy (NWQMS). The NWQMS developed much of the current policy, process and national guideline material for water quality management. As part of the program, the Australian Guidelines for Urban Stormwater Management (ANZECC & ARMCANZ, 2000) were developed to provide a uniform approach to urban stormwater management.

More recently, the Council of Australian Governments have signed the *Intergovernmental agreement on a national water initiative*[10] with a view to providing a strategic plan for sustainable water management. Under Clause 92 of the agreement, an agreement was made by all parties as follows:

> *"Innovation and Capacity Building to Create Water Sensitive Australian Cities*
>
> *92. The Parties agree to undertake the following actions in regard to innovation:*
>
> *i) develop national health and environmental guidelines for priority elements of water sensitive urban designs (initially recycled water and stormwater) by 2005;*
>
> *ii) develop national guidelines for evaluating options for water sensitive urban developments, both in new urban sub-divisions and high rise buildings by 2006;*
>
> *iii) evaluate existing 'icon water sensitive urban developments' to identify gaps in knowledge and lessons for future strategically located developments by 2005;*
>
> *iv) review the institutional and regulatory models for achieving integrated urban water cycle planning and management, followed by preparation of best practice guidelines by 2006; and*
>
> *v) review of incentives to stimulate innovation by 2006".*

[10] http://www.coag.gov.au/coag_meeting_outcomes/2004-06-25/index.cfm, accessed May 2011

In 2009, the report titled *Evaluating Options for Water Sensitive Urban Design – A National Guide* (BMT WBM Pty. Ltd., 2009) was released which aimed to:

- *"Identify issues that should be considered in evaluating strategies to achieve WSUD;*
- *Provide a consistent framework which can be applied nationally for the facilitation and evaluation of WSUD proposals. The framework may be used by developers and development assessors and will maximise the success of WSUD proposals;*
- *Supplement (but not replace) existing WSUD regulations and detailed design and implementation guidelines. In areas where local guidelines don't exist, these Guidelines may assist with the assessment and evaluation of WSUD proposals;*
- *Direct readers to more detailed technical WSUD literature on specific issues and for location specific advice; and*
- *Could be used or considered in developing WSUD planning scheme provisions."*

The guideline specifically indicates that the requirements of relevant state or local government authorities take precedence over advice provided by the national guidelines as the national guidelines *are not mandatory and are not legally enforceable*. The guidelines simply provide a common national objective but are open to different standards taking into account local conditions. Moreover, it recommends practitioners consider existing State or Local Authority guidelines for Water Sensitive Urban Design (WSUD), sediment and erosion control and *locally specific targets* to be applied in WSUD.

As such, the guidelines do not set water quality objectives (WQOs), but rather provide "example conditions" that a local Authority can place on developments. Definite objectives are not set as they may not be transferable across Australia. The example guidelines provided by BMT WBM Pty. Ltd. (2009) are as follows:

> *"During the construction phase, total suspended solids concentrations for all flows up to the 1 year Average Recurrence Interval event to be less than 100 mg/L; and*
>
> *During the operational phase, achieve the following minimum reductions in total pollutant load, when compared to untreated stormwater run-off:*

- *80%* reduction in total suspended solids
- *60% reduction in total phosphorus*
- *45% reduction in total nitrogen*
- *90% reduction in gross pollutants."*

The guidelines not only consider water quality but also provide advice on water quantity, planning and environmental elements of WSUD implementation. State and local authorities have provided different sets of objectives in terms of water quality and quantity management, as discussed in the following sections.

### 3.2.1 Queensland

The main legislation in Queensland regarding water quality management is the Environmental Protection Act 1994, which establishes the framework for environmental values and WQOs. The Act establishes environmental values for Queensland waterways as well as water quality objectives to achieve and maintain these values. Development in Queensland is governed by the Integrated Planning Act 1997 which aims to achieve ecologically sustainable development through balanced use of natural resources whilst minimising the ecological impacts associated with developments. The Integrated Planning Act also provides the framework for local governments to prepare a planning scheme specifying 'desired environmental outcomes' and strategies within the planning scheme to achieve such outcomes.

In 2006, the WSUD Technical Design Guidelines for South East Queensland (SEQHWP, 2006) set mean annual loads reduction targets for stormwater discharges recognising the difficulties in using concentration based targets. These difficulties included the temporal variability in outflow concentration and its associated issues in defining a median value, as well as the fact that moderate concentrations associated with large volumes of stormwater may still lead to degradation of ecosystems. The adopted design objectives in the guidelines were:

- 80% reduction in total suspended solids load
- 60% reduction in total phosphorus load
- 45% reduction on total nitrogen load
- 90% reduction in gross pollutant load.

In 2009 the Queensland Government amended the Environmental Protection (Water) Policy 2009 establishing urban stormwater management as part of the total water cycle management context. This policy outlines the hierarchy to be used in applying water quality guidelines in the context of water planning when there are multiple or conflicting guidelines. In summary, the appropriate policies are those which are available from local government. In the absence of these, state policies are selected, which in turn take precedence over national guidelines (DERM, 2009a). The Policy also sets acceptable methodologies for defining the water quality objectives of urban stormwater based on monitoring, modelling or best management practices.

The Queensland Water Quality Guidelines (DERM, 2009a) present revised urban stormwater quality objectives for urban development in Queensland for pre- and post-development phases, but ultimately refer the reader to the *Draft Urban Stormwater-Queensland Best Practice Environmental Management Guidelines* (released September 2009) which have been subsequently replaced by the *Urban Stormwater Quality Planning (USQP) Guidelines 2010* (DERM, 2010). The USQP guidelines establish climatic regions for Queensland based on rainfall statistics (seasonality, pattern and annual mean). For localities in the boundary of regions, the most astringent condition is to be adopted. The conditions for different regions in Queensland as set by the USQP guidelines for pre- and post-development are shown in Figure 3-1 and Figure 3-2 respectively.

| Construction phase stormwater design objectives | | Notes |
|---|---|---|
| **Drainage control** | Design life and design storm of temporary drainage works:<br>1. Disturbed area open for <12 months—1 in 2 ARI<br>2. Disturbed area open for 12-24 months—1 in 5 ARI<br>3. Disturbed area open for > 24 months—1 in 10 ARI | ARI = Average Return Interval (see Engineers Australia document Australian Rainfall and Runoff).<br>Design capacity excludes minimum 150 mm freeboard.<br>A higher drainage design objective may be required for temporary drainage structures upslope of occupied properties.<br>A revised drainage design storm may be required if these design objectives are found to be impracticable (e.g. in North Queensland). |
| **Erosion control** | 1. Minimise exposure of disturbed soils at any time<br>2. Avoid or minimise large construction activities in the wet season<br>3. Divert water run-off from undisturbed areas around disturbed areas<br>4. Use erosion risk ratings to determine appropriate erosion control measures | 'Wet season' means the high rainfall months, e.g. the four highest rainfall months.<br>For point 4, determine the erosion risk rating using local rainfall erosivity, rainfall depth, or soil loss rate or other acceptable method. A rating scale such as very low, low, moderate, high, extreme should be applied. Such ratings should reflect the local area. Example ratings may be shown in local council guidelines or detailed in best practice guidelines. |
| **Sediment control** | Use soil loss rates to determine appropriate sediment control measures<br>Design storm for sediment control basins should be based on retaining the maximum sediment quantity for the maximum volume of water run-off<br>Site discharge during sediment basin dewatering should not exceed 50 mg/L TSS and pH between 6.5–8.5 | For point 1, surrogate determinations may be used such as monthly erosivity or average monthly rainfall.<br>For point 2, a commonly used design storm for basin sizing is 80th% five-day event. Depending on the settling characteristics of local soils, a higher 'operational' design storm can be achieved with chemical dosing operated in flow-through mode in a large storm with rainfall-activated<br>auto-flocculent dosing, and advanced hydraulic efficiency features such as floating off-takes, and a sediment forebay.<br>For example, on the Sunshine Coast operation of the basin can achieve the water quality outcomes in any rainfall event up to 125 mm rainfall depth in any five-day period[2].<br>For point 3, TSS = total suspended solids. Turbidity measurements (e.g. 60 Nephelometric Turbidity Units (NTU)) could be used; however, for accuracy, a site-specific relationship should be developed between turbidity and total suspended solids. |

| | | |
|---|---|---|
| **Water quality outcomes** | **Stormwater flows from undisturbed and disturbed areas**—manage to help protect environmental values | As far as is reasonable and practicable, all run-off from disturbed areas is collected and drained to a sediment basin—up to the design storm event. |
| | **Coarse sediment**—coarse sediment is retained on site<br>**Fine sediment**—Site discharge during sediment basin dewatering has a TSS concentration less than 50 mg/L | Achieve site discharge water quality through, for example, appropriate sediment basin design and operation with flocculation as required. |
| | **Turbidity**—Site discharge during sediment basin dewatering has a turbidity (NTU) less than 10% above receiving waters turbidity—measured immediately upstream of the site | A site-specific relationship should be developed between turbidity and suspended solids, prior to the commencement of construction on large and medium scale construction sites. |
| | **Nutrients (N & P)**—Nitrogen and phosphorus are managed through sediment control. | |
| | **pH**—Site discharge during sediment basin dewatering has a pH range 6.5–8.5 | May be further limited to prevent mobilisation of specific elements. |
| | **Litter and other waste**—Prevent litter/waste entering the site, the stormwater system or watercourses that discharge from the site. Also minimise or sufficiently contain on-site litter and waste production and regularly clear waste bins | Avoid wind blown litter; remove gross pollutants. |
| | **Hydrocarbons and other contaminants**—Hydrocarbons and other contaminants are prevented from entering the stormwater system or internal watercourses that discharge from the site | See the prescribed water contaminants in schedule 9 of the *Environmental Protection Regulation 2008*. Waste containing contaminants must be disposed of at authorised facilities. Store oil and fuel in accordance with Australian Standard AS1940—no visible oil or grease sheen on released waters. |
| | **Wash down water**—Wash down water is prevented from entering the stormwater system or internal watercourses that discharge from the site | |
| | **Cations and anions**—Cations and anions including aluminium, iron and sulfate are managed as required under an approved acid sulfate soil management plan | |
| **Stormwater drainage/flow management** | Hydraulics and hydrology—Take all reasonable and practicable measures to minimise significant changes to the natural waterway hydraulics and hydrology from:<br>• peak flow for the one-year and 100-year ARI event (respectively for aquatic ecosystems and flood protection)<br>• run-off frequency and volumes entering receiving waters<br>• uncontrolled release of contaminated stormwater | Including making best use of constructed sediment basins to attenuate the discharge rate of stormwater from the site. |

Figure 3-1 - Summary of design objectives for management of stormwater quality-construction phase of development (DERM, 2010)

| Region (see Figure 2.5) | Minimum reductions in mean annual loads from unmitigated development (%) | | | | Notes It is expected that application of an appropriately designed and sequenced treatment train will result in operational performance that exceeds the design objectives presented here. |
|---|---|---|---|---|---|
| | Total suspended solids (TSS) | Total phosphorus (TP) | Total nitrogen (TN) | Gross pollutants > 5 mm | If a site is adjacent to a regional boundary in Figure 2.5 or if in doubt about which regional design objectives apply, the most stringent regional design objectives should be adopted. |
| Eastern Cape York | 75 | 60 | 35 | 90 | |
| Central and Western Cape York (north) | 75 | 60 | 40 | 90 | |
| Central and Western Cape York (south) | 80 | 65 | 40 | 90 | |
| Wet Tropics | 80 | 65 | 40 | 90 | |
| Dry Tropics | 80 | 65 | 40 | 90 | |
| Central Coast (north) | 75 | 60 | 35* | 90 | * Mackay Regional Council advises that the minimum reduction for TN for the Central Coast (north) to be adopted is 40%, as detailed modelling shows that this is achievable using bioretention systems or wetlands in this local government area. |
| Central Coast (south) | 85 | 70 | 45 | 90 | |
| South East Queensland | 80 | 60 | 45 | 90 | |
| Western districts | 85 | 70 | 45 | 90 | |

Figure 3-2 - Summary of design objectives for management of stormwater quality-operational (post-construction) phase of development (DERM, 2010)

The load reduction targets for Queensland were derived from predictive computer modelling using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 3 (CRCCH, 2005) as detailed in the Urban Stormwater - Queensland Best Practice Environmental Management Guidelines 2009 Technical Note: Derivation of Design Objectives (DERM, 2009b). The reductions are based on achievable reductions when applying current “best practice” stormwater management, taking into account infrastructure operating in Queensland’s climatic and pollutant export conditions (DERM, 2009b). “Best Practice”, in this context, is defined as infrastructure designed and constructed to contemporary standards and sized to operate at a reasonable limit of economic performance and benefit to water quality.

The technical note acknowledges that bioretention treatment systems are widely considered to be the most efficient stormwater treatment technology, although a gross pollutant capture device is recommended if gross pollutants are present. The load targets for Queensland were derived by sizing bioretention treatment systems at the “point of diminishing return” and, for all regions of Queensland, this was found to be a bioretention treatment area equivalent to 1.5% of the contributing catchment area, as shown in the example of Figure 3-3. The guidelines further recommended runoff and pollutant generation parameters as well as set bioretention parameters. In addition to bioretention, further modelling was undertaken using other technologies to demonstrate that combinations of different stormwater treatment technologies (other than bioretention) could also be used to achieve the target to allow flexibility in solutions for particular developments.

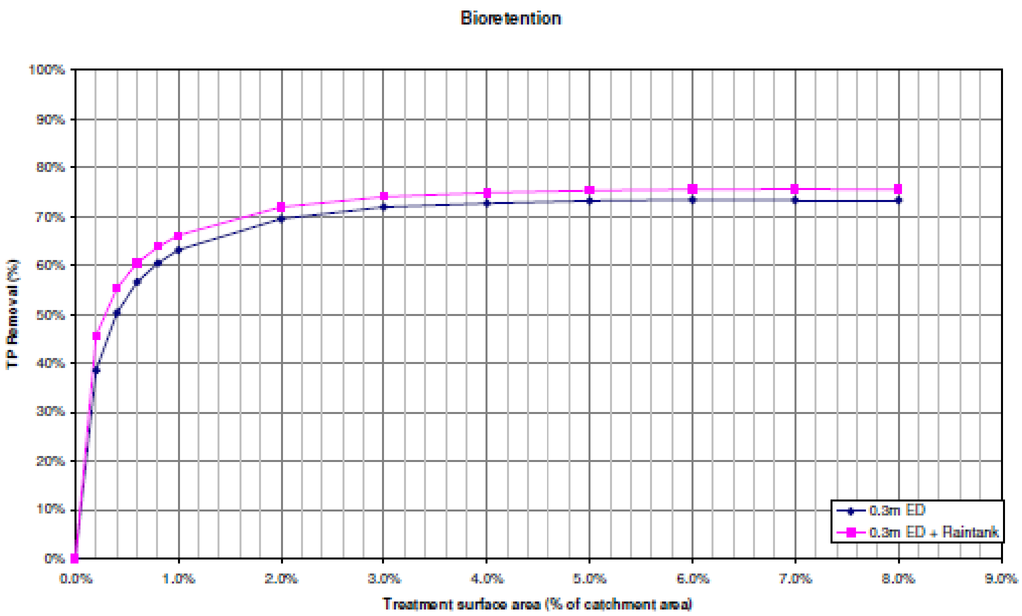


Figure 3-3 - TP removal performance as a function of the bioretention size (where bioretention size is expressed as a percentage of the catchment area) (DERM, 2009b)

In addition to these Queensland State Government guidelines, there are guidelines which have been produced by local authorities for specific regions including Mackay (DesignFlow, 2008) and South East Queensland (WaterbyDesign, 2010). These guidelines also set water quality target values and provide locally specific guidelines for pollutant export modelling with tools such as MUSIC.

### 3.2.2 Victoria

In Victoria, all elements of WSUD - water, wastewater and stormwater - are integrated in Victorian planning policy. An example of this includes the Melbourne 2030 Greener City[11] initiatives and their translation into Clause 12.07 of the Victoria Planning provisions.

The Victoria Planning Provisions regulate the implementation of WSUD in Victoria through Clause 56.07 (Integrated Water Management requirements). Clause 56.07-4 Standard 25 states that:

> *"The urban stormwater management system must be: (...)*
>
> *Designed to meet the current best practice performance objectives for stormwater quality as contained in the Urban Stormwater – Best Practice Environmental Management Guidelines (Victorian Stormwater Committee 1999) as amended."*

New subdivision and greenfield developments must meet the Clause 56.07 requirements, but some existing urban areas can have developments approved under Clause 55 which are not subjected to these requirements (usually for residential subdivision of one lot into two lots, or 'infill' development)

[11] http://www.nre.vic.gov.au/melbourne2030online/content/site_functions/pdfs.html

The State Environment Protection Policies (SEPPs) provide the statutory framework of publicly agreed environmental objectives, based on beneficial uses and environmental values. The SEPP also contains some catchment specific schedules - for example Port Phillip Bay and Yarra River. The policy requires that receiving waters should not be compromised by runoff from urban and rural areas and some sections specifically refer to stormwater control.

The *Urban Stormwater: Best Practice Environmental Management Guidelines* (Victorian Stormwater Committee, 1999) set water quality objectives for Victoria. It recognised that there are several ways to estimate the level of treatment required to meet the SEPP objectives such as monitoring, modelling or generic values. The guidelines provide objectives based on receiving waters and best practice as shown in Table 3-1. The guidelines do not present any information on how the best practice objectives were determined, but rather suggest that those were the objectives that could be met using best practices at the time of publication.

Table 3-1 - Objectives for environmental management of stormwater in Victoria (adapted from Victorian Stormwater Committee, 1999)

| Pollutant | Receiving water objective | Current best practice performance objective |
|---|---|---|
| **Post construction phase** | | |
| Suspended solids | Comply with SEPP (e.g. not exceed the $90^{th}$ percentile of 80 mg/L)[a] | 80% retention of the typical urban annual load |
| Total phosphorous | Comply with SEPP (e.g. base flow concentration not to exceed 0.08 mg/L)[b] | 45% retention of the typical urban annual load |
| Total nitrogen | Comply with SEPP (e.g. base flow concentration not to exceed 0.9 mg/L) | 45% retention of the typical urban annual load |
| Litter | Comply with SEPP (e.g. no litter in waterways) | 70% reduction of typical urban annual load[c] |
| Flows | Maintain flows at pre-urbanisation levels | Maintain discharges for the 1.5 year ARI at pre-development levels |
| **Construction phase** | | |
| Suspended solids | Comply with SEPP | Effective treatment of 90% of daily run-off events (e.g. < 4 months ARI) Effective treatment equates to a 50 %ile SS concentration of 50 mg/L. |
| Litter | Comply with SEPP (e.g. no litter in waterways) | Prevent litter from entering the stormwater system |
| Other pollutants | Comply with SEPP | Limit the application , generation and migration of toxic substances to the maximum extent practicable |
| [a] an example using SEPP (Waters of Victoria, 1998), general surface waters segment<br>[b] SEPP Schedule F7 – Yarra Catchment – urban waterways for the Yarra River main stream<br>[c] Litter is defined as anthropogenic material larger than five millimetres | | |

To standardize the assessment of proposed WSUD measures to meet the water quality objectives, which are commonly reported using MUSIC modelling, Melbourne Water has a detailed set of guidelines on the appropriate use of MUSIC modelling within the Melbourne Water catchment zone. The guidelines for the use of MUSIC (Melbourne Water, 2010) define rainfall zones, representative years, modelling parameters for runoff and pollutant generation as well as suggestions for appropriate treatment measures. The purpose of the guidelines is to maintain consistency and to ensure that the assessment and approval process is as efficient as possible.

Guidance for regions outside of Greater Melbourne are provided by the *WSUD Engineering Procedures: Stormwater* (Melbourne Water, 2005), which establish hydrological regions for the remainder of Victoria as well as adjustment factors based on mean annual rainfall. In this scenario, one can determine the area required by a particular treatment to achieve the reduction in pollutants for a development in Melbourne and using the adjustment factors, calculate the required area for a treatment device in a different region of Victoria. This approach is similar to that used by the Tasmanian WSUD guidelines, discussed in Section 3.2.5.

### 3.2.3 New South Wales

In New South Wales, the Environmental Planning and Assessment Act 1979 and the Local Government Act 1993 establish the framework within which planning and local government operate, however the adoption of WSUD in NSW is not enacted by any State legislation or policies. State Environment Protection Policies and Regional Environmental Plans set objectives, policies and requirements for developments, guiding establishment of local planning schemes. Local Councils are responsible for the development of local plans and for establishing objectives and targets for stormwater quality. Due to the lack of consistent State policy and direction, some local councils have established WSUD programs and set water quality objectives, whereas other councils have made little progress (McAuley *et al.*, 2009).

Several councils across NSW such as Tweed Shire Council and Ku-Ring-Gai have set local guidelines and objectives for stormwater management. In the Sydney region, the Sydney Metropolitan Catchment Management Authority (CMA) as part of its WSUD Program has released *Draft NSW MUSIC Modelling Guidelines* (BMT WBM, 2010) and the *WSUD Interim Reference Guideline for the South East Queensland Concept Design Guidelines* (SMCMA, 2010) which provide advice on adapting guidelines from SEQ (SEQHWP and Ecological Engineering, 2007) to the Sydney region.

WSUD objectives derived for the Sydney region based on stormwater planning provisions are typically adopted by councils in Sydney within their development control plan. The guidelines address not only stormwater quality but flow management, and wetland protection. The WQO are to be applied to larger developments such as medium or high density residential development, commercial areas (with impervious area larger than 150 $m^2$) or subdivisions with more than 6 lots or 2,500 $m^2$ in size. The interim guidelines (SMCMA, 2010) set objectives for a reduction in post-development runoff pollutant loads compared to untreated stormwater from the same development type, and are shown in Table 3-2. The performance and sizing of treatment measures are to be demonstrated using appropriate modelling techniques such as the MUSIC model, and in accordance with the draft NSW MUSIC Modelling Guidelines (BMT WBM, 2010).

Table 3-2 – Interim WSUD targets for the Sydney region (adapted from SMCMA, 2010)

| Pollutant | Stormwater treatment objective* |
|---|---|
| Suspended solids | 80% reduction in mean annual load |
| Total phosphorous | 65% reduction in mean annual load |
| Total nitrogen | 45% reduction in mean annual load |
| Gross pollutants | 90% reduction in mean annual load greater than 5 mm |
| * reduction compared to stormwater runoff from an untreated equivalent development | |

### 3.2.4 Australian Capital Territory

In 2004, the Australian Capital Territory (ACT) Government released *Think Water, Act Water – A Strategy for Sustainable Water Resource Management in the ACT* (ACT Government, 2004) setting an objective of establishing world-class urban water management in the ACT. The strategy targets were to reduce water mains usage, increase reuse of wastewater, improve management of peak flows and manage the level of nutrients entering waterways. The ACT's planning legislation sets out the provisions for land use in the ACT, establishing development principles. Water quality standards are detailed in the *Environment Protection Act 1997* and the *Environment Protection Regulation 2005*, setting the necessary water quality objectives to support the water uses in the Territory.

In 2009, the ACT Planning and Land Authority released *Waterways: Water Sensitive Urban Design – General Code* (ACT Planning and Land Authority, 2009) where water quantity and quality targets for greenfield and redevelopment sites were set out. It establishes that the onus for meeting water quality targets on development or redevelopment sites lies with the developer, but regional and catchment-wide targets lie with Government. The water quality targets shown in Table 3-3 and must be met by all developments greater than 2000 m$^2$. The use of the MUSIC software is recommended, although other models may be used with the agreement of the ACT Planning and Land Authority.

Table 3-3 – WSUD targets for stormwater quality management in the ACT (ACT Planning and Land Authority, 2009)

| | Development or redevelopment sites | Regional or catchment wide |
|---|---|---|
| Reduction in average annual suspended solids export load* | 60% | 85% |
| Reduction in average annual total phosphorous export load* | 45% | 70% |
| Reduction in average annual total nitrogen export load* | 40% | 60% |
| * reduction compared to stormwater runoff from an untreated equivalent development | | |

The General Code (ACT Planning and Land Authority, 2009) also provides a set of parameters suitable for adoption in any MUSIC modelling, based on calibration of five ACT catchments (one rural and four urban). The final set of runoff parameters is a compromise to achieve acceptable results in all the catchments. The parameter set also sets event mean concentration values for suspended solids, phosphorus and nitrogen and explicitly recommends the use of mean values without the MUSIC model's stochastic generation tool in order to avoid variation between model runs and ensure reproducibility of modelling results.

### 3.2.5 Tasmania

The water quality objectives for Tasmania are set in the State Policy on Water Quality Management 1997 (SPWQM). The policy establishes a framework for the identification of environmental values to help set water quality objectives which maintain or enhance those values. The policy also establishes that planning schemes should require stormwater management strategies to address both the construction phase and the operational phase of development.

To assist with the implementation of the policy, the Tasmanian Government has prepared the State Stormwater Strategy (DPIWE, 2010), providing a state wide approach to stormwater management. It aims to help organisations and professionals with planning and regulatory responsibilities under the SPWQM. The strategy sets quality and quantity targets for new developments based on Integrated Water Cycle Management (IWCM) and WSUD principles. The water quality objectives set by the strategy are applicable to any development which creates an area of impervious surface equal to or greater than 500 $m^2$. Developments that create impervious areas below 500 $m^2$ do not have stormwater management targets. Under the Strategy, stormwater treatment measures should be implemented to achieve the water quality objectives in Table 3-4.

Table 3-4 – WSUD targets for stormwater quality management in Tasmania (adapted from DPIWE, 2010)

| **Pollutant** | **Stormwater treatment objective*** |
|---|---|
| Suspended solids | A minimum 80% reduction in mean annual load |
| Total phosphorous | A minimum 60% reduction in mean annual load |
| Total nitrogen | A minimum 45% reduction in mean annual load |
| Gross pollutants | A minimum 90% reduction in mean annual load |
| * reduction compared to untreated stormwater from the untreated equivalent development | |

The water targets were selected taking into account other Australian states and national practices, available data on stormwater characterization and performance of stormwater best management practices (DPIWE, 2010). The Strategy stipulates that these targets should be used in conjunction with local site-specific conditions such as hydrology, hydraulics or existing water quality to assure management of impact on downstream waterways. However, the strategy also allows for developers to dispute the need to meet the targets. In this scenario, a detailed assessment by a suitably qualified professional must be submitted for consideration, outlining how the development will not affect the water quality objectives of the proposed affected waterway. In the absence of identified values, ANZECC guideline values (ANZECC and ARMCANZ, 2000) should be adopted.

Developments should be designed to achieve the stormwater quality targets based on accepted Australian practice, such as modelling using MUSIC (CRCCH, 2005), procedures in the *WSUD Engineering Manual for Southern Tasmania* (Derwent Estuary Program, 2005) and the *WSUD Engineering Manual for Tasmania* (in prep.). *The WSUD Engineering Manual for Southern Tasmania* defines hydrological regions and adjustment factors based on annual rainfall. The manual provides sizes (as a % of the impervious area of the catchment) for constructed wetlands, ponds, bioretention systems and vegetated swales for 25 locations in the South Region based on MUSIC modelling. Each device was sized to achieve a 45% reduction in total nitrogen, as it is often the limiting pollutant in efforts to achieve water quality objectives in Tasmania (Derwent Estuary Program, 2005). The results for each of the 25 sites were used to develop adjustment factors based on the mean annual rainfall for each site. Due to uncertainties in the relationship between mean annual rainfall and the variability of treatment site, the manual recommends the inclusion of a 10% safety margin in the recommended adjustment factors provided, or the use of site specific modelling using MUSIC.

### 3.2.6 Northern Territory

In 2010 a report by the Northern Territory EPA (NTEPA, 2010) found that at the time there was no clear overarching policy statement on the goal of sustainability or value of environmentally sustainable design principles. The Darwin Harbour Strategy however provided a basis for strategic development planning for the Darwin Harbour region by establishing a vision and goals, even though it required supporting mechanisms to be effective.

The Northern Territory Water Act regulates the use of water, and allows for beneficial use declarations for water bodies, defining applicable environmental values and associated water quality objectives. In terms of stormwater, the Northern Territory Water Act does not regulate diffuse sources of potential pollutants, but The Northern Territory government identified the need to incorporate water sensitive urban design principles to all new development and redevelopment areas in Darwin Harbour (McAuley et al, 2009).

The current focus of WSUD implementation in Darwin Harbour is on greenfield developments because as there is a lack of WSUD applications in Darwin and the focus is on large development to trial the application of WSUD in the region. Also, WSUD application from other states demonstrates that greenfield sites are the most successful examples of applying WSUD, have large potential for improvement and have greater potential to involve specialist WSUD consultants due to their size (McAuley *et al.*, 2009; McAuley and McManus, 2009).

Through a workshop involving industry practioners, researchers and local planners, a preliminary suite of WSUD design objectives suitable for application in the Darwin Region have been developed. According the guidelines, stormwater discharged from development areas should be treated with best practice measures which produce the pollutant load reductions in Table 3-5.

Table 3-5 – WSUD Objectives for the Darwin Region (adapted from McAuley and McManus, 2009)

| **Pollutant** | **Stormwater treatment objective*** |
|---|---|
| Suspended solids | 80% reduction in mean annual load |
| Total phosphorous | 60% reduction in mean annual load |
| Total nitrogen | 45% reduction in mean annual load |
| Gross pollutants | 90% reduction in mean annual load |
| * When compared to an equivalent development area without treatment measures | |

The load base values derived in the WSUD Planning Guide are based on MUSIC modelling taking account of local conditions and best practice stormwater treatment infrastructure sized to operate at their limit of economic performance. At the limit of economic performance, further increase in size (and hence cost) result in minimal improvement in performance (EDAW, 2007). The MUSIC modelling used a typical urban development in Darwin and evaluated the performance of two treatment systems: a bioretention system and a wetland.

The treatment systems were modelled using standard design parameters for subtropical and temperate regions, although systems in the wet-dry climate of Darwin need to be modified and the impact of such changes in the system performance is unknown (EDAW, 2007). The treatment performance curves indicated an optimal treatment size for bioretention and wetland system as 2% and 6% of the catchment area, respectively.

### 3.2.7 Western Australia

The 2006 State Planning Policy *2.9 Water Resources* listed several objectives, one of which was that Total Water Cycle Management (TWCM) should take into account principles of WSUD to ensure any new developments are consistent with current best management practice. The policy seeks to achieve no net difference in terms of water quality, unless the post development conditions are better than pre development. To provide guidance on the implementation of the Policy, the Western Australia Planning Commission has released the document *Better Urban Water Management* (WAPC and WADPI, 2008), providing a framework for the consideration of water resources at different planning stages. Moreover, it identifies the agencies responsible for the required actions at different planning stages and project scales.

The *Better Urban Water Management* document reiterates the *overall objectives of TWCM as outlined in the Stormwater* Management Manual for Western Australia (Department of Environment, 2004). The objectives are to maintain an appropriate water regime, maintain and if possible, enhance water quality, environmental, recreational and cultural values and encourage conservation. To achieve these objectives, stormwater management relies on protection of natural systems and water quality, integration of stormwater management into the landscape and management of peak flows, all while trying to minimise costs (Department of Environment, 2004).

According to *Better Urban Water Management*, developments should maintain surface water concentrations at pre-development levels and, if possible, improve on these conditions. If the stormwater discharges (measured or modelled concentrations) exceed the ambient conditions, the proponent must achieve water quality improvements in the development area or achieve an equivalent water quality improvement offset inside the catchment. Achievement of water quality objectives may be demonstrated using appropriate modelling or other assessment methods acceptable to the Department of Water. If stormwater modelling is used, the water quality objectives in Table 3-6 are recommended.

Table 3-6 –Western Australian water quality objectives applicable when modelling is used to assess stormwater runoff quality objectives (WAPC and WADPI, 2008)

| Pollutant | Stormwater treatment objective* |
|---|---|
| Suspended solids | At least 80% reduction |
| Total phosphorous | At least 60% reduction |
| Total nitrogen | At least 45% reduction |
| Gross pollutants | At least 70% reduction |
| * When compared to an equivalent development area without treatment measures | |

### 3.2.8 South Australia

There are currently no state-wide WSUD targets applied in South Australia. The South Australian EPA (SA EPA) administers the *Environment Protection Act* 1993 (EP Act), to which the Environment Protection (Water Quality) Policy 2003 (WQEPP) is subordinate. The SA EPA have indicated support for the development of interim WSUD targets for the greater Adelaide region and Attachment A contains the full response of the SA EPA to the proposed development of interim targets, including further details on water quality policy in South Australia.

In recognition of the importance of stormwater runoff quality, the EPA has produced a series of stormwater code of practice documents for federal and state government entities (Botting and Bellette, 1998), for the community in general (Bellette and Ockenden, 1999) and for the building and construction industry (Botting and Bellette, 1999). The SA EPA has also implemented WSUD targets on a regional basis. In the South East of South Australia, the SA EPA presented the *EPA Guidelines for Stormwater Management in Mt Gambier* (SA EPA, 2007). These guidelines were developed to 'help landowners and developers meet their environmental duty of care under section 25 of the Environment Protection Act 1993 and their obligations under the Environment Protection (Water Quality) Policy 2003' (WQEPP). Two key aspects of the WQEPP are:

- people must not discharge listed pollutants into waters including stormwater
- any stormwater discharged to the aquifer must not degrade the quality of the groundwater (Note: This is of particular relevance to the Mount Gambier region where stormwater is discharged directly into the aquifer and groundwater is the main drinking water supply in the Mt. Gambier area).

SA EPA has also promoted WSUD targets on a regional basis. In the South East of South Australia, the SA EPA maintains the *EPA Guidelines for Stormwater Management in Mt Gambier* (SA EPA, 2007). These guidelines were developed to 'help landowners and developers meet their environmental duty of care under section 25 of the Environment Protection Act 1993 and their obligations under the Environment Protection (Water Quality) Policy 2003' (WQEPP).

The *SA EPA Guidelines for Stormwater Management in Mt. Gambier* indicate that development shall incorporate stormwater treatment systems that achieve a minimum standard for treatment, as reproduced in Table 3-7. According to the guidelines, the 'demonstration of [stormwater treatment system] performance will include the use of acceptable modelling methods, such as MUSIC by suitably qualified professionals'.

Table 3-7 - Treatment objectives for stormwater management in Mt Gambier, South Australia (SA EPA, 2007)

| **Pollutant** | **Stormwater treatment objective** |
|---|---|
| Suspended solids (SS) | 80% retention of the average annual load |
| Total phosphorous (TP) | 45% retention of the average annual load |
| Total nitrogen (TN) | 45% retention of the average annual load |
| Litter | Retention of litter greater than 50 mm for flow up to the 3-month average recurrence interval (ARI) peak flow |
| Coarse sediment | Retention of sediment coarser than 0.125 mm for flows up to the 3-month ARI peak flow |
| Oil and grease | No visible oils for flow up to the 3-month ARI peak flow |

Local governments in the Greater Adelaide region have also applied water quality targets to encourage implementation of WSUD. At the time of writing, City of Onkaparinga had implemented WSUD targets for runoff quality for all new developments, which were equivalent to those for TSS, TP and TN in Table 3-7. WSUD targets for water quality were administered by the council as an engineering condition and were adopted based on the successful implementation of targets by Melbourne Water (Section 3.2.2). In situations where WSUD was not practical, or where targets could not be achieved, a fee based offset scheme was being implemented by the City of Onkaparinga. A water quality levy was applied to non-compliant development which was effectively a contribution to larger WSUD systems being planned by the City of Onkaparinga for retrofit of WSUD infrastructure downstream or elsewhere in the council area. At the time of writing, the levy was $6500 per hectare.

City of Salisbury have also applied water quality targets as a condition for new developments, although the targets are not currently presented in a written form. The targets are equivalent to those in Table 3-7 for TSS, TP and TN, and were established based on the successful implementation of water quality targets by Melbourne Water (Section 3.2.2). At time of writing, there were two developments which had proceeded in the City of Salisbury on the basis of these targets. In each case, bioretention systems were used to achieve the targets.

Other developments in South Australia have adopted stormwater quality assessment criteria similar to those in Table 3-7 to assess water quality management in the planning stage. For example, in the development of the Kingsford Regional Industrial Estate (KRIE) in Greater Adelaide's north, objectives identical to those above have been recommended by the development *Strategic Master Plan* (URPS, 2007) to restrict TSS, TP and TN loads from the series of new industrial developments. The plan also recommended demonstrating a 70% reduction in litter, as opposed to the particle size based guideline in Table 3-7. The figures recommended by UPRS (2007) were sourced from the *CSIRO Urban Stormwater Best Practice Guidelines* and administered by Melbourne Water (Victorian Stormwater Committee, 1999; Section 3.2.2).

The desire to implement WSUD in the Greater Adelaide region has been further recognised in recent years. The *Institutionalising WSUD in the Greater Adelaide Region* project, managed by Planning SA, consisted of a multidisciplinary team focussed on developing methodologies for implementing WSUD in Greater Adelaide. A significant output from the project was the *WSUD Technical Guidelines - Greater Adelaide Region Technical manual* (DPLG, 2010). The project also developed draft stormwater quality targets for runoff water quality (**Error! Reference source not found.**) and gross ollutants (Table 3-9). These targets have been actively supported by the South Australian EPA who has recommended them to be applied to new developments. At the time of writing, these targets have not been formally released in policy, but several developments have applied them and proceeded accordingly

Table 3-8 - Draft runoff quality targets for Greater Adelaide developed in 2007-2008 by the *Institutionalising WSUD in the Greater Adelaide Region* project (adapted from figures supplied by SA EPA, pers. Comm.)

| **Water quality parameter** | **Target** |
|---|---|
| Reduction in average annual total suspended solids export | 80%[a] |
| Reduction in average annual total phosphorous export | 45%[a] |
| Reduction in average annual total nitrogen export | 45%[a] |
| [a] - % reduction refers to average annual pollutant load compared to an equivalent urban catchment with no water quality management controls. | |

Table 3-9 - Draft gross pollutant targets for Greater Adelaide developed in 2007-2008 by the *Institutionalising WSUD in the Greater Adelaide Region* project (adapted from figures supplied by SA EPA, pers. Comm.)

| Parameter | Target |
|---|---|
| Litter/gross pollutants | Retention of all litter greater than 50 mm for flows up to the 3 month ARI peak flow |
| Oil and grease | No visible oils for flows up to the 3 month ARI peak flow |

### 3.2.9 A Review of Nutrient Offset and Trading Schemes

In situations where developers are not able to meet water quality objectives, or where the cost to achieve the objectives is prohibitive, the use of market based initiatives may provide a solution to achieve water quality objectives. Market based initiatives can be broadly divided into price based instruments, which assign a price to impacts through charges, taxes or subsidies, and quantity based instruments, which create a market in rights to engage in an activity (that may have an impact on water quality). Quantity based instruments may be broadly divided into two further types: trading schemes, where polluters are assigned load permits based on sustainable loads for the catchment which can be traded or offset; and offset contribution schemes where developers of new pollution sources make a financial contribution to a fund which will manage the reduction of loads on their behalf elsewhere (BDA Group, 2009).

An important part of any market based initiative is the consideration that different sources of stormwater pollution abatement have different costs associated with the reduction of a unit mass of pollutant, and as such, costs and effectiveness have varied across schemes. In Australia, there are currently several operating schemes related to stormwater. This includes a simple fee based system like that currently described for South Australia described in Section 3.2.8. On the larger scale, the Stormwater Quality Offset Strategy operated by Melbourne Water and the South Creek Nutrient Offset Pilot in NSW present models which may be explored at the state government level.

As discussed in Section 3.2.2, targets for stormwater treatment in developments for Victoria are based on best practice performance objectives to retain 80% of the suspended solids, 45% of total phosphorus and 45% of total nitrogen load in annual runoff from a develop catchment (compared to the undeveloped case). For developments which cannot achieve the best management practice targets, Melbourne Water operates a Stormwater Quality offset program. In this program, developers make a financial contribution to Melbourne Water which is utilized for water quality improvement works undertaken in other parts of Greater Melbourne as a means to offset the loads not treated within the catchment. Currently the scheme operates in the Port Phillip and Western Port catchments. It is the responsibility of local councils to determine whether the runoff quality compliance of a proposed development must be achieved on-site or whether developers may use the stormwater quality offset scheme to achieve targets (Melbourne Water, 2006).

The offsets are calculated based on the percentage of the water quality objective that is achieved on-site i.e. a development reducing the nitrogen load by 30% makes a contribution based on the 15% needed to meet the water quality treatment objective. Nitrogen was chosen as the currency for the scheme as it is usually the limiting pollutant for removal, and if the nitrogen removal target is achieved, then the targets for phosphorus and suspended sediment are also achieved (Melbourne Water, 2006). The actual price for one kilogram of TN to be removed depends on the locality where the development takes place, the size and density of the development. To be consistent with existing developer contributions for hydraulic works the offset contribution rates are expressed as a rate in dollars per hectare

In NSW, the Department of Environment and Conservation (now the NSW Office for Environment and heritage, NSW OEH) is running a voluntary program, the *South Creek Nutrient Offset Pilot*, to offset the diffuse sources of nutrient pollution in the South Creek catchment. The scheme allows licensees and developers to offset nutrient loads by reducing pollution at locations outside their development site (but within the South Creek catchment). The offset pilot also allows for the implementation of nutrient reduction measures from diffuse sources to generate credits which can be traded with other schemes, particularly the South Creek Bubble Licensing Scheme, a point to point nutrient trading scheme between major wastewater treatment plants. While construction and implementation of measures have started at many sites, the DEC is conducting monitoring to assess the effectiveness of the pilot (NSW OEH, 2011).

In addition to these two schemes, there are currently several schemes being investigated across Australia, but these are yet to be implemented due a range of factors including legislative barriers, lack of institutional arrangements or uncertainties related to their efficacy. Schemes being considered include the Moreton Bay Water Quality Offset Schemes and the offset scheme for the Swan-Canning river system being considered by the Swan River Trust.

## 3.3 Development of Stormwater Runoff Water Quality Targets

### 3.3.1 Review of Existing Development Methodologies

The methodology adopted for developing targets for the Greater Adelaide Region is based on methods used to develop targets for other regions in Australia including Queensland and the Northern Territory (DesignFlow, 2009; SSEQHWP and Ecological Engineering, 2007; EDAW, 2007; EDAW/AECOM, 2009). This methodology, which is largely based around determining the most appropriate 'footprint' for a standard WSUD treatment system (bioretention) on an assumed development site. In summary, modelling is undertaken to investigate the effects of bioretention treatment on this site to determine the point of ‘diminishing return’, where a balance can be found between treatment area (cost) and environmental benefit. Other methods have been used in Australia to develop WSUD targets, such as those for Tasmania (Derwent Estuary Program, 2005). However these were based on first assuming a water quality treatment target for TN, for which the required size of a standard WSUD element (bioretention) in several regions was back-calculated, to determine both the required reduction in TSS and TP, and a standard ‘footprint’ for the application of bioretention. It should be noted that a number of other WSUD target references, including the source of current targets in the ACT (ACT Planning and Land Authority, 2009) and Western Australia (WAPC and WADPI, 2008), do not acknowledge a development methodology, and as such the means of WSUD target derivation are unclear.

### 3.3.2 Development Methodology Adopted for the greater Adelaide Region

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 4.10 (eWater, 2011) was used for the development of stormwater runoff quality targets. MUSIC was selected as it presents the ability to:

- model the rainfall runoff process (both surface and baseflow) in urban catchments
- generate characteristic pollutant loads from elements of the catchment surface (tailored to local conditions where possible); and
- assess the level of treatment provided by an assortment of common structural WSUD elements, based on extensive Australian and international research

There were few other available models with all of these characteristics which are as widely acknowledged as suitable in WSUD literature. Other models, such as XP-AQUALM, may also be suitable for developing and assessing stormwater runoff quality targets, but do not provide algorithms for modelling WSUD elements. MUSIC is applied across Australia by government and private entities for the conceptual design and assessment of stormwater runoff treatment designs.

To develop targets, the following general procedure was undertaken. The procedure is based on the procedures used to develop targets in Queensland and Western Australia by DesignFlow (2009), SSEQHWP and Ecological Engineering (2007), EDAW (2007) and EDAW/AECOM (2009) to enable a direct comparison of targets in the greater Adelaide region with those developed for other states and regions.

1. Development of a suitable one Hectare residential catchment scenario with a reference stormwater runoff treatment system.
2. Continuous modelling of this scenario with the four climate zones of Adelaide, where the reference treatment system comprises a gradually increasing portion of the catchment area
3. Development of a relationship between the modelled treatment system area and predicted treatment performance.
4. Identification of the ‘point of diminishing return’, where increases in the area of the treatment system to improve treatment performance do not justify the financial costs required to increase the treatment area. This point can be used to set targets for water quality improvement. An example of the ‘point of diminishing return’, as identified by SEQHWP and Ecological Engineering (2007), is illustrated in Figure 3-4.

5. Scenario analysis testing of the proposed targets, where treatment scenarios are applied to real catchments in the greater Adelaide region to assess the feasibility of the adopted targets (3.3.4)

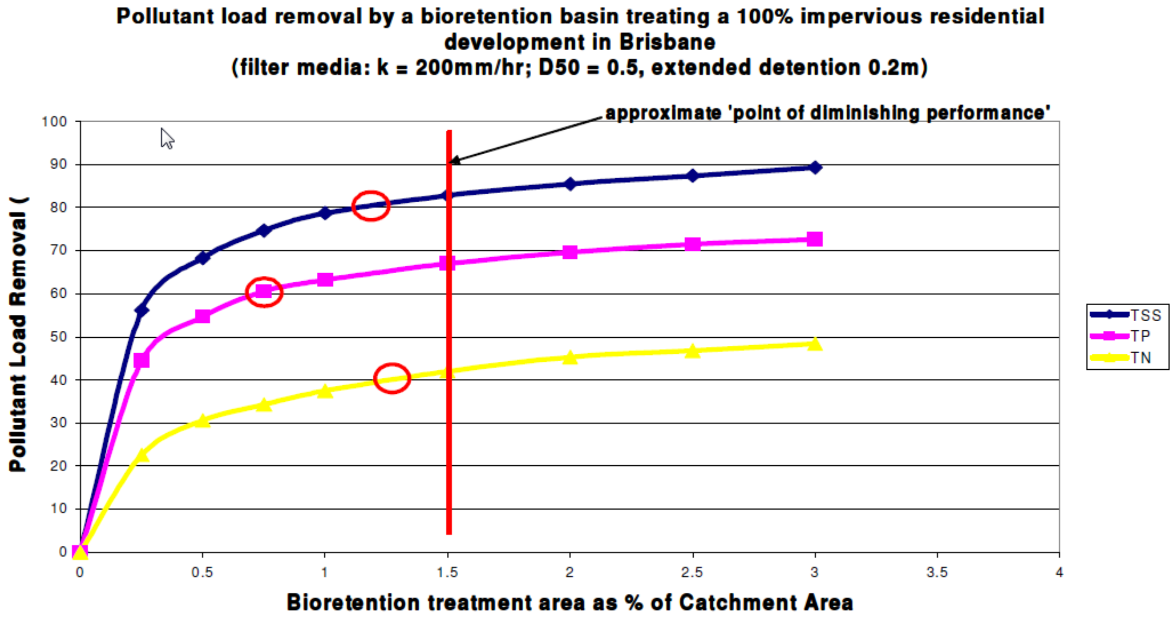


Figure 3-4 – Identification of the point of diminishing performance for South East Queensland (SEQHWP and Ecological Engineering, 2007)

For the development of targets in the Greater Adelaide Region, a recently developed multiple residential development in Northern Adelaide was analysed to determine the portion of the catchment which consisted of roofs, road, other impervious areas (such as paths) and other pervious areas (such as community parkland, yard space). The catchment was found to have the characteristics indicated in Table 3-10.

Table 3-10 – Characteristics of the recently developed residential catchment in Northern Adelaide

| Surface description | Area of catchment (% of total) |
|---|---|
| Roofs | 39.8 |
| Road pavement | 12.3% |
| Other impervious area | 9.3 % |
| Other pervious area | 38.6 |

The characteristics in Table 3-10 were found to be almost identical to the characteristics of the catchment which were assumed for residential development in Queensland by EDAW (2009). Because of this, the parameters adopted by EDAW (2009) were adopted to allow for development of parameters water quality objectives that are suitable for development in Greater Adelaide, and comparable with interstate targets. The parameters of the catchment were as follows:

- A 1 Ha catchment with the following individual treatment nodes
    - 0.4 Ha roof area (100% impervious)
    - 0.08 Ha ground level impervious area to represent footpath, driveway, parking (100% impervious)

    - 0.32 Ha ground level pervious area to represent the unpaved landscape (0% impervious)
    - 0.2 Ha road reserve (60% impervious)
- The catchment rainfall included four climate zones at 6-minute timesteps, as indicated in Table 3-11. These zones were selected based on the rainfall regions identified in the *Water sensitive urban design technical manual - Greater Adelaide region* (SA DPLG, 2009). Data was sourced from the Bureau of Meteorology. The patch point data used for water savings targets (outlined in Section 1.4.1) was not used because it was limited to a daily timestep, which was not considered adequate for event based modelling in MUSIC. As complete records were unavailable at a six minute timestep, gaps in the data were filled synthetically using the methodology of Frost *et al.* (2004). This methodology involved:
    - Identification of gaps in the continuous rainfall records.
    - Gaps in the rainfall record were cross checked with daily rainfall records maintained by the Bureau of Meteorology 'Climate data online' service (http://www.bom.gov.au/climate/data/).
    - In cases where zero rainfall was found to occur in the daily rainfall record of this station, or the nearest station, the gap in this series was filled with zero values.
    - In cases where rainfall was found to occur in the daily rainfall record of this station, or the nearest station, the recorded daily rainfall values were evenly distributed across the gap period on a daily basis.
    - Note that gaps in the data were less than 1% of the total rainfall timeseries for each rainfall station in Table 3-11.
- Pervious area infiltration parameters to reflect Adelaide conditions as per the *MUSIC User Guide* (eWater, 2009). All other pervious area parameters were left at default values
- Stormwater pollutant characteristics were adopted from the wide ranging research of runoff quality by Duncan (2005) for ground level pollutant sources, and from the compilation of recent data on roofwater quality by the NRMMC, EPHC & NHMRC (2009). These pollutant characteristics were identified in Table 3-12. Baseflow characteristics were not altered from the default values provided in the urban node of the MUSIC model (Version 4.10). Pollutant characteristics of stormflow and baseflow were adopted based on the mean concentration (i.e. pollutants were not stochastically generated) to allow for ease of replication.
- Stormwater runoff was assumed to be treated by a bioretention system. The characteristics of the bioretention system are reproduced in Table 3-13. The default parameters provided in the MUSIC manual for treatment performance (based on the k-C* model) were used.

Table 3-11 – Rainfall stations from which 6-minute data was extracted

| Region | Station Name | Station number | Period of rainfall |
|---|---|---|---|
| **Adelaide Hills** | Kersbrook | 023877 | 1995 – 2005 |
| **Adelaide City** | Adelaide (Kent Town) | 023090 | 1992 – 2002 |
| **Coastal** | Largs Bay | 523000 | 1998 – 2003 |
| **Plains** | Adelaide airport | 023034 | 1993 – 2005 |

Table 3-12 – Stormwater runoff quality data adopted in the analysis

| Land use category | TSS | | TP | | TN | |
|---|---|---|---|---|---|---|
| | mg/L | $log_{10}$ mg/L | mg/L | $log_{10}$ mg/L | mg/L | $log_{10}$ mg/L |
| **Road reserve**[1] | 208 | 2.324 | 0.56 | -0.532 | 3.09 | 0.491 |
| **Roof**[2] | 17.7 | 1.248 | 0.12 | -0.921 | 1.53 | 0.185 |
| **Other impervious**[1] | 100 | 2.000 | 0.48 | -0.319 | 3.09 | 0.490 |
| **Other pervious**[1] | 100 | 2.000 | 0.48 | -0.319 | 3.09 | 0.490 |

(1) Duncan, 2005
(2) NRMMC, EPHC & NHMRC, 2009

Table 3-13 – Parameters of the bioretention system

| Model parameter | Units | Value | |
|---|---|---|---|
| | | MUSIC v 4.10 | MUSIC v 3.01 |
| Low flow bypass | $m^3/s$ | 0 | 0 |
| High flow bypass | $m^3/s$ | 100 | 100 |
| Extended detention depth | m | 0.3 | 0.3 |
| Surface area[a] | $m^2$ | Based on % of catchment | |
| Seepage loss | mm/hr | 0 | 0 |
| Filter area[a] | $m^2$ | Based on % of catchment | |
| Unlined filter media perimeter | m | 0 | N/A |
| Saturated hydraulic conductivity | mm/hr | 200 | 200 |
| Filter depth | m | 0.8 | 0.8 |
| TN content of filter media | mg/kg | 800 | N/A |
| Proportion of organic material in filter | % | < 5 | N/A |
| Orthophosphate content of filter media | mg/kg | < 55 | N/A |
| Is base lined? | Y/N | Yes | N/A |
| Vegetation properties | - | Vegetated with effective plants | N/A |
| Overflow weir width | m | 2 | 2 |
| Underdrain present | Y/N | Yes | N/A |
| Submerged zone with carbon present | Y/N | No | N/A |
| Exfiltration rate | mm/hr | 0 | 0 |
| Depth below underdrain | % filter depth | N/A | 0 |
| Filter median particle diameter | mm | N/A | 0.5 |

a - Surface area and filter area were assumed to be equal

### 3.3.3 Development of Water Quality Targets

The stormwater quality treatment curves developed using the methods outlined in Section 3.3.2 are shown in Figure 3-5 to Figure 3-8. The point of diminishing performance identified in each case is indicated by a bold vertical line in each figure. It should be noted that the nature of treatment curves was different to those developed in analyses for other Australian states and regions. This is because the bioretention treatment algorithms have been adjusted in MUSIC version 4.10 to reflect a greater degree of research into bioretention system performance.

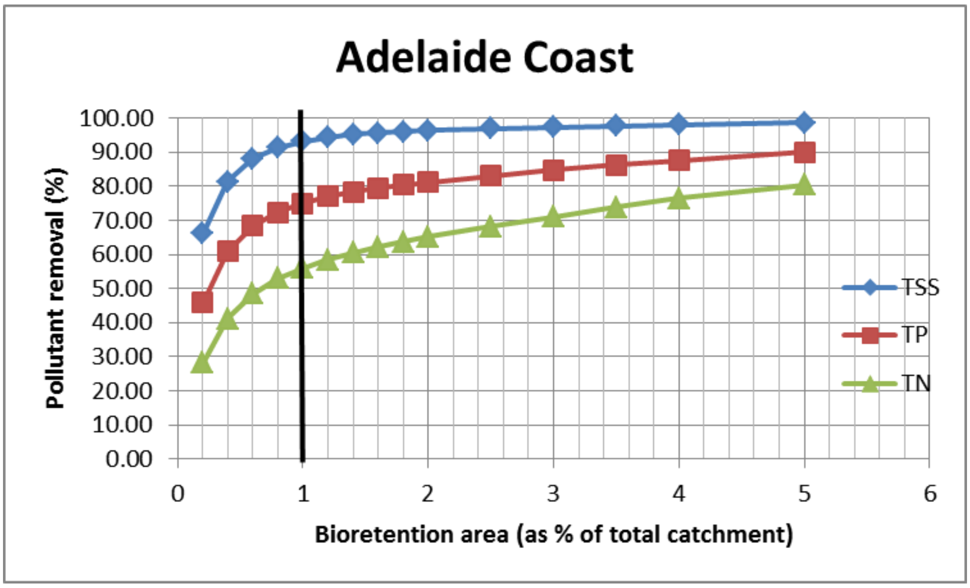


Figure 3-5 – Bioretention system treatment performance curve for Adelaide Coast (Largs Bay, 523000)

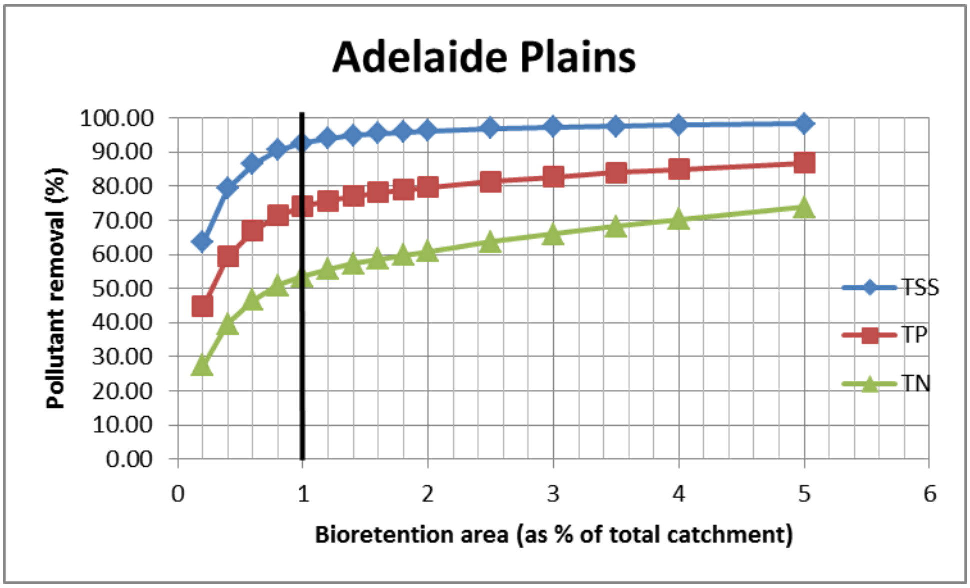


Figure 3-6 – Bioretention system treatment performance curve for Adelaide Plains (Adelaide airport, 023034)

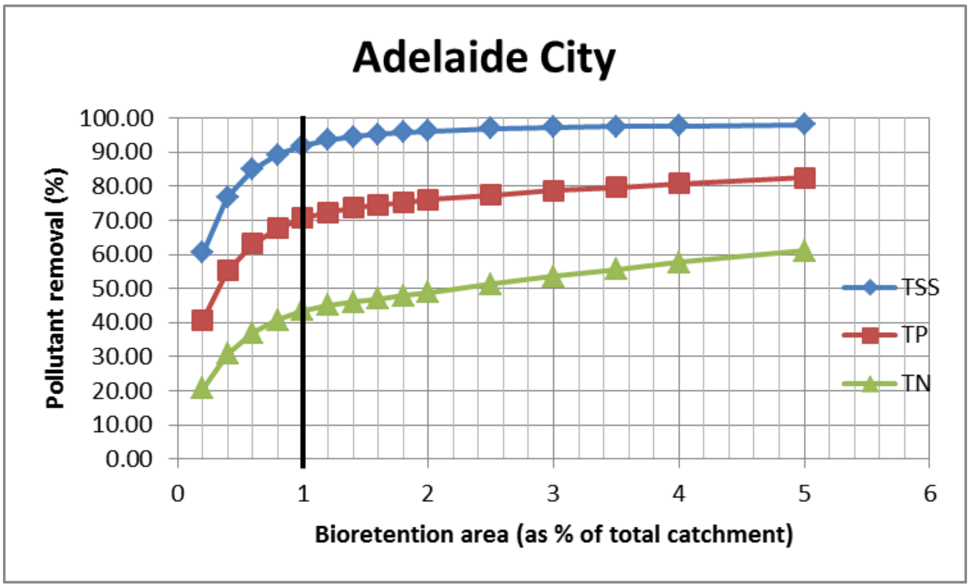


Figure 3-7 – Bioretention system treatment performance curve for Adelaide City (Kent Town, 023090)

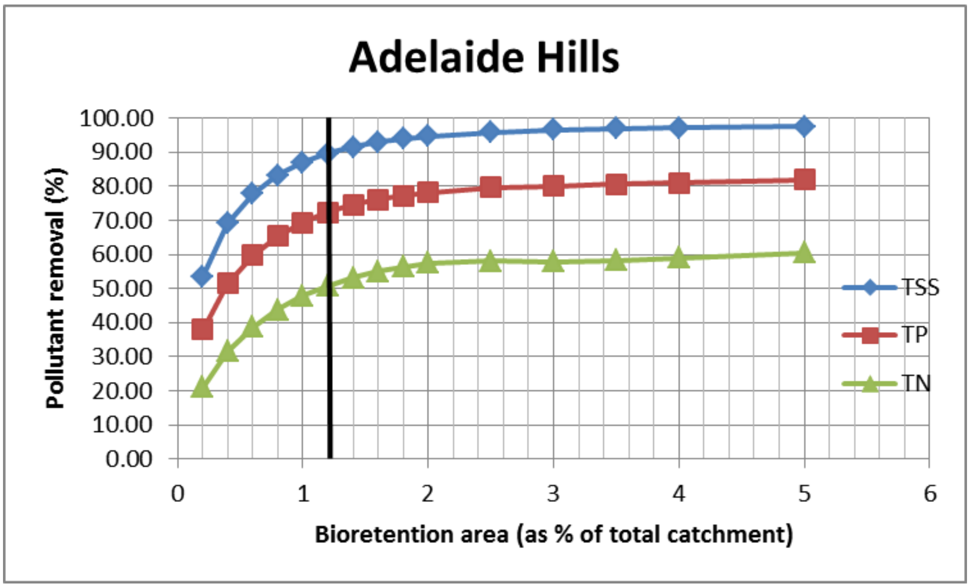


Figure 3-8 – Bioretention system treatment performance curve for Adelaide Hills (Kersbrook, 023877)

The approximate point of diminishing treatment performance was found to occur when approximately 1% of the total catchment area consisted of bioretention. A greater area may achieve better results in the Adelaide Hills and Adelaide City, however the 1% value was used as a final value to present a uniform WSUD adoption across the Greater Adelaide Region that was not weighted toward greater performance in one area of the Greater Adelaide Region. Using this 1% treatment area, the minimum recommended performance target was found to be in the Adelaide Hills (for TSS and TP) and Adelaide City (for TN). The subsequent recommended targets are summarised in Table 3-14. It should be noted that the required treatment area identified by the 'point of diminishing treatment performance' compares favourably with the treatment area identified as suitable for other regions of Australia. Across Queensland, due to generally higher rainfall characteristics, a treatment area of 1.5% was adopted to determine WSUD targets (EDAW/AECOM, 2009). For Darwin, again due to higher rainfall quantities, the point of diminishing treatment performance was found to occur when treatment area consisted of at least 2% of the developed catchment area.

Table 3-14 - Recommended water quality improvement targets for the Greater Adelaide Region

| **Pollutant** | **Stormwater treatment objective*** |
|---|---|
| Suspended solids (SS) | 80 % retention of the average annual load |
| Total phosphorous (TP) | 60 % retention of the average annual load |
| Total nitrogen (TN) | 45 % retention of the average annual load |
| * Compared to an equivalent untreated catchment | |

It should be noted that the recommended targets for total suspended solids (TSS) and total nitrogen (TN) in Table 3-14 correspond with those already recommended to developers by the SA EPA. The target for TSS and TN also correspond with values implemented for new development in the City of Onkaparinga and City of Salisbury.

The results indicate that the bioretention system treatment performance for TSS and TP generally decreases with higher levels of rainfall from the coast (low rainfall) to the hills environment. However, the results for TN indicate that bioretention system performance decreases from the coast to the city, but improves marginally for lower bioretention areas in the Adelaide Hills environment. When target development was replicated using MUSIC Version 3.01 (for comparison), the same performance was not found to occur. MUSIC Version 3.01 found deterioration in treatment performance for all pollutant types as mean annual rainfall increased. Given that the only variation in these modelling procedures is the amount of rainfall and potential evapotranspiration (PET), this is a result of the more complex treatment algorithm used in MUSIC Version 4.10. These results also emphasise that the achievement of performance targets can be influenced by model selection. It is therefore important that when modelling is used to assess the achievement of the targets recommended in Table 3-14, targets should:

- be assessed based on assessment in the MUSIC version 4 algorithm
- be reviewed when further improvements in modelling are implemented to account for new techniques in WSUD element performance assessment
- be considerate of cases where developers and consultants can only access models which are no longer current
- be supported by guidelines for assessing the performance of systems. MUSIC modelling guidelines for the Greater Adelaide Region should be produced which are similar in nature to those produced for Melbourne (Melbourne Water, 2010), New South Wales (BMT WBM, 2010) and Brisbane (WaterbyDesign, 2010).

During the completion of this research, eWater CRC released MUSIC Version 5 for the assessment of WSUD systems. Due to changes in the treatment algorithm for bioretention systems (among other changes to the MUSIC model), the stormwater quality treatment recommendations may be somewhat different to those proposed in Table 3-14. Issues surrounding the use of MUSIC Version 5 are discussed further in Section 3.5, and a complete re-assessment of treatment curves for the four Adelaide climate zones is provided for reference in Appendix D.

It should also be noted that the TN treatment performance indicated in Figure 3-4 to Figure 3-8 is strongly contingent on the assumption of having effective nutrient removing vegetation at the surface of the biofiltration system design as assessed in MUSIC v4.10. Assuming plants which are not effective for nutrient removal in the MUSIC v4.10 model indicates high levels of annual pollutant export, particularly in the case of nitrogen. An example of this export is shown in Figure 3-9, for Adelaide Kent Town.

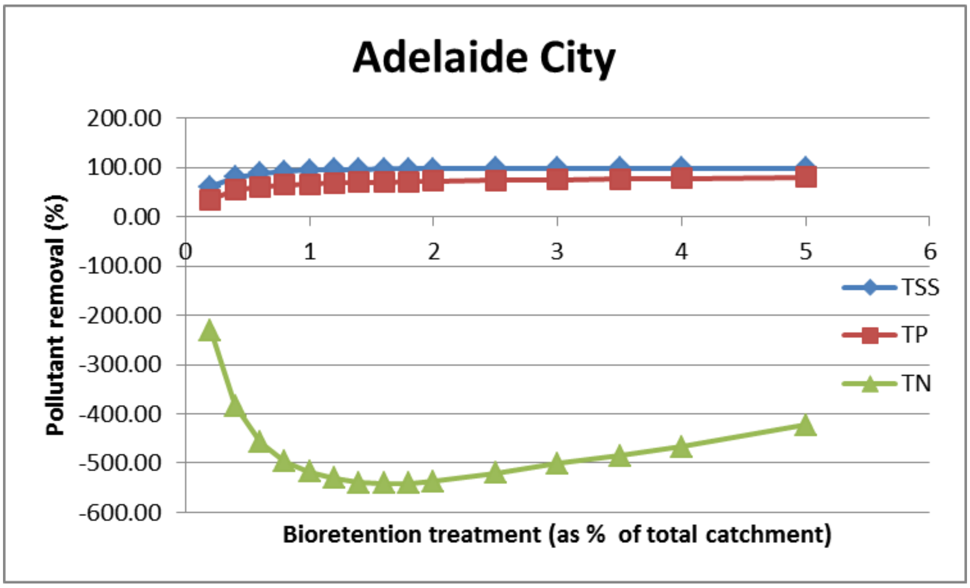


Figure 3-9 - The effect of excluding 'effective nutrient removing vegetation' from the MUSIC v 4.10 bioretention node

Figure 3-9 represents the case where the imported filtration media actually leaches organic matter into the sub-base drain. This is especially notable for total nitrogen, which tends not to be associated with solid particles. These results stress the importance of adopting appropriate modelling parameters to achieve reasonable results, which also must be reflected in final system design. Based on the unusual results indicated in Figure 3-9, it is suggested that policy and planning tools for bioretention systems stress the importance of planting these systems with *effective* nutrient removing vegetation to avoid leaching nutrients from soil.

Communication with representatives of Clay and Mineral Sales Pty. Ltd. (a supplier of bioretention filter media in the Greater Adelaide region) indicated that bioretention system design in Adelaide has been undertaken with a variety of organic material contents, typically ranging from 3% by volume to a media with little or no organic materials. Based on this, it is also suggested that research is undertaken to determine the most effective and reproducible filtration soil media characteristics for biofiltration systems in the Greater Adelaide Region. This research should focus specifically on materials able to be sourced in commercial quantities by soil and mineral suppliers in Greater Adelaide. Such research should address the variation in specifications for filtration soil media, and the effort and cost required by producers in meeting these requests.

Further to the targets in Table 3-14, the following reductions in litter, oils and grease contaminants were previously recommended during from the *Institutionalising WSUD in the Greater Adelaide Region* project (see Table 3-9):

- Litter and gross pollutants: removal of all litter greater than 50 mm for flows up to the 3 month ARI peak flow
- Oil and grease: No visible oils for flows up to the 3 month ARI peak flow

These targets have been actively supported by the South Australian EPA who has recommended them to be applied to new developments. These targets are also currently implemented the area surrounding Mt. Gambier (SA EPA, 2007). Based on this, it is recommended that the gross pollutant target be adopted in a slightly modified form to ensure that developers can easily demonstrate compliance, and that the target is comparable to that recommended nationally and adopted by other states as follows:

- 90% reduction in the annual load of litter / gross pollutants (BMT WBM, 2009)

This target is similar to targets adopted in Queensland, Victoria, New South Wales, Tasmania, Darwin and Western Australia (see summary of proposed and existing targets in Appendix C) and like TSS, TN and TP targets, may be demonstrated using computer modelling tools such as MUSIC. Achievement of the aforementioned oil and grease target is less straightforward to demonstrate, and it is currently assessed qualitatively in developments where point sources of oil and grease contaminants are identified (pers. comm. SA EPA). As such, it is recommended that research is undertaken into the implementation of oil and grease targets suitable for residential development and how they may be quantitatively demonstrated. Discussions with eWater indicate that MUSIC may be capable of simulating oil and grease using TSS as an indicator contaminant, but this will need further research and guidance before being adopted. The current arrangements within the SA EPA should still apply to commercial and industrial areas where a qualitative assessment procedure is used to assess retention of oil and grease contaminants from known point sources of oil and grease contamination.

### 3.3.4 Assessment of Stormwater Runoff Quality Targets

Following the development of interim stormwater runoff quality targets for residential development in the Greater Adelaide Region, recommendations were assessed by examining how achievable WSUD targets were in typical developments using WSUD elements. These common development scenarios included:

- A residential allotment
- A residential subdivision (infill development)
- A cluster development (multi-residential units)
- A residential high rise development
- A large scale development (> 50 allotments)

Treatment systems assessed for each scenario included bioretention systems, wetlands and rainwater tanks. In each scenario, a rainwater tank was assumed to consist of a single 1 kL rainwater tank in compliance with South Australian legislation which requires an alternative water supply to be installed into Class 1 dwellings. In some of these cases, larger communal rainwater tank supplies are also examined as indicated.

Due to the nature of rainfall in the Adelaide region, a wetland was only assumed for the large scale development scenario. The installation of small scale wetlands, like those assessed by SEQHWP and Ecological Engineering (2007), are not considered appropriate for greater Adelaide, where high evaporation and limited rainfall over the period from October to March threaten the viability of hydrophytic vegetation. According to the *WSUD Technical Guidelines for the Greater Adelaide Region* (DPLG, 2010), wetlands 'should only be used in areas that have enough inflow from rain, upstream runoff, treated wastewater or groundwater inflow to ensure the long term viability of the wetland process'.

In all modelling, the properties of bioretention systems corresponded with the reference case outlined in Table 3-13. The assumed characteristics of the wetland are presented in Table 3-15. The characteristics of rainwater tanks are presented in Table 3-16. Rainwater tank usage was adopted as a daily demand varying on a monthly basis based on the rainwater tank usage in the four zones of the Greater Adelaide region as outlined in Section 2.5.2. Demand was assumed to include outdoor irrigation, indoor toilet flushing and laundry.

Table 3-15 – Characteristics of the wetlands assumed in scenario five

| **Characteristic** | **Units** | **Value** |
|---|---|---|
| Low flow bypass | $m^3/s$ | 0 |
| High flow bypass | $m^3/s$ | 100 |
| Inlet pond volume | $m^3$ | 50 |
| Surface area | $m^2$ | 800 |
| Extended detention depth | m | 0.5 |
| Permanent pool volume | $m^3$ | 50 |
| Vegetation cover | - | Not enabled in MUSIC v4.10 |
| Exfiltration rate | mm/hr | 0 |
| Evaporative loss as % of PET | % PET | 125 |
| Equivalent pipe diameter | mm | 35 |
| Overflow weir width | m | 3 |
| Notional detention time | hours | 55.1 |

Table 3-16 – Characteristics of rainwater tanks assumed in Scenarios 1 to 5

| Characteristic | Units | 1 kL | 23.9 kL | 61 kL |
|---|---|---|---|---|
| Low flow bypass | $m^3/s$ | 0 | 0 | 0 |
| High flow bypass | $m^3/s$ | 100 | 100 | 100 |
| Volume below overflow pipe | $m^3$ | 1.0 | 23.9 | 61.0 |
| Depth above overflow | m | 0.13 | .05 | .05 |
| Surface area | $m^2$ | 1 | 10.7 | 27.3 |
| Overflow pipe diameter | mm | 25 | 50 | 50 |
| Use stored water | - | Yes | Yes | Yes |
| Monthly distribution of annual demand | - | Section 2.5.2 | | |

The following sections provide the details for each of the scenarios used to assess the recommended targets.

**<u>Scenario 1 - Residential allotment</u>**

The design of a typical new residential allotment was based on research into private open space from old and new residential allotments in the Adelaide region (Mobbs and Sivam, 2009). The residential allotment was considered an important scenario as much greenfield development is scheduled to take place in the *30 Year Plan for Greater Adelaide* (SA DPLG, 2010). Two scenarios are examined:

(a) a recent higher density case (23% private open space per dwelling) and

(b) a recent lower density case (38% private open space per dwelling)

The characteristics of the two developments are indicated in Table 3-17.

Table 3-17 –Assumed characteristics of Scenario 1 – residential allotments

| | **Recent higher density** | **Recent lower density** |
|---|---|---|
| **Description** | Single residential allotment | Single residential allotment |
| **Rainwater tank** | 1 kL | 1 kL |
| **Total area** | 415 $m^2$ | 500 $m^2$ |
| **Total roof area** | 220 $m^2$ | 220 $m^2$ |
| **Ground level impervious** | 98 $m^2$ | 90 $m^2$ |
| **Ground level pervious** | 97 $m^2$ | 190 $m^2$ |

The achievement of water quality objectives will be assessed with the implementation of:

- No treatment
- 1 kL rainwater tank

- A raingarden (small scale bioretention system) and 1 kL rainwater tank

**Scenario 2 - Residential Allotment Subdivision (Infill development)**

The feasibility of recommended targets for a residential subdivision in the Greater Adelaide region was assessed based on the characteristics of residential subdivision in Adelaide and interstate. The assumed characteristics are summarised in Table 3-18. The characteristics of residential subdivision in Adelaide were adopted based on data of residential subdivision characteristics in two Adelaide suburbs (Mobbs and Sivam, 2009). To compare this target with an interstate case, the allotment scenario in Figure 3-10 was also examined based on the work presented by SEQHWP and Ecological Engineering (2007).

Table 3-18 – Assumed characteristics of Scenario 2 – residential allotment subdivision (infill development)

| | **Adelaide subdivision** | **Brisbane subdivision** |
|---|---|---|
| **Description** | Single residential allotment | Single residential allotment |
| **Rainwater tank** | 1 kL | 1 kL |
| **Total area** | 370 $m^2$ | 430 $m^2$ |
| **Total roof area** | 200 $m^2$ | 120 $m^2$ |
| **Ground level impervious** | 81 $m^2$ | 50 $m^2$ |
| **Ground level pervious** | 88 $m^2$ | 160 $m^2$ |

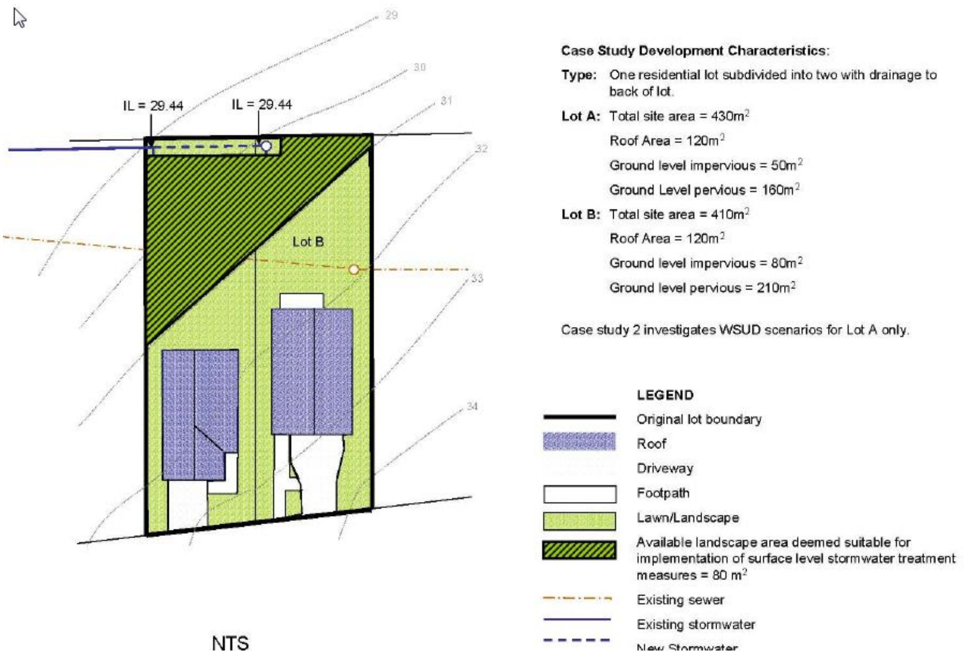


Figure 3-10 – Residential subdivision (infill development) scenario adopted from SEQHWP and Ecological Engineering (2007)

The achievement of water quality objectives will be assessed with the implementation of:

- No treatment
- 1 kL rainwater tank
- A raingarden (small scale bioretention system) and 1 kL rainwater tank

**Scenario 3 - Cluster development**

The cluster development is adapted from an existing cluster of units owned by Housing SA in Southern Adelaide. A plan of the development is shown in Figure 3-11.


Figure 3-11 – Cluster development case study scenario

Characteristics of the development in Figure 3-11 are summarised in Table 3-19.

Table 3-19 - Assumed characteristics of Scenario 3 - cluster development

| | **Adelaide subdivision** |
|---|---|
| **Description** | 12 single level residential units |
| **Rainwater tank** | 1 kL tank (each) |
| **Total area** | 6000 $m^2$ |
| **Total roof area** | 1413 $m^2$ |
| **Ground level impervious** | 2085 $m^2$ |
| **Ground level pervious** | 2502 $m^2$ |

The achievement of water quality objectives was assessed with the implementation of:

- No treatment
- A single 1 kL rainwater tank for each unit
- A bioretention system and single 1 kL rainwater tank for each unit
- An 'communal' water supply (21 kL rainwater tank)

**Scenario 4 - Residential High-Rise**

The residential high rise development is adopted from the target development and assessment study for South East Queensland by SEQHWP and Ecological Engineering (2007). A plan of the development is shown in Figure 3-12. The development case assumed is a five storey building, based on the observed characteristics of TOD style development currently in place and under construction around Mawson Lakes railway station. Characteristics of the development in Figure 3-12 are summarised in

Table 3-20.

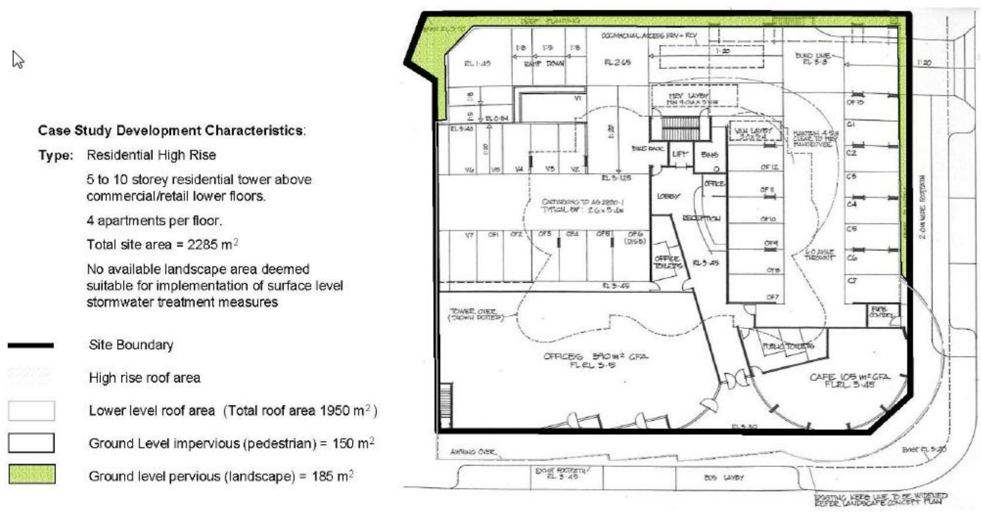


Figure 3-12 – Residential high-rise development scenario

Table 3-20 - Assumed characteristics of Scenario 4 – residential high-rise

| | **Adelaide subdivision** |
|---|---|
| **Description** | 5 storey residential apartment building, 4 units per floor |
| **Rainwater tank** | Communal - 23.9 kL and 61 kL |
| **Total area** | 2285 m$^2$ |
| **Total roof area** | 1950 m$^2$ |
| **Ground level impervious** | 150 m$^2$ |
| **Ground level pervious** | 185 m$^2$ |

Due to restrictions on the space available for WSUD elements, a communal rainwater tank is the only water quality treatment scenario which is analysed for the residential high rise development scenario. There were two cases examined – a 23.9 kL rainwater tank and a 61 kL rainwater tank.

**Scenario 5 - Large scale development > 50 allotments**

The feasibility of recommended targets for a residential subdivision in the Greater Adelaide region was assessed based on the characteristics of residential subdivision in Adelaide and interstate. The assumed characteristics are summarised in Table 3-21. The characteristics of large scale development were adopted based on an analysis of a recent development in northern Adelaide which is illustrated in Figure 3-13. For comparison purposes, the characteristics of a multi-allotment scenario in Queensland is also presented in Table 3-21 based on the work presented by SEQHWP and Ecological Engineering (2007). This interstate case was not examined in the MUSIC model because the overall pervious/impervious areas are quite similar in each case.

Table 3-21 – Assumed characteristics of Scenario 4 – large scale development > 50 allotments

| | Adelaide development | Brisbane development |
|---|---|---|
| **Description** | 57 allotments | 58 allotments |
| **Rainwater tank** | 1 kL cylindrical tank | 1 kL cylindrical tank |
| **Total area** | 3.03 Ha | 4.50 Ha |
| **Total roof area** | 1.21 Ha | 1.16 Ha |
| **Ground level impervious** | 0.28 Ha | 0.57 Ha |
| **Ground level pervious** | 1.17 Ha | 1.70 Ha |
| **Road** | 0.373 Ha | 1.07 Ha (60% paved) |

Figure 3-13 – Northern Adelaide catchment (marked in in red) analysed to represent a development with greater than 50 allotments (GoogleMaps, 2011)

The achievement of water quality objectives for the multi-residential allotment scenario will be assessed with the implementation of:

- No treatment
- Individual 1 kL rainwater tanks
- An ‘end of pipe’ wetland and individual 1 kL rainwater tanks
- An ‘end of pipe’ bioretention system and individual 1 kL rainwater tanks

### 3.3.5 Results of Stormwater Quality Runoff Targets Assessment

The results of the stormwater runoff quality targets assessment are presented in Table 3-22. Overall, the results of the feasibility analysis indicate that almost all developments were able to achieve the stormwater runoff quality targets recommended for the Greater Adelaide Region in Table 3-14. The exceptions for this are in the case of the high rise residential development, where allotment size restricts the use of landscape based WSUD treatment options. It should be noted however that the installation of communal water harvesting (with the installation of a 23.9 kL or 61 kL rainwater tank) made a significant impact on water quality improvement by intercepting runoff from the large impermeable area (roof runoff tends to contain concentrations of nitrogen from the atmosphere and some particulate matter).

Table 3-22 - Results of the water quality improvement scenario analysis

| | Tank | Bioretention | Adelaide Coast Load reduction (%) | | | Adelaide Plains Load reduction (%) | | | Adelaide City Load reduction (%) | | | Adelaide Hills Load reduction (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario 1 – Residential allotment – High density** | | | | | | | | | | | | | | |
| | kL | $m^2$ | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN |
| No treatment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rainwater tank | 1 | 0 | 9.2 | 7.8 | 13.1 | 7.5 | 5.4 | 9.7 | 6.8 | 5 | 8.9 | 5 | 3.8 | 6.8 |
| Rainwater tank +bioretention | 1 | 3.5 | 88.4 | 77 | 58 | 87.4 | 75 | 53.8 | 86.2 | 72.4 | 47.7 | 80.1 | 68.2 | 45.5 |

| | Tank | Bioretention | Adelaide Coast Load reduction (%) | | | Adelaide Plains Load reduction (%) | | | Adelaide City Load reduction (%) | | | Adelaide Hills Load reduction (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario 1 – Residential allotment - Low density** | | | | | | | | | | | | | | |
| | kL | $m^2$ | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN |
| No treatment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rainwater tank | 1 | 0 | 9.7 | 8.2 | 13.5 | 7.5 | 5.3 | 9.4 | 6.6 | 4.9 | 8.6 | 4.4 | 3.4 | 6.1 |
| Rainwater tank +bioretention | 1 | 3.5 | 88.3 | 76.7 | 57.9 | 86.3 | 73.9 | 53 | 84.8 | 71.1 | 46.6 | 81 | 68.8 | 45 |

| | Tank | Bioretention | Adelaide Coast Load reduction (%) | | | Adelaide Plains Load reduction (%) | | | Adelaide City Load reduction (%) | | | Adelaide Hills Load reduction (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario 2 – Residential allotment subdivision (Infill development) - Brisbane** | | | | | | | | | | | | | | |
| | kL | $m^2$ | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN |
| No treatment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rainwater tank | 1 | 0 | 14.6 | 14.5 | 22.6 | 10.6 | 9.3 | 15.4 | 9.3 | 8.1 | 13.6 | 5.9 | 5.3 | 9.2 |
| Rainwater tank & bioretention | 1 | 4.3 | 95.1 | 86.3 | 72.2 | 93.8 | 83.2 | 65.5 | 93.2 | 80.3 | 57.2 | 89.4 | 77 | 52.7 |

**Scenario 2 – Residential allotment subdivision (Infill development) - Adelaide**

| | | | Adelaide Coast | | | Adelaide Plains | | | Adelaide City | | | Adelaide Hills | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tank | Bioretention | Load reduction (%) | | | Load reduction (%) | | | Load reduction (%) | | | Load reduction (%) | | |
| | kL | $m^2$ | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN |
| No treatment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rainwater tank | 1 | 0 | 10 | 8.7 | 14.4 | 8.2 | 6.1 | 10.7 | 7.4 | 5.6 | 9.8 | 5.5 | 4.4 | 7.6 |
| Rainwater tank & bioretention | 1 | 4.3 | 90.3 | 79.2 | 60.9 | 89.6 | 77.2 | 56.2 | 88.7 | 74.6 | 49.7 | 83.4 | 71.2 | 49.1 |

**Scenario 3 – Cluster development**

| | | | Adelaide Coast | | | Adelaide Plains | | | Adelaide City | | | Adelaide Hills | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tank | Bioretention | Load reduction (%) | | | Load reduction (%) | | | Load reduction (%) | | | Load reduction (%) | | |
| | kL | $m^2$ | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN |
| No treatment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 kL RWT | 1 | 0 | 5.5 | 5.9 | 10.9 | 4.3 | 4.1 | 7.8 | 3.9 | 3.6 | 7 | 2.8 | 2.6 | 5.1 |
| Bioretention + 1 kL RWT | 1 | 60 | 94.3 | 86.4 | 69.5 | 93.5 | 84.2 | 64.2 | 92.7 | 81.4 | 54.6 | 87.8 | 78.2 | 56.2 |
| Communal rainwater tank (CRT) | 23.9 | 0 | 5.5 | 5.9 | 10.9 | 4.3 | 4.1 | 7.8 | 0 | 0 | 0 | 0 | 0 | 0 |

**Scenario 4 – Residential High rise**

| | | | Adelaide Coast | | | Adelaide Plains | | | Adelaide City | | | Adelaide Hills | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tank | Bioretention | Load reduction (%) | | | Load reduction (%) | | | Load reduction (%) | | | Load reduction (%) | | |
| | kL | $m^2$ | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN |
| No treatment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rainwater tank (23.9 kL) | 23.9 | 0 | 42.3 | 39.7 | 47.2 | 34.4 | 29.3 | 36.2 | 31.7 | 27 | 33.5 | 25.1 | 21.8 | 27.5 |
| Rainwater tank (61 kL) | 61 | 0 | 47.3 | 41.5 | 51.1 | 38.7 | 29.3 | 38.6 | 37.4 | 28.7 | 37.6 | 30.6 | 22.7 | 30.6 |

**Scenario 5 – Large scale development (> 50 allotments)**

| | Tank | Bioretention | Wetland | Adelaide Coast Load reduction (%) | | | Adelaide Plains Load reduction (%) | | | Adelaide City Load reduction (%) | | | Adelaide Hills Load reduction (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kL | $m^2$ | $m^2$ | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN | TSS | TP | TN |
| No treatment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rainwater tank | 1 | 0 | 0 | 5.4 | 7.6 | 11.4 | 4.5 | 5.4 | 8.5 | 4 | 4.9 | 7.7 | 2.9 | 3.3 | 5.5 |
| Rainwater tanks & bioretention | 1 | 300 | 0 | 94.2 | 79.4 | 63.3 | 93.4 | 76.8 | 57.4 | 92.6 | 73.4 | 47.5 | 88.1 | 72.4 | 52 |
| Rainwater tanks & wetland | 1 | 0 | 800 | 91.1 | 77 | 58.2 | 85.3 | 70.8 | 52.6 | 82.3 | 67.6 | 48.8 | 88.1 | 72.4 | 52 |

## 3.4 Recommended Stormwater Runoff Quality Targets

Based on the analysis in undertaken for this report, the runoff quality targets for greater Adelaide should correspond to those determined in Table 3-14 and in subsequent text of Section 3.3.3. These targets may be summarised as follows:

- 80% reduction in annual loads of TSS compared to an equivalent, untreated catchment
- 60% reduction in the annual loads of TP compared to an equivalent, untreated catchment
- 45% reduction in the annual loads of TN compared to an equivalent, untreated catchment
- 90% reduction in annual loads of gross pollutants/litter compared to an equivalent, untreated catchment

It should be noted that the TSS, TP and TN targets are based on modelling in the eWater software MUSIC Version 4.10. eWater CRC released MUSIC Version 5 on 1 August 2011, and a complete reassessment of bioretention treatment performance, based on the procedures in Section 3.3.2, is provided for consideration in Appendix D, with noticeable changes in the treatment of TP and TN. The target for gross pollutants was based on outcomes from the *Institutionalising WSUD in the Greater Adelaide Region* project, and was adapted to suit national recommendations and interstate targets for gross pollutants. For comparison, the proposed targets are compared with targets for other Australian states or state capitals in Appendix C.

The South Australian EPA has recommended oil and grease targets be applied to new development in Greater Adelaide. Recommended targets for gross pollutants, oils and grease are more difficult to assess in a standardised manner for residential development at the present time. One method of assessing the performance is to specifically identify whether there are point sources of oil and grease contaminants in a catchment. Where point sources of oils and grease are identified, such as workshops and retail fuel producers, developers may need to demonstrate that treatment systems capable of treating oil and grease contaminants for the 3 month ARI peak flow have been implemented in the developed catchment proposal.

## 3.5 Comment on Implementation of Stormwater Runoff Quality Targets

The targets recommended in this section of the report have been developed and assessed using a widely applied methodology from other states with consideration for conditions in the Greater Adelaide Region. It is acknowledged that some developments may not be suitable for WSUD elements, where proposed water quality targets cannot be met. In such cases, it may be possible for development proposers to make up for this non-compliance by payment of a fee (to be collected and used for large scale WSUD adoption by state or local government), by the adoption of an export offset (retrofitting of WSUD measures at some other location outside the development) or by participation in an export permit trading system. Such schemes have been implemented elsewhere in Australia and a summary of these is provided in Section 3.2.9.

Communications with local government planning and engineering staff indicated that some local governments were in the process of developing targets specific for their region, including Yankalilla and Adelaide Hills. In the case of Yankalilla, the issue of a relatively undisturbed coastline was raised, as seagrass was found to be relatively intact in the Yankalilla coastal region compared to other coastal areas of Adelaide. As such, it should be noted that the targets developed in this project should not be implemented to over-ride targets developed at the local level where catchment processes may better understood. Rather, these targets should be considered as a minimum standard *in lieu* of targets which have been developed based on local knowledge (i.e. by local government) which may consider the state of the local environment, localised climate conditions and forward planning measures. It is not recommended that local governments adopt lower levels of water quality improvement, but a local council that requires higher reductions in one or more indicators should not be discouraged or impeded from implementing these targets.

In addition to the issue of local knowledge, it is recognised that there is more research required into targets for upland streams. Some commentary around the implementation of targets has indicated that due to the limited buffering capacity of upland streams in areas including the Adelaide Hills, targets specific to upland streams may be required in light of new development scheduled to occur in the region, such as Mt. Barker. Such targets may include stronger load based targets at the local scale (such as a local council) or concentration based targets like those for the health of aquatic ecosystems (such as those recommended by ANZECC and ARMCANZ [2000]).

The recommended stormwater runoff quality targets may be suitable for commercial and industrial development, but the site characteristics of these developments across Adelaide were not assessed in this research. It is recommended that the targets currently supported by the SA EPA and currently recommended for new development (see Table 3-8 and Table 3-9, Page 68) remain in place for commercial and industrial developments in the interim period. Alternately, the recommended targets may be adopted on an interim basis to gauge the level of acceptance by the development industry.

The stormwater runoff improvement targets should not be considered to encompass all aspects of stormwater runoff quality management in South Australia. It is highly recommended that these targets are supported by other planning policies to manage the export of other pollutants in the Greater Adelaide region. For example, other typical contaminants that tend to be controlled include oil and grease contaminants, as previously discussed. Other more specific chemical pollutants should also be considered in future studies. Herbicides, such as simazine and atrazine, are known to be prevalent in stormwater runoff across Adelaide. Increased concentrations of these herbicides can pose a threat to ecosystems, as well as a risk to the increasing number of stormwater harvesting and reuse facilities in the Greater Adelaide Region. This may require catchment management protocols or other qualitative measures because, at present, models are limited in being able to assess the transport and treatment of such contaminants.

The development and assessment of stormwater runoff quality improvement targets using models has however demonstrated the importance of assuming suitable parameters in the MUSIC model to demonstrate the effectiveness of WSUD measures. For this reason, it is recommended that targets are supported by further research into:

- Suitable design and materials used for WSUD measures in the Adelaide region, including the commercial availability/feasibility of soil media (where relevant)

- Suitable parameters to reflect Greater Adelaide in the MUSIC model in the form of MUSIC modelling guidelines for Greater Adelaide

It is also obvious that the parameters which yield best results in MUSIC should be reflected in the detailed design of the WSUD system to be implemented in the field.

Finally, it is recommended that further development of these targets should be undertaken given the recent release of MUSIC Version 5 on 1 August, 2011. This version of the software includes significant changes to the bioretention treatment node on which stormwater quality improvement in this section of the report has largely been based. Some initial trials have found that targets may be subject to change should MUSIC Version 5 prove to be more accurate (See Appendix D). The analysis indicates that TN is no longer the limiting pollutant for a bioretention system, which is a significant change to the research outcomes. Discussions are underway with eWater CRC representatives regarding the implications of these changes to the MUSIC model performance.

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# 4 Stormwater Runoff Quantity Management Targets

## 4.1 Introduction

### 4.1.1 Managing the impact of urbanisation on flow regimes

Urbanisation has a profound impact on flow regimes in waterways that receive flows from urban areas. The impacts affect nearly every component of the water cycle. Impacts include decreased evaporation, infiltration, time of concentration and base flows, and increased runoff volumes, peak flows and frequency of runoff events. The changes to flow regimes in streams in urban areas are conceptually illustrated in Figure 4-1 . These changes in flow regimes along with decreased water quality can cause a significant degradation of the ecosystem in waterways receiving runoff from urban areas. The most obvious sign of stream degradation is bank erosion, as shown in Figure 4-2a. Where urbanisation has resulted in severe impact to the stream, engineered solutions have either been to line the stream with concrete or to pipe the runoff and cover the stream bed, as shown in Figure 4-2b and 4-2c. The need to improve on this approach to urban waterways has been identified by the recently released stormwater strategy for South Australia (Government of South Australia, 2011). This includes improving both stormwater runoff quality and quantity.

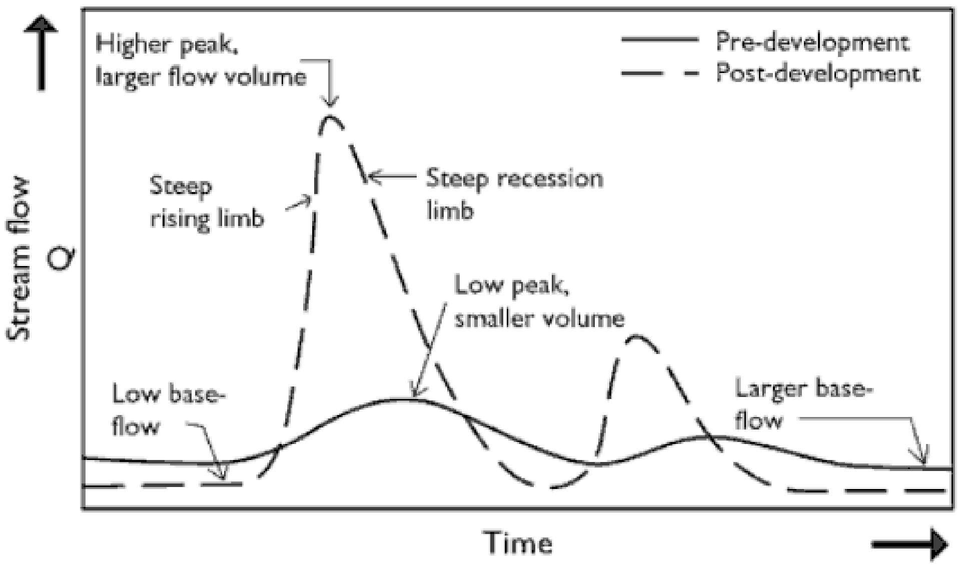


Figure 4-1 - Schematic illustration of impacts of urbanisation on catchment hydrology (source: Marsalek, *et al.*, 2007)

Guideline documents such as *Urban Stormwater: Best Practice Environmental Management Guidelines* (Victorian Stormwater Committee, 1999) describe commonly adopted methods for managing the impact of urbanisation on waterways in urban areas. These describe control measures required to mitigate changes to both the quantity and quality of urban runoff caused by changes to land use, and provide stormwater management objectives. The Victorian Stormwater Committee (1999) gives emphasis to quality of runoff rather than the quantity of runoff.

However, as shown in Figure 4-1, urbanisation has a significant impact on flow regimes and emerging research suggests that changes in flow regimes can affect the health of the overall ecosystem in urban waterways (Walsh, 2000; Argue, 2004; Fletcher *et al.*, 2007; Marsalek *et al.*, 2007; Lee *et al.*, 2008; Walsh *et al.*, 2010).

(a)

(b)

(c)

Figure 4-2 – Images demonstrating the effects of (a) stream erosion (b) engineered solutions to the effects of increased flow due to urban development

In recent years, there has been increased recognition of the link between hydrology driven stream flow characteristics and stream ecology. This has led to the search for new approaches to flow management in urban waterways in a manner that maintains those elements of the pre-development flow regime which are important to maintain stream ecology (Poff *et al.*, 2010). One such approach was described by Hewa *et al.* (2009), which proposed to maintain pre-development channel-forming flows to protect aquatic ecosystems in urban streams. The channel-forming flow is the flow regime that determines shape and geometry in a natural stream. The widely agreed frequency with which this flow re-occurs in a natural channel is within the range of the 1-2 year ARI (Gippel, 2002 as cited by Hewa *et al.* 2009). Maintenance of channel-forming flows has the potential to reduce in-stream erosion downstream of urban areas.

A similar approach has been proposed in South East Queensland's WSUD Guidelines (Water by Design, 2007) to protect aquatic ecosystems in urban waterways. The approach aims at minimising the change in frequency of disturbance to aquatic ecosystems by managing the volume and frequency of runoff during small rainfall events, and reducing in-stream erosion by managing peak flows. Controlling in-stream erosion (or maintaining channel-forming flows) can protect in-stream ecosystems and coastal ecosystems from frequent flows containing sediments and nutrients.

The key challenge in managing flow regimes in urban streams (or runoff quantity) is the identification of elements of stream flow that are important to maintain stream ecology. The elements or variables considered in the literature for measuring the impact of urbanisation on natural streams have potential for quantitatively assessing the degree of impact urbanisation has had on the flow regimes of urban waterways. Generally, the impact is measured relative to the pre-development flow regimes. These impact assessment variables can be grouped into hydrological and physical measures (or indicators), which are described below.

### 4.1.2 Hydrological indicators

Hydrological indicators are flow-related variables that can be quantified directly from the flow timeseries of a stream. Examples for hydrological indicators include total daily runoff volume, number of days with flows above some threshold volume and peak flows with various average recurrence intervals (ARI), such as the 1 month ARI, 3 month ARI, I year ARI and 3 year ARI. Peak flows of magnitude up to the 1.5 year ARI are generally considered responsible for a large proportion of total sediment movement in streams (Queensland Environmental Protection Authority, 2009).

Richter *et al.* (1996) described 32 different hydrologic indicators that could be used to describe the flow regimes of streams. DeGasperi *et al.* (2009) found that only some indicators identified by Richter *et al.* (1996) could be used as measures of urbanisation. Such indicators included flow frequency and duration, low and high flow rates and 'flashiness' of the flow. Low and high flows were measured relative to a set threshold estimated based on pre-development data. Recently, Kennard *et al.* (2010) described 120 different hydrologic indicators to support the management of environmental flows in streams at the catchment scale. Hewa *et al.* (2009) proposed the use of pre-development peak flows with a 1-2 year ARI as an indicator for maintaining pre-development channel-forming flows. At present, however, there is no commonly accepted set of hydrological indicators for assessing the degree of impact of urbanisation on the flow regimes of urban waterways.

### 4.1.3 Physical Indicators

Physical indicators are non-flow variables, but they are considered to be highly correlated to changes in flow regimes and/or changes in stream macroinvertebrate populations. The commonly used physical indicators to measure the impact of urbanisation on urban waterways are "total imperviousness" (Schueler, 1994) and "effective imperviousness" (Hatt *et al.*, 2004; Walsh and Kunapo, 2009). The latter indicator is also known as "directly connected imperviousness". The total imperviousness of a catchment represents the sum of all impervious areas in a catchment while effective imperviousness represents impervious areas in a catchment that are directly connected to stream channels through drainage systems. In directly connected impervious areas, precipitation falling on the area is effectively transported to the stream. Walsh and Kunapo (2009) showed a close correlation between effective imperviousness and stream macroinvertebrate populations in an urban catchment.

Recently, Walsh (2010) suggested four indicators, which linked physical, hydrological and water quality indicators. The four indicators measure changes in (1) frequency of flow from directly connected impervious areas to the stream, (2) volume and temporal pattern of subsurface flow, (3) median concentrations of P, N and TSS flowing to the stream and (4) the total volume of water flowing to the stream. Of the four suggested indicators, three are related to runoff quantity, which shows the importance of managing flow regimes in urban streams to maintain a healthy water ecosystem.

## 4.2 Review of Existing Stormwater Runoff Quantity and Flow Targets

### 4.2.1 National Targets and Variables for Stormwater Flow Management

Throughout much of Australia, stormwater management targets focus primarily on reducing long-term pollutant loads (Fletcher *et al.*, 2011). Therefore, at present, there is no nationally accepted set of flow management objectives for urban waterways in Australia. This is mainly due to the fact that the link between changes to hydrology in urban areas and stream ecology is an emerging area of science and there is no widely accepted set of variables that link hydrology to urban stream ecology. Consequently, Australian states have each begun to use different sets of indicators to manage the regeneration pre-development flow regimes. However, as a planning measure, stormwater flow management targets have been rarely enforced (Fletcher *et al.*, 2011). The various management measures being considered for flow management include Water Sensitive Urban Design (WSUD) elements (e.g. bio-retention systems, porous pavements and rain gardens) and stormwater harvesting. Approaches used by the states of Australia for flow rate and volume management in urban waterways are described in the following sections.

### 4.2.2 Victoria

The State of Victoria adopts practices outlined in the document *Urban Stormwater: Best Practice Environmental Management Guidelines* (Victorian Stormwater Committee, 1999). The flow management objective given by Victorian Stormwater Committee (1999) states that stormwater runoff from developments should be maintained at the pre-development 1.5 year ARI level.

ARI is the probability of the occurrence of a given event, found through statistical means (flow frequency analysis). Maintaining a flow regime at an ARI of 1.5 years means that the peak flow which is expected to occur with a 1.5 year recurrence interval (measured in volume, e.g. litres/second) in a developed catchment should be approximately equal to the peak flow which can be expected to occur with a 1.5 recurrence interval corresponding to an undeveloped (natural) catchment. In general, ten or more years of either observed or simulated stream flow data are required to undertake flow frequency analysis. The confidence of the analysis increases with the use of more years of stream flow data. The flow frequency analysis method is described by McMahon and Adeloye (2005).

### 4.2.3 Australian Capital Territory

The Australian Capital Territory (ACT) uses the document *Waterways: Water Sensitive Urban Design General Code* (ACT Planning and Land Authority, 2009) to control stormwater runoff quantity. The flow management objectives are as follows:

- 3 month ARI: reduction of runoff peak flow to no more than pre-development levels and release of captured flow over a period of 1 to 3 days
- 5 year to 100 year ARI: Reduction of peak flows to pre-development levels

According to the ACT Planning and Land Authority (2009), opportunities should be sought to utilise stormwater as a substitution for mains water, particularly for the irrigation of sportsgrounds and public open space. Where this is proposed (i.e. stormwater harvesting), there is a requirement to comply with environmental flow guidelines to protect natural waterways against erosion and to maintain healthy water ecosystems. The recommended parameters and procedures to be used for the ACT are given in the TAMS publication titled "*Design Standards for Urban Infrastructure, 1 Stormwater*"[12].

### 4.2.4 New South Wales

Interim WSUD Guidelines for NSW are currently being developed by the Sydney Metropolitan Catchment Management Authority's (CMA) Water Sensitive Urban Design (WSUD) Program[13]. It is expected that the flow management target in NSW would be part of the WSUD guidelines. The interim WSUD Guidelines for NSW would act as a bridging document providing a regional context to South East Queensland's Water by Design Program suite of WSUD Guidelines that assist practitioners with the planning, design and construction of WSUD elements. Hence it can be expected that NSW's flow management targets would be similar to those of South East Queensland (described in Section 4.2.5).

Prior to the establishment of Sydney Metropolitan Catchment Management Authority's (CMA) Water Sensitive Urban Design (WSUD) Program, Landcom adopted its Water Sensitive Urban Design Strategy (2009) to Greenfield sites, or wherever there is a natural stream downstream of a development. In Landcom's Water Sensitive Urban Design Strategy (2009), a "Stream Erosion Index" has been identified as the flow target set for developments in north-west and south-west Sydney (see Table 4-1). These flow targets are defined as the ratio of the post development duration of stormwater flows greater than the "stream-forming flow" to the duration of flows greater than the "stream-forming flow" for the catchment under pre-development, natural conditions. At other sites, flow management objectives should be considered on a case-by-case basis.

[12] Available for download at www.roads.act.gov.au/documents/index.html#stormwater

[13] Available for download at http://www.wsud.org

Table 4-1 - Flow management targets used by north-west and south-west Sydney

| Baseline flow management target | Stretch flow management target |
|---|---|
| Maintain 1.5 year ARI peak discharge to pre-development magnitude<br><br>Stream Erosion Index = 2.0 | Maintain 1.5 year ARI peak discharge to pre-development magnitude<br><br>Stream Erosion Index = 1.0 |

The stretch targets reflect the stormwater outcomes considered necessary to protect the receiving environment from the impact of urban development (i.e. to achieve a degree of sustainable development that maintains high environmental values). Stretch targets are included to demonstrate the gap between environmental objectives and the extent to which those objectives can be met by 'best practice' WSUD. They encourage the attainment of outcomes beyond the standard targets where practicable.

### 4.2.5 Queensland

Water by Design (2007) described two stormwater quantity management design (performance) objectives as part of WSUD Guidelines for South East Queensland, and they are the:

- Frequent Flow Management Design Objective
- Waterway Stability Management Design Objective

The Frequent Flow Management Design Objective (FFMDO) aims to protect in-stream ecosystems from the significant effects of increased runoff frequency by capturing the initial portion of runoff (referred to as the design runoff capture depth) from impervious areas. This approach ensures that the frequency of hydraulic disturbance to in-stream ecosystems in developed catchments is similar to the fully pervious, pre-developed catchment conditions. The design runoff capture depth was selected to provide a similar frequency of surface runoff for small rainfall events and to achieve a similar overall annual volume of runoff (AVR) to an un-developed catchment.

The Queensland FFMDO is to capture and manage the following design runoff capture depths (mm/day) from all impervious surfaces:

- Developments with a total fraction impervious < 40%: design runoff capture depth = 10mm/day
- Developments with a total fraction impervious ≥ 40%: design runoff capture depth = 15mm/day

The FFMDO is only expected to be applied in catchments which drain to waterways and wetlands that are classified as *High Environmental Value (HEV) systems*, or if the local council intends to rehabilitate a modified system. The spatial distribution of the required capture volume (i.e. impervious area × design runoff capture depth) within an urban development may be adapted to suit individual site conditions, provided that the required capture volume from all impervious areas is captured before leaving the site.

Implementing the required capture volume will also reduce pollutant load according to SEQHWP and Ecological Engineering (2007), providing a synergistic benefit for water quality. Hence, there may be an opportunity to incorporate the required capture volume within stormwater quality treatment measures, potentially eliminating the need for separate additional runoff storage volumes to meet the frequent flow management design objective.

The FFMDO requires that the capture volume of a flow interception system should be available each day. Therefore, the disposal of the captured stormwater (either by infiltration, evapotranspiration, reuse, discharge via bioretention, or combinations of these) must be capable of drawing down the captured stormwater within 24 hours. In most cases it will not be possible to fully draw down the capture volume within 24 hours if relying only on local infiltration, evapotranspiration and/or re-use as the disposal methods. This is because the rate at which these disposal methods can draw down the capture volume will typically be too slow. Therefore, discharge via collection pipes at the base of storage or WSUD systems will be required in addition to any on-site infiltration in most situations.

According to SEQHWP and Ecological Engineering (2007), HEV waterways and wetlands, in particular ephemeral systems, may be highly vulnerable to increased baseflow conditions. It is therefore important to assess the instream ecology of the receiving waterway before deciding on the appropriate disposal method. In particular, care should be taken to ensure the in-stream ecology of the receiving waterway is resilient to the extended baseflow conditions that may result from discharge via on-site infiltration. Certain HEV waterways that are determined to be vulnerable to an increase in baseflow may require measures to avoid urban development within their catchment areas (unless it can be demonstrated that infiltration, evapotranspiration and re-use disposal methods can be employed *in lieu* of discharge via bioretention). Disposal of the capture volume by infiltration should only be considered when local soil and groundwater conditions are suitable. Urban salinity can be a problem if excessive infiltration is attempted in areas of low infiltration capacity or where there is a shallow groundwater table. Contamination of groundwater aquifers by poor quality stormwater runoff may also be a problem, particularly if there are existing beneficial users of the local groundwater resource (including the environment).

The Waterway Stability Management Design Objective (WSMDO) aims to prevent exacerbated in-stream erosion downstream of urban areas by controlling the magnitude and duration of sediment-transporting flows. This is similar to the channel-forming flow criterion of Hewa *et al.* (2009). The WSMDO limits the post-development peak one-year ARI event discharge to the receiving waterway to the pre-development peak one-year ARI event discharge. This objective is applicable where runoff from or within the site passes through or drains to an unlined channel, or non-tidal waterway or wetland. Where a receiving waterway is degraded, the local or regional authority may choose not to require compliance with this objective, on the basis that the receiving waterway and its associated catchment/s have been identified by the authority as having limited potential for future rehabilitation and/or WSUD retrofitting. The local authority may substitute an alternative criterion where catchment-scale studies have been undertaken to develop a catchment-specific approach to the management of in-stream erosion impacts.

Compliance with The WSMDO can be demonstrated using one of the following methods depending on the scale of the development:

- Method A (for all developments < 10 ha gross site area): Calculate the required detention storage using the following simple hydrograph method in the Queensland Urban Drainage manual (QUDM) (1994, Equation 6.01): $V_s/V_i = 1 – 0.5\ Q_o/Q_i$; where: $V_s$ = Required Detention Storage (m3); $V_i$ = Volume of inflow hydrograph (m3); $Q_o$ = Desired peak 1yr ARI outflow rate (m3/s); $Q_i$ = Peak inflow rate (m3/s); $Q_o$ is to be calculated using the Rational Method and pre-developed site conditions (assuming zero % impervious and vegetation cover representative of the development site and surrounding areas over recent years) and a storm duration of 60 minutes for selecting the design 1 yr ARI rainfall intensity. $Q_i$ is to be calculated using the Rational Method and post-developed site conditions. Values of $Q_i$ should be calculated for storm durations from 5 minutes up to 60 minutes. Values of $V_i$ corresponding to each of the calculated values of $Q_i$ are to be calculated using the following equation: $Vi = 4 \times t_d \times Q_i / 3$; where $t_d$ = storm duration (minutes).
- Method B: (for all developments > 10 ha gross site area). This method uses runoff routing methods to establish the Desired Peak 1yr ARI Outflow ($m^3/s$) and Required Detention Storage ($m^3$) for development sites.

SEQHWP and Ecological Engineering (2007) recommended that local governments apply Method B to establish catchment specific values for Desired Peak 1 year ARI Outflow ($m^3/s$) and Required Detention Storage ($m^3$). These values can then be prescribed in relevant planning assessment and approval instruments. It should be recognised that the use of detention storages will promote extended periods at the target flow and the effects of this should be taken into consideration.

### 4.2.6 Northern Territory

There are no guidelines available for stormwater flow management in the Northern Territory at the time of publication. Initial feasibility assessment (EDAW, 2007) indicated it “may” be practical to adopt a waterway stability objective for Darwin which aims to limit the impacts of urban development on in-stream habitat disturbance and erosion by controlling the magnitude and duration of stormwater discharges. At this stage, technical investigations are being conducted to define a waterway stability objective.

### 4.2.7 Western Australia

The *Stormwater Management Manual* for Western Australia (Department of Environment, 2004) identified that stormwater is a resource with social, environmental and economic value. The manual reflects the *Western Australian State Water Strategy* (Government of Western Australia, 2003) and includes the following objectives for stormwater management:

- Water quality: to maintain or improve surface and groundwater quality within development areas relative to predevelopment conditions
- Water quantity: to maintain the total water cycle balance within development areas relative to predevelopment conditions
- Water conservation: to maximise the reuse of stormwater
- Ecosystem health: to retain natural drainage systems and protect ecosystem health

- Economic viability: to implement stormwater management systems that are economically viable in the long term
- Public health: to minimise risk, including risk from injury or loss of life, to the community
- Protection of property: to protect the built environment from flooding and water-logging.
- Social values: to ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater
- Development: to ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles

Currently, no target values have been defined for the stormwater flow management.

### 4.2.8 South Australia

The Adelaide Coastal Waters Study identified suspended solids in stormwater runoff as a critical contribution to the die back of coastal sea grass. Soil erosion in streams due to increased flows has a significant impact on suspended solid loads and transport. The water quantity objectives of stormwater management in the Greater Adelaide Region are outlined in development plans for individual local government areas[14]. The main objectives stated in these plans are to:

- prevent erosion and prevent or minimise the risk of downstream flooding;
- maximise the use of stormwater
- protect stormwater from pollution sources; and
- protect or enhance the environmental values of receiving waters.

The current recommendations for achieving these objectives are listed below.

- To prevent erosion and prevent or minimise the risk of downstream flooding:
    - The major storm drainage system of new developments should have the capacity to safely convey stormwater flows for ARI = 100 years (assuming 50% minor system blockage); and the design outflow is matched to the capacity of any existing downstream system.
    - The stormwater system should have the capacity for minor stormwater flows and should: (a) not overload adjoining downstream systems; and (b) where practicable, provide for stormwater flows to be detained and retained close to its source.
    - The minor storm drainage system should have the capacity to convey stormwater 5 year ARI flows for suburban residential lots with neighbourhood densities not

[14] A collection of development control plans for the Greater Adelaide region are available for download at:
http://www.sa.gov.au/subject/Housing%2C+property+and+land/Building+and+development/Building+and+development+applications/Development+plans+and+their+use/Accessing+relevant+development+plans/Online+development+plans (viewed in May 2011)

greater than 20 dwellings per ha, and 20 year ARI flows for neighbourhood densities greater than 20 dwellings per ha; and

- For the purposes of assessing coastal developments the standard sea flood risk level for a development site is defined as the 100 year average return interval extreme sea level (tide, stormwater and associated wave effects combined), plus an allowance for land subsidence for 50 years at that site.

- To maximise the use of stormwater and protect stormwater from pollution sources:
  - incorporate WSUD measures to manage, protect and conserve water through features which retain, detain and, re-use water on-site;
  - maximise the potential for stormwater harvesting; and
  - incorporate detention measures to minimise any concentrated stormwater discharge from the site.
- To Protect or enhance the environmental values of receiving waters:
  - Stormwater runoff flow contributions from developments to the receiving waterway must be in harmony with the waterway's channel-forming flow (at each section of entry) in terms of frequency (ARI), peak flow and hydrograph volume (Hewa *et al.,* 2009 and Argue *et al.,* 2011); channel-forming peak flow in a natural channel ('greenfield' catchment) is flow with ARI, Y = 1 to 2 years (Engineers Australia, 2006).
  - environmental flows (in terms of *yield* and *spell characteristics*) should be as close to those of the original 'greenfield' catchment as possible;
  - the floodplain should be managed so that intermittent entry of floodwaters can occur without threatening life or causing serious damage to property or prolonged interruption to services.

## 4.3 Methodology for Runoff Quantity Management Targets

The objectives of the development of stormwater quantity management targets are to:

1. Protect the in-stream ecosystem of waterways from frequent stormwater flows; and
2. Reduce sediment and nutrient transport to coastal waters of the Greater Adelaide Region by maintaining channel-forming peak flows, which is considered as peak flows corresponding to the pre-development 1.5 year ARI, for the development of interim runoff quantity targets in this study. It should be noted that the WSUD Guidelines for South East Queensland (Water by Design, 2007) suggest the use of the 1-year ARI flow, whereas Hewa *et al.* (2009) suggest the 1-2 year ARI should be used to maintain channel-forming flows. This study uses the mid-range value of that suggested.

Note that Objectives 1 and 2 above are called the "frequent flow management" and "waterway stability management" objectives respectively, by the South East Queensland WSUD Guidelines (Water by Design, 2007). In order to maintain consistency with other state approaches the methodology adopted for the development of interim stormwater quantity targets for the Greater Adelaide Region was based on the method adopted by the Queensland Environment Protection Authority (2009) for the derivation of urban stormwater quantity targets in Queensland. However, this was not the case for waterway stability management. The Queensland approached examined the use of detention systems in the modelling to meet the water stability management objectives. An inherent problem with the use of detention systems is the resultant prolonged periods at the target peak flows, say at the 1.5 year ARI, which can subject a stream to critical flows for longer periods, increase flow volume, erosion and sediment transport and bank instability (Hewa *et al.*, 2009). For this reason the approach taken in this study was to examine the amount of rainfall on the impervious area that needed to be “captured” to maintain the 1.5 year ARI flow with a similar flow volume.

Briefly, the methodology used to develop an interim stormwater quantity target involved the use of the MUSIC model (Version 4.10) to simulate changes to runoff characteristics of a one hectare hypothetical catchment under different development scenarios, and to compare the simulated changes to runoff with pre-developed runoff characteristics. Different development scenarios were defined by changing the total impervious area of the catchment, from 0% (i.e. pre-developed state) to 80% (fully developed state) in increments of 20%.

The annual volumetric runoff (AVR) in ML, the flow duration curve and 1.5 year ARI (i.e. channel-forming flow) were used as hydrological indicators (note: the purpose of the hydrological indicators is described in Section 4.1.2). In accordance with Gold Coast City Council Music Modelling Guidelines (2006), the AVR is defined as:

$$\frac{area\ (square\ m) \times\ average\ annual\ rainfall\ (m)\ \times\ annual\ volumetric\ runoff\ coefficient}{1000\ (conversion\ to\ ML)}$$

The capture and retention/detention of a defined volume of runoff at the onset of runoff from impervious areas was considered as a possible management measure that can allow hydrological regimes of developed catchments to mimic those characteristics exhibited by the pre-developed catchment. A number of rainfall runoff capture depths were considered: 0 mm (i.e. no capture), 5 mm, 10 mm, 15 mm and 20 mm, to examine their ability to return flow regimes to the pre-developed state. The capture volume was found by multiplying the rainfall runoff capture depth with the impervious area.

Application of the methodology described above to data specific to the Greater Adelaide Region was conducted following the steps described below:

Step 1. Configure the MUSIC model for a 1 ha hypothetical catchment using the MUSIC model default values for the soil parameters in Adelaide (see Table 4-2). The MUSIC model default values for the soil parameters in Queensland are also shown in Table 4-2, for comparison purposes.

Table 4-2 - Soil parameters used for the MUSIC model

| Location | Soil store capacity (mm) | Field capacity (mm) |
|---|---|---|
| Adelaide | 40 | 30 |
| Queensland | 120 | 80 |

Step 2. Define climate data for each climatic zone in the Greater Adelaide Region. As outlined in Section 1.4, four climatic zones were used in this study to represent the spatial variability of the climate across the Greater Adelaide Region (see Table 4-3). Six-minute

rainfall and monthly potential evapotranspiration data that is representative of the four climatic zones outlined in Section 1.4 were used in the analysis (see Table 4-3). Daily rainfall characteristics of the four climatic zones are given in Table 4-3 and Table 4-4. Kersbrook had the highest mean daily rainfall and Largs Bay had the lowest mean daily rainfall. In addition, Largs Bay rainfall exhibits the highest temporal variability out of the all four climatic zones.

Table 4-3 - Rainfall data of the four climatic zones used in the study

| Region | Station name | Station number | Period of rainfall |
|---|---|---|---|
| **Adelaide Hills** | Kersbrook | 023877 | 1995 – 2005 |
| **Adelaide City** | Adelaide (Kent Town) | 023090 | 1992 – 2002 |
| **Coastal** | Largs Bay | 523000 | 1998 – 2003 |
| **Plains** | Adelaide airport | 023034 | 1993 – 2005 |

Table 4-4 - Daily Rainfall Characteristics of the four climatic zones

| | Airport | Kent Town | Kersbrook | Largs Bay |
|---|---|---|---|---|
| **Mean (mm)** | 1.2 | 1.4 | 2.1 | 0.9 |
| **Median (mm)** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Mode (mm)** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Coefficient of variation** | 3.0 | 3.0 | 2.8 | 3.3 |
| **Skewness** | 6.0 | 5.3 | 4.4 | 5.9 |
| **Range** | 66.2 | 71.0 | 68.4 | 38.0 |
| **Minimum (mm)** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Maximum (mm)** | 66.2 | 71.0 | 68.4 | 38.0 |

Step 3. Run the MUSIC model configured with the default soil parameters for the four climatic zones in the Greater Adelaide Region to determine runoff characteristics under the “pre-development” catchment condition or 0% impervious area. Compute annual runoff volume (in ML) corresponding to the pre-development catchment condition.

Step 4. Model the post-development catchment for the following proportion of impervious areas: 20%, 40%, 60% and 80%. Compute annual runoff volume (in ML) corresponding to the post-development catchment conditions. For each developed scenario, consider capture volumes of first 0 mm, 5 mm, 10 mm, 15 mm and 20 mm daily runoff from impervious areas. Compute annual runoff volume (in ML) corresponding to each scenario.

Step 5. Develop flow duration curves and compute 1.5 ARI values for each climatic zone and each impervious scenario. Compare the flow duration curves and 1.5 ARI values of the post-development with that of the pre-development conditions.

The results of this analysis are given in the sections below.

## 4.4 Results and Discussion of Runoff Analysis

The AVR calculations for each climatic region in the Greater Adelaide are given in Table 4-5 to Table 4-8.

Table 4-5 - AVR for Adelaide Airport

| Total fraction Impervious (%) | **Daily capture mm/day** | **Target AVR (Pre-development) ML/year** | **Actual AVR (ML/year)** |
|---|---|---|---|
| 20 | 0 | 0.69 | 1.42 |
| | 5 | 0.69 | 0.88 |
| | 10 | 0.69 | 0.71 |
| | 15 | 0.69 | 0.63 |
| | 20 | 0.69 | 0.59 |
| 40 | 0 | 0.69 | 2.16 |
| | 5 | 0.69 | 1.08 |
| | 10 | 0.69 | 0.73 |
| | 15 | 0.69 | 0.57 |
| | 20 | 0.69 | 0.50 |
| 60 | 0 | 0.69 | 2.90 |
| | 5 | 0.69 | 1.28 |
| | 10 | 0.69 | 0.75 |
| | 15 | 0.69 | 0.52 |
| | 20 | 0.69 | 0.41 |
| 80 | 0 | 0.69 | 3.64 |
| | 5 | 0.69 | 1.48 |
| | 10 | 0.69 | 0.77 |
| | 15 | 0.69 | 0.46 |
| | 20 | 0.69 | 0.31 |

Table 4-6 - AVR for Kent Town

| Total fraction Impervious (%) | **Daily capture mm/day** | **Target AVR (Pre-development) ML/year** | **Actual AVR (ML/year)** |
|---|---|---|---|
| 20 | 0 | 0.99 | 1.80 |
| | 5 | 0.99 | 1.25 |
| | 10 | 0.99 | 1.02 |
| | 15 | 0.99 | 0.91 |
| | 20 | 0.99 | 0.86 |
| 40 | 0 | 0.99 | 2.61 |
| | 5 | 0.99 | 1.50 |
| | 10 | 0.99 | 1.06 |
| | 15 | 0.99 | 0.84 |
| | 20 | 0.99 | 0.72 |
| 60 | 0 | 0.99 | 3.41 |
| | 5 | 0.99 | 1.76 |
| | 10 | 0.99 | 1.10 |
| | 15 | 0.99 | 0.76 |
| | 20 | 0.99 | 0.59 |
| 80 | 0 | 0.99 | 4.22 |
| | 5 | 0.99 | 2.02 |
| | 10 | 0.99 | 1.13 |
| | 15 | 0.99 | 0.68 |
| | 20 | 0.99 | 0.46 |

Table 4-7 - AVR for Kersbrook

| Total fraction Impervious (%) | **Daily capture mm/day** | **Target AVR (Pre-development) ML/year** | **Actual AVR (ML/year)** |
|---|---|---|---|
| 20 | 0 | 3.10 | 4.03 |
| | 5 | 3.10 | 3.34 |
| | 10 | 3.10 | 3.00 |
| | 15 | 3.10 | 2.80 |
| | 20 | 3.10 | 2.68 |
| 40 | 0 | 3.10 | 4.96 |
| | 5 | 3.10 | 3.57 |
| | 10 | 3.10 | 2.90 |
| | 15 | 3.10 | 2.50 |
| | 20 | 3.10 | 2.25 |
| 60 | 0 | 3.10 | 5.89 |
| | 5 | 3.10 | 3.80 |
| | 10 | 3.10 | 2.80 |
| | 15 | 3.10 | 2.20 |
| | 20 | 3.10 | 1.83 |
| 80 | 0 | 3.10 | 6.81 |
| | 5 | 3.10 | 4.04 |
| | 10 | 3.10 | 2.70 |
| | 15 | 3.10 | 1.90 |
| | 20 | 3.10 | 1.40 |

Table 4-8 - AVR for Largs Bay

| Total fraction Impervious (%) | **Daily capture mm/day** | **Target AVR (Pre-development) ML/year** | **Actual AVR (ML/year)** |
|---|---|---|---|
| 20 | 0 | 0.15 | 0.79 |
| | 5 | 0.15 | 0.36 |
| | 10 | 0.15 | 0.23 |
| | 15 | 0.15 | 0.18 |
| | 20 | 0.15 | 0.15 |
| 40 | 0 | 0.15 | 1.43 |
| | 5 | 0.15 | 0.57 |
| | 10 | 0.15 | 0.31 |
| | 15 | 0.15 | 0.21 |
| | 20 | 0.15 | 0.15 |
| 60 | 0 | 0.15 | 2.07 |
| | 5 | 0.15 | 0.78 |
| | 10 | 0.15 | 0.39 |
| | 15 | 0.15 | 0.23 |
| | 20 | 0.15 | 0.14 |
| 80 | 0 | 0.15 | 2.71 |
| | 5 | 0.15 | 1.00 |
| | 10 | 0.15 | 0.47 |
| | 15 | 0.15 | 0.26 |
| | 20 | 0.15 | 0.14 |

The figures in “red” text indicate the daily capture depth that allows the post-development AVR value to replicate the pre-development AVR value as closely as possible. These figures are summarised in Table 4-9. The results in Table 4-9 indicate that, with the exception of Largs Bay, a daily capture depth of 10 mm from impervious areas can replicate the pre-development AVR as close as possible if the total impervious area is greater than or equal to 20%.

For Largs Bay, a daily capture depth of 20 mm from impervious areas can replicate pre-development AVR as close as possible. The reason for the different capture depth in Largs Bay may be related to the low and highly variable rainfall in Largs Bay (i.e. mean daily rainfall is 0.9 mm and coefficient of variation ($C_v$) is 3.3, see Table 4-4) compared to the rainfall in other climatic zones (i.e. mean daily rainfall and $C_v$ for Adelaide Airport, Kent Town and Kersbrook are: 1.2 mm and 3.0; 1.4 mm and 3.0 and 2.1 mm and 2.8 respectively, see Table 4-4). As expected, low and highly variable rainfall has caused low and highly variable runoff with frequent occurrences of a ‘cease-to-flow’ condition. The flow duration curve (FDC) of Largs Bay for the pre-developed state (given in Figure 4-15 to Figure 4-18) exhibits this observation clearly. It has a steep slope with a cease-to-flow condition occurring about 92% of the time during the simulation period, which means the pre-developed flow regime is highly variable with very low base flows. This is because of the high losses associated with low rainfall intensities and the frequent occurrence of zero rainfall-runoff spells (or dry spells) due to infiltration and evaporation from the surface and sub-surface. This means that surface runoff is a key contributor to the pre-developed flow regime in Largs Bay. Consequently, as the impervious areas increase in Largs Bay, more runoff must be captured to replicate the pre-development flow regimes in comparison to the other flow-regimes where there is no 'cease-to-flow' condition. As shown in the FDCs of Adelaide Airport, Kent Town and Kersbrook (given in given in Figure 4-15 to Figure 4-18), the pre-developed flow regimes corresponding to these climatic zones have low or base flows occurring 100% of the time during the simulation period. For the flow-regimes with no occurrence of cease-to-flow condition occurring, capturing of more runoff from impervious areas will lead to a reduction in base flows. Accordingly, the analysis indicates that a 10 mm capture depth for the regions represented by Adelaide Airport, Kent Town and Kersbrook.

Table 4-9 - Capture depth values that allow post-development AVR value to replicate pre-development AVR value as close as possible for the four climatic zones

| **Total fraction Impervious (%)** | **Impervious area capture depth (in mm) required to maintain AVR values as closely as possible to pre-development AVR values** | | | |
|---|---|---|---|---|
| | **Adelaide Airport** | **Kent Town** | **Kersbrook** | **Largs Bay** |
| **20** | 10 | 10 | 10 | 20 |
| **40** | 10 | 10 | 10 | 20 |
| **60** | 10 | 10 | 10 | 20 |
| **80** | 10 | 10 | 10 | 20 |

The channel-forming flow (i.e. 1.5 ARI) was computed for all four zones and for all of the impervious and capture scenarios using partial series flood frequency analysis. The method involved extracting daily peaks from the 6-minute runoff time series computed by MUSIC over the simulation period, selecting the 30 highest peak flow values out of the daily peak flow time series and fitting the 30 highest peak flow values to Generalized Extreme Value Distribution using the method of L-moments. The figures in "red" text in Table 4-10 indicate the daily capture depth that allows the post-development 1.5 ARI peak flows to replicate the pre-development 1.5 ARI peak flows value as close as possible. These figures are summarised in Table 4-11.

Results given in Table 4-10 (in particular figures highlighted in "red") indicate that, with the exception of Largs Bay, a daily capture depth of 5 mm from impervious areas can replicate the pre-development 1.5 year ARI peak flow (i.e. pre-development channel-forming flow) as closely as possible if the total impervious area is less than or equal to 20%. A daily capture depth of 10 mm is required to replicate pre-development 1.5 year ARI peak flow if the total impervious area is greater than 20%. Largs Bay has a significantly low pre-development 1.5 year ARI peak flow compared to that of the other climatic zones. Due to the reasons discussed previously for Largs Bay stream flows, a daily capture depth of 20 mm from impervious areas is required to replicate the pre-development 1.5 year ARI peak flow.

Based on the results given in Table 4-9 and Table 4-11, it is proposed that the following volumes of stormwater runoff from impervious areas be captured to achieve both frequent flow management objective and the channel-forming (or waterway stability management) objective:

- Capture runoff equivalent to the volume generated from 5 mm of rainfall on connected impervious areas, for catchments with total impervious area up to 20%

- Capture runoff equivalent to the volume generated from 10 mm of rainfall on connected impervious areas , for catchments with total impervious area greater than 20%

The disposal of the captured runoff must be capable of drawing down the captured runoff within a day i.e. 24 hours. Capture of runoff can be achieved in a number of ways and consideration can be given to available storage in rainwater water tanks and surface depression storage.

Table 4-10 - 1.5 ARI peak flows corresponding to different levels of urbanisation of the 1 ha hypothetical catchment for the four climatic zones and different capture volumes of runoff from impervious areas

| Fraction Impervious | Capture depth (mm) | 1.5 ARI flow in L/s | | | |
|---|---|---|---|---|---|
| | | Adelaide Airport | Kent Town | Kersbrook | Largs Bay |
| 0% (pre-development case) | **0** | **43.4** | **51.1** | **107.2** | **0.2** |
| 20% | 0 | 46.5 | 53.1 | 117.3 | 12.5 |
| | 5 | 43.3 | 50 | 110.4 | 9.1 |
| | 10 | 39.6 | 46.9 | 101.3 | 5.5 |
| | 15 | 37.6 | 44.3 | 95.4 | 2.7 |
| | 20 | 35.3 | 42.3 | 92.3 | 0.9 |
| 40% | 0 | 56.6 | 58.7 | 138 | 24.2 |
| | 5 | 49.5 | 56.2 | 117.7 | 17.1 |
| | 10 | 38.8 | 48.1 | 98.6 | 9.5 |
| | 15 | 34.4 | 40.7 | 86 | 4.1 |
| | 20 | 29.8 | 35.1 | 78.3 | 1.1 |
| 60% | 0 | 72.6 | 69.4 | 164.9 | 35.4 |
| | 5 | 58.8 | 64.1 | 127.6 | 25.2 |
| | 10 | 40.8 | 52.3 | 98 | 13.1 |
| | 15 | 31.6 | 37.4 | 79 | 4.7 |
| | 20 | 25.2 | 29.6 | 66.8 | 1.1 |
| 80% | 0 | 0 | 90.2 | 81.5 | 196.2 |
| | 5 | 5 | 68.7 | 74.5 | 141.6 |
| | 10 | 10 | 46.1 | 57.7 | 98.4 |
| | 15 | 15 | 32.8 | 39.9 | 76.3 |
| | 20 | 20 | 21.8 | 26.6 | 56.7 |

Table 4-11 - Capture depth values that allow post-development 1.5 ARI peak flows to replicate pre-development 1.5 ARI peak flows as close as possible for the four climatic zones

| **Total fraction impervious (%)** | **Impervious Area Capture depth (mm) required to maintain the 1.5 year ARI as close as possible to the pre-development 1.5 year ARI** | | | |
|---|---|---|---|---|
| | **Adelaide Airport** | **Kent Town** | **Kersbrook** | **Largs Bay** |
| **20** | 5 | 5 | 5 | 20 |
| **40** | 10 | 10 | 10 | 20 |
| **60** | 10 | 10 | 10 | 20 |
| **80** | 10 | 10 | 10 | 20 |

The effect of the proposed runoff capture volumes from impervious areas on daily flows were examined using the daily flow duration curve (FDC) of each scenario. The FDC for each climatic zone for different levels of urbanisation (or different fractions of impervious areas) and different capture volumes of runoff from impervious areas are shown in Figure 4-3 to Figure 4-18. Note that the “natural” FDC represents the FDC under pre-development condition.

The FDCs of the natural or pre-developed state of the four climatic zones indicate that for Largs Bay, the ‘cease-to-flow’ condition occurs about 92% of time in contrast to Adelaide Airport, Kent Town and Kersbrook where the ‘cease-to-flow’ conditions have never occurred. In addition, the pre-developed FDC of Largs Bay is steep, which indicates that Largs Bay has low base flow or small groundwater storage whereas all other climatic zones, in particular Adelaide Airport and Kersbrook, show occurrences of significant base flows. The base flow of Kent Town appears to be highly variable with very low flow conditions (daily flow less than 0.5 mm) occurring 50% of the time. Characteristics of the pre-developed flow regimes exhibited by the FDC indicate non-homogeneity of the pre-developed flow regimes across the Greater Adelaide Region.

The following observations can be made from FDCs corresponding to different levels of urbanisation and different capture volumes of runoff from impervious areas (i.e. from Figure 4-3 to Figure 4-18):

- **Adelaide Airport**: The 10 mm capture depth can replicate the pre-developed FDC if the fraction impervious is up to 20% (see Figure 4-3) more effectively than the 5 mm capture depth. Therefore it appears that the proposed target for impervious areas up to 20% (i.e. 5 mm capture depth) cannot achieve the frequent flow objective for this climatic zone. The FDCs also indicate that when the fraction impervious is greater than 20%, the 10 mm capture depth cannot replicate flows less than 2 mm/day. The FDCs of the 40% and 60% impervious cases indicate that the 10 mm capture depth has resulted in a drastic reduction of low (or base) flows (i.e. less than 0.5 mm/day for 50% of time when the pre-developed flow is greater than 0.5 mm/day for 100% of time) (see Figure 4-4 and Figure 4-5). For an impervious ratio of 80%, the 10 mm capture depth seems to generate more base flows than the pre-development base flows. This is simply because there has been too much runoff generation from the impervious areas. Therefore, it can be said that the proposed interim targets have low potential to restore pre-development low flow regimes in this climate zone. Gradual release of the captured runoff from impervious areas may result in restoration of pre-development low flow regimes. However, this hypothesis needs further analysis.
- **Kent Town**: The target capture depths cannot replicate flows less than 2 mm/day. As mentioned earlier, Kent Town has highly variable base flow with a daily flow less than 0.5 mm occurring 50% of the time. The target capture depths cannot replicate this highly variable low or base flow.
- **Kersbrook**: The pre-development FDC of Kersbrook is similar to that of Adelaide Airport, but Kersbrook has higher mean annual rainfall than Adelaide Airport (mean rainfall of 2.1 mm/day in Kersbrook compared to 1.2 mm/day at Adelaide Airport). This has resulted in a higher base flow from Kersbrook than the base flow computed for Adelaide Airport. Like Adelaide Airport and Kent Town, the target capture depths cannot replicate base flows (i.e. flows less than 2 mm/day) in Kersbrook. It appears that the key problem associated with the target capture depths is the inability to replicate low flows.

- **Largs Bay**: The pre-development FDC of Largs Bay is very different to that of the other climate zones. As discussed above, the pre-development FDC of Largs Bay indicates that a 'cease-to-flow' condition occurs about 92% of time. In addition, flows less than 2 mm/day occur 99% of time. As seen in Figure 4-16 to Figure 4-18, target capture depth cannot restore the pre-development FDC for any urbanised scenarios. However, a 20 mm capture depth can restore the pre-development FDC if the impervious ratio is 20%. The possible reasons for this change from a 10 mm to a 20 mm capture depth have been discussed earlier in this section. However, as the impervious ratio increases in Largs Bay, the ability of the 20 mm capture depth to restore flows reduces (i.e. a 20 mm capture depth is unable to restore flows less than 0.5 mm/day with higher levels of imperviousness). Therefore, it can be said that even though the 20 mm capture depth can replicate the AVR of the pre-developed condition when the fraction impervious is greater than 20% (as per Table 4-9), the FDC analysis shows that the 20 mm depth can restore pre-development flow regimes only when the fraction impervious is 20%.

The overall observation from the FDC analysis is that capturing a defined volume of runoff from impervious areas as per the WSUD Guidelines developed for Queensland (Water by Design, 2007; Queensland Environmental Protection Agency, 2009) cannot restore the base flow present in pre-development flow regimes adequately. As per the WSUD Guidelines developed for South East Queensland (SEQHWP and Ecological Engineering, 2007), the capture volume has to be disposed of within a day. However, this has a significant effect on base flows. This effect will not be visible if only AVR and channel-forming flows are examined. However, analysis of the low flow characteristics can reveal that the concept of capturing runoff from impervious areas cannot restore the low or base flow component of the pre-development flow regimes adequately.

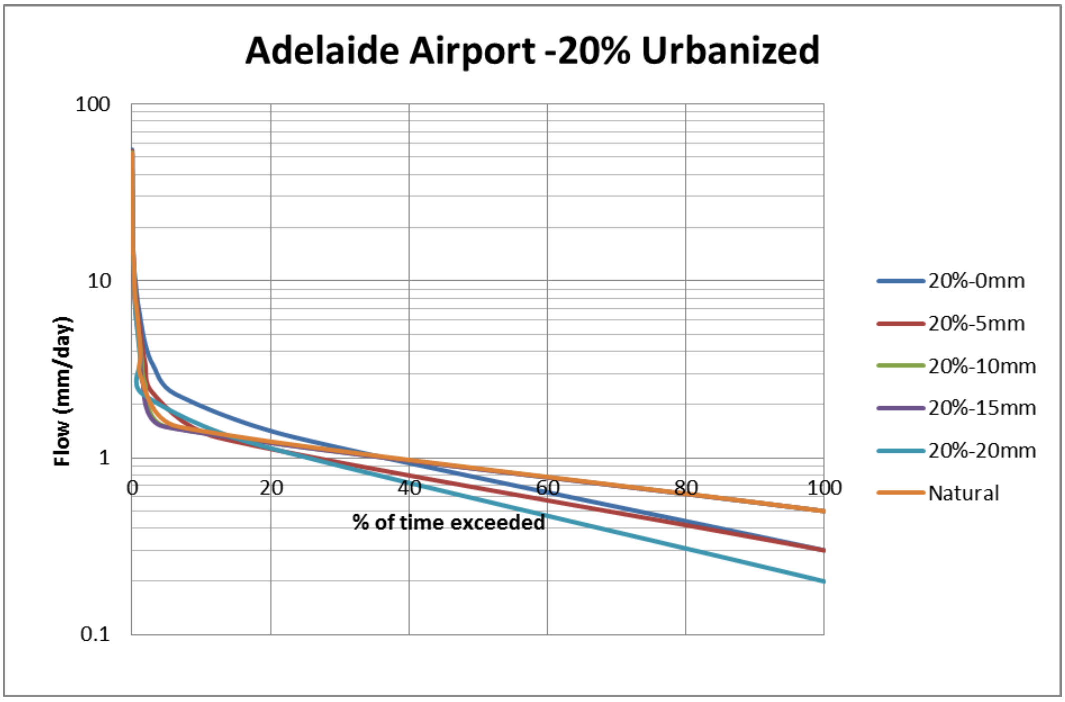


Figure 4-3 - Flow Duration Curve for Adelaide Airport – 20% impervious (note: 20%-10mm and 20%-15mm lie under Natural)

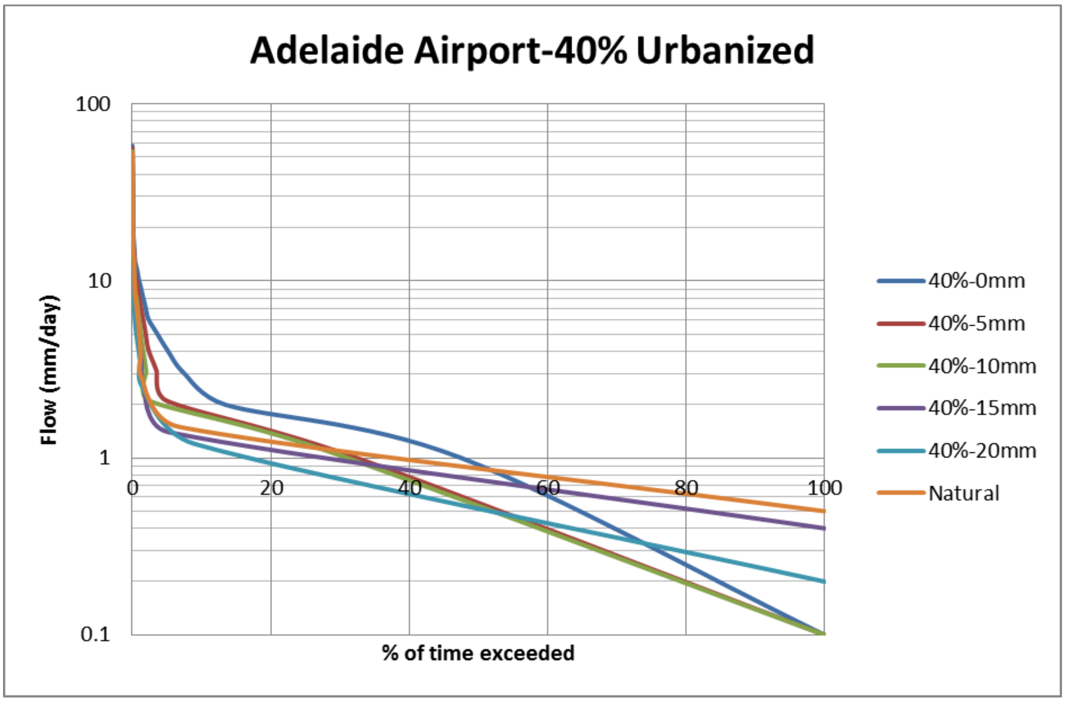


Figure 4-4 - Flow Duration Curve for Adelaide Airport – 40% impervious

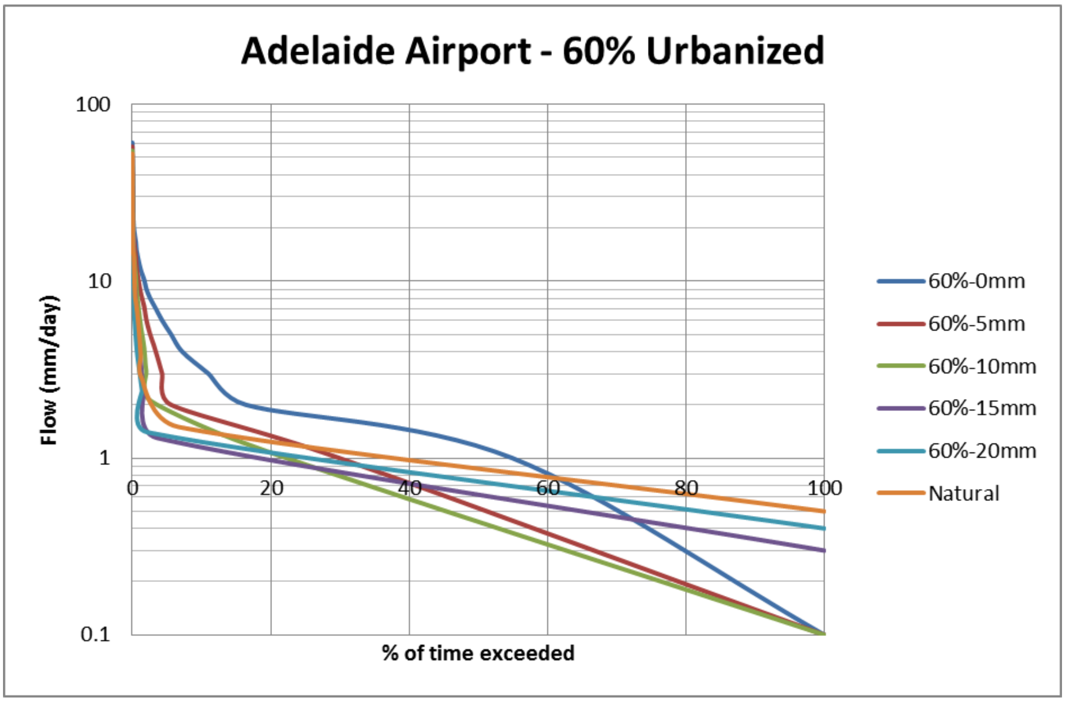


Figure 4-5 - Flow Duration Curve for Adelaide Airport – 60% impervious

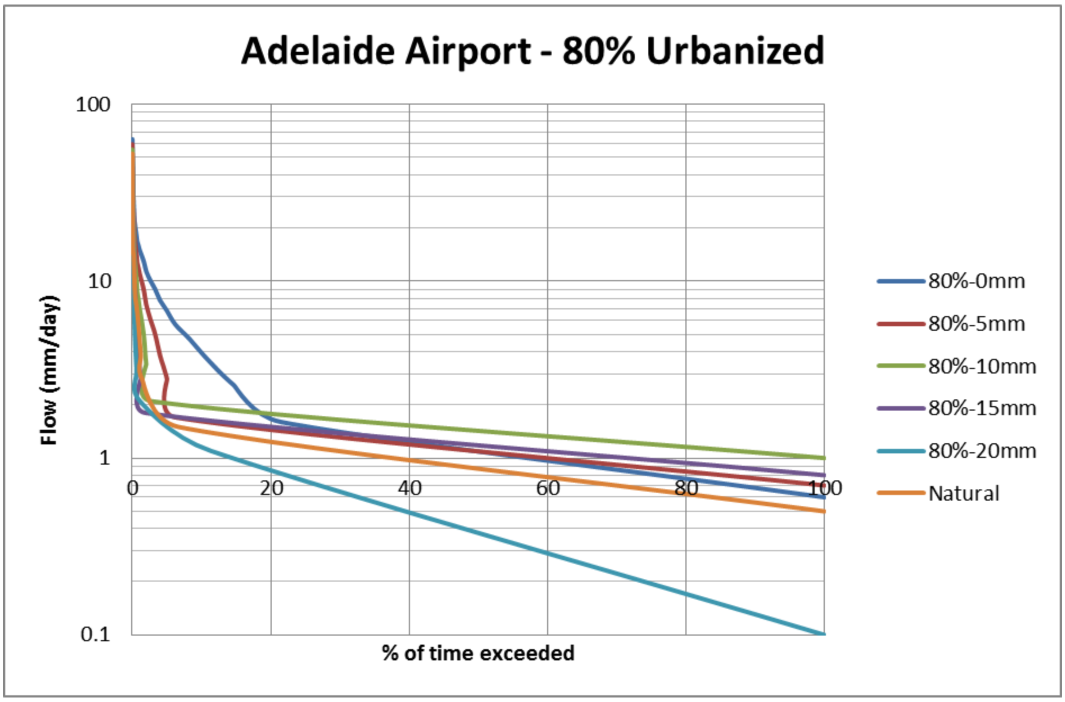


Figure 4-6 - Flow Duration Curve for Adelaide Airport – 80% impervious

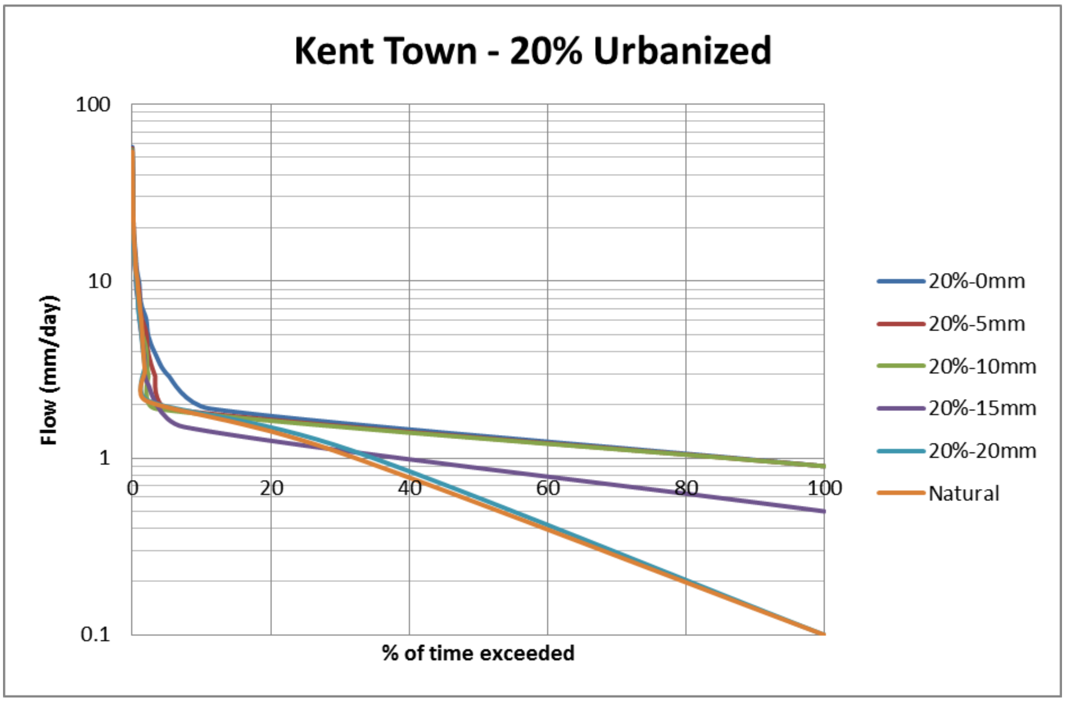


Figure 4-7 - Flow Duration Curve for Kent Town – 20% impervious

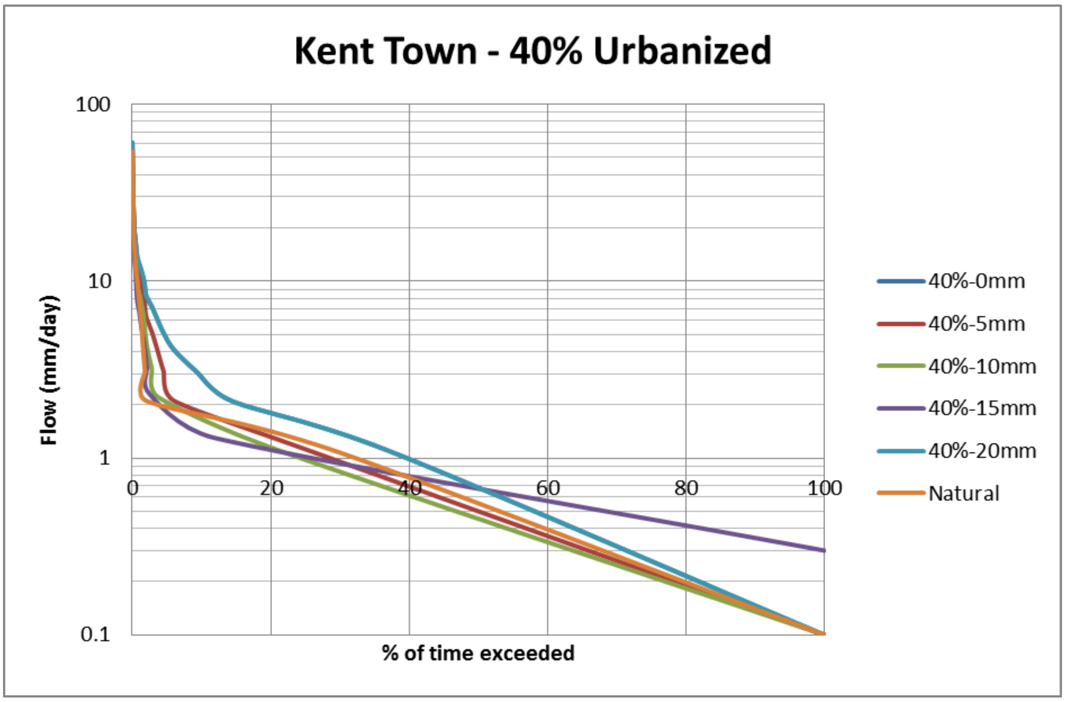


Figure 4-8 - Flow Duration Curve for Kent Town – 40% impervious

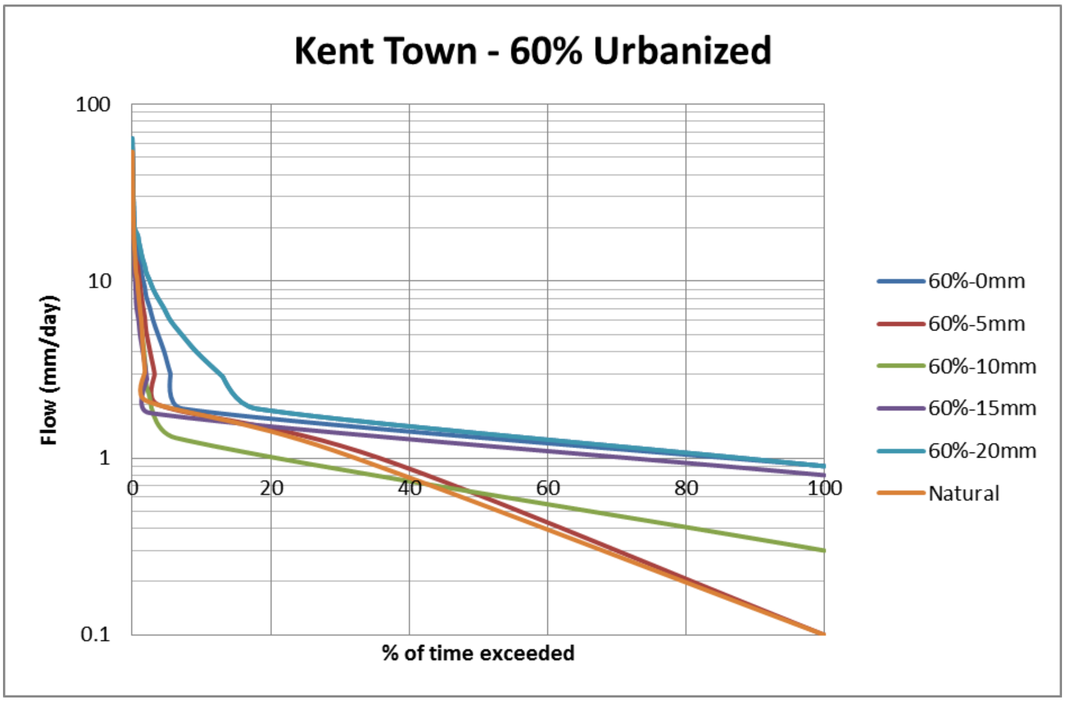


Figure 4-9 - Flow Duration Curve for Kent Town – 60% impervious

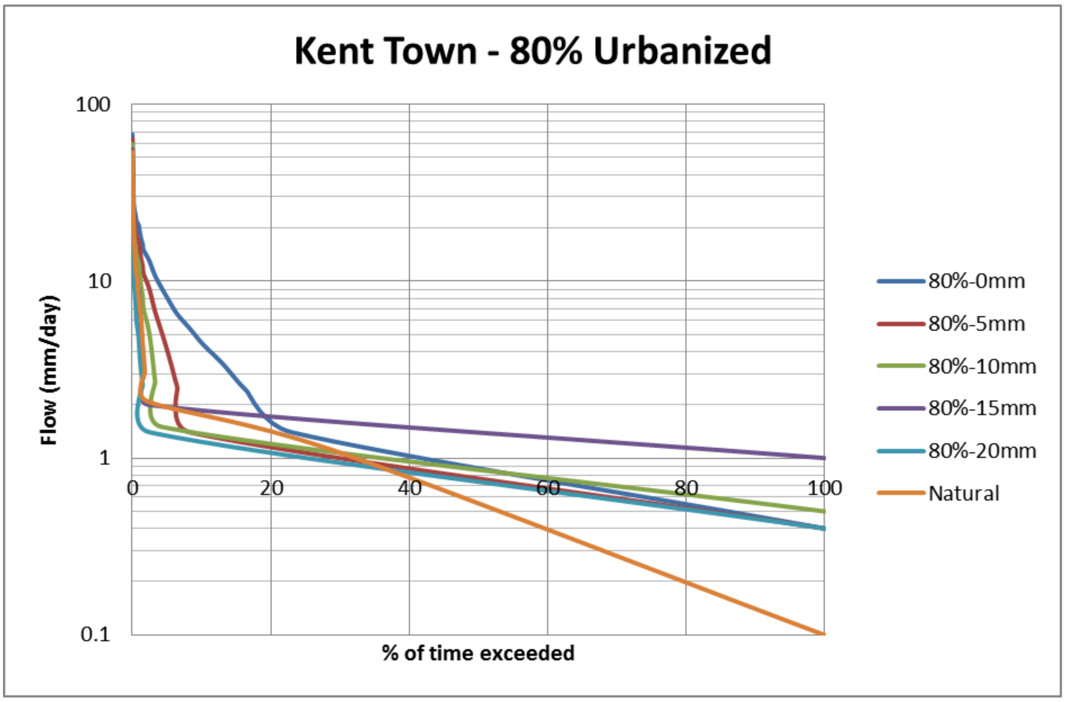


Figure 4-10 - Flow Duration Curve for Kent Town – 80% impervious

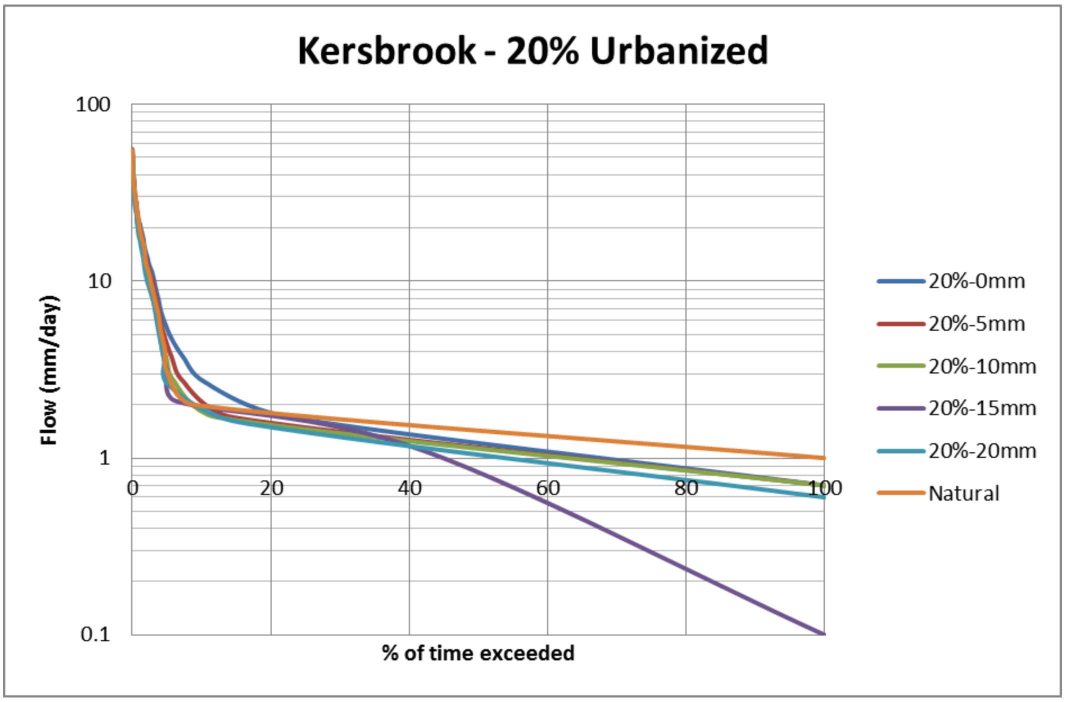


Figure 4-11 - Flow Duration Curve for Kersbrook – 20% impervious

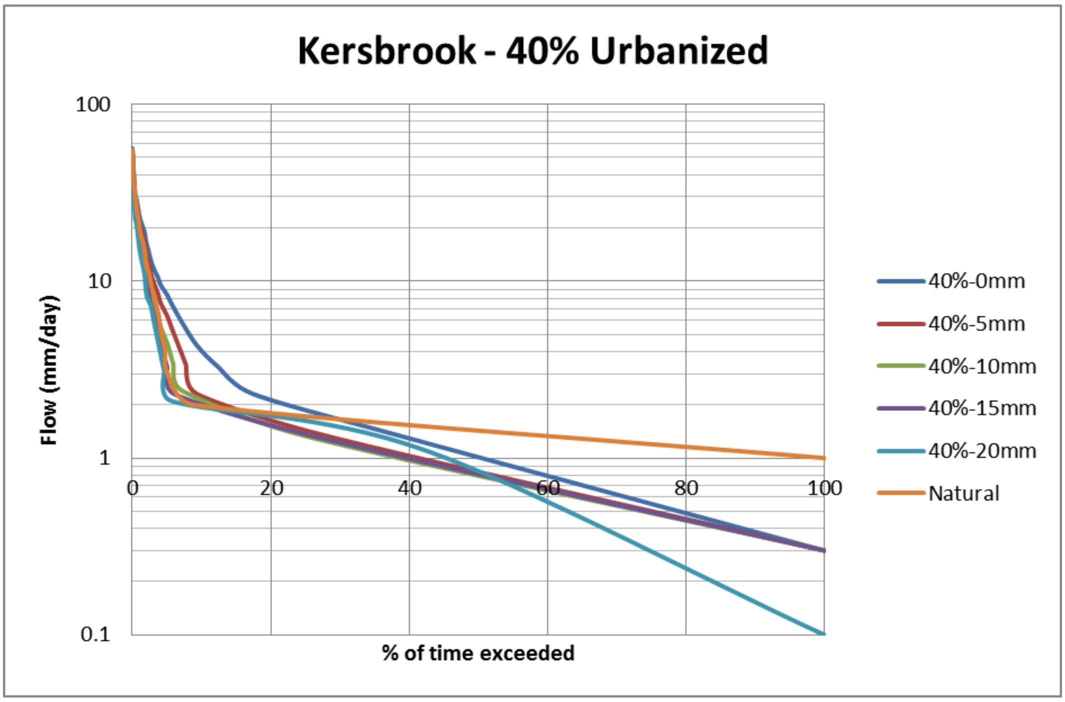


Figure 4-12 - Flow Duration Curve for Kersbrook – 40% impervious

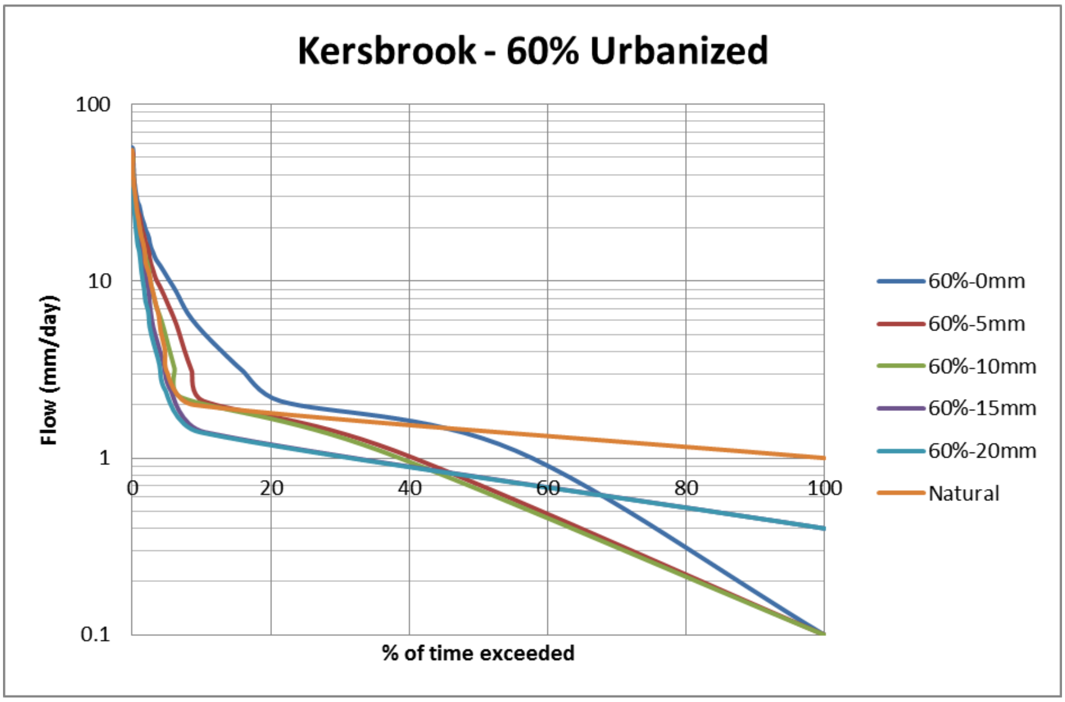


Figure 4-13 - Flow Duration Curve for Kersbrook – 60% impervious

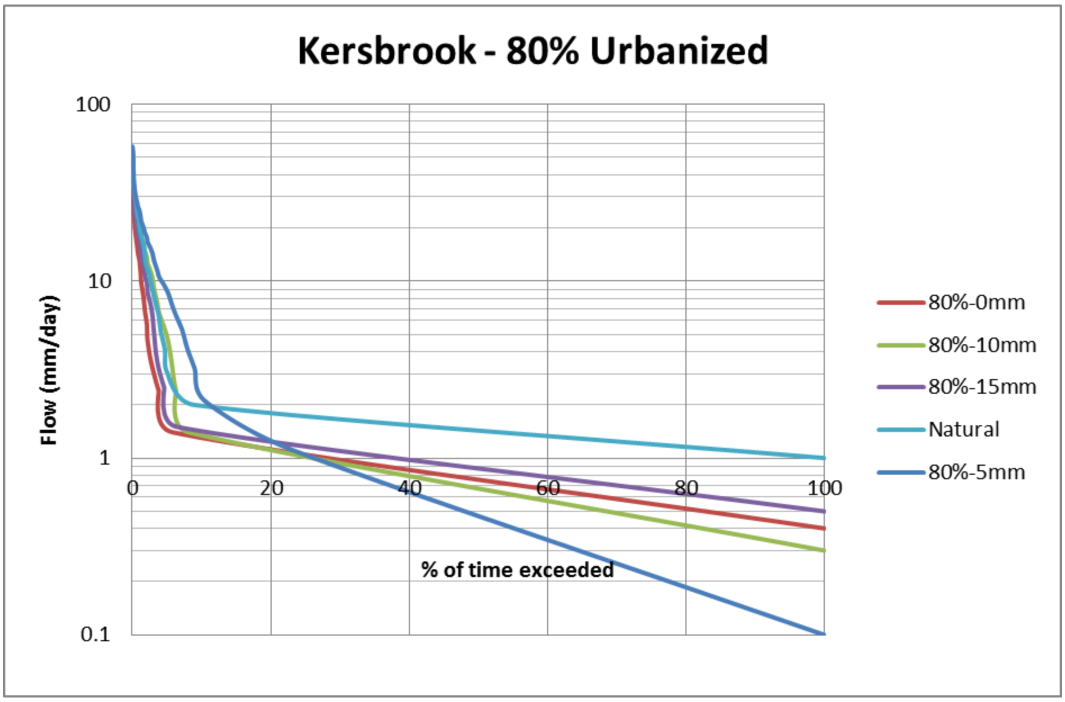


Figure 4-14 - Flow Duration Curve for Kersbrook – 80% impervious

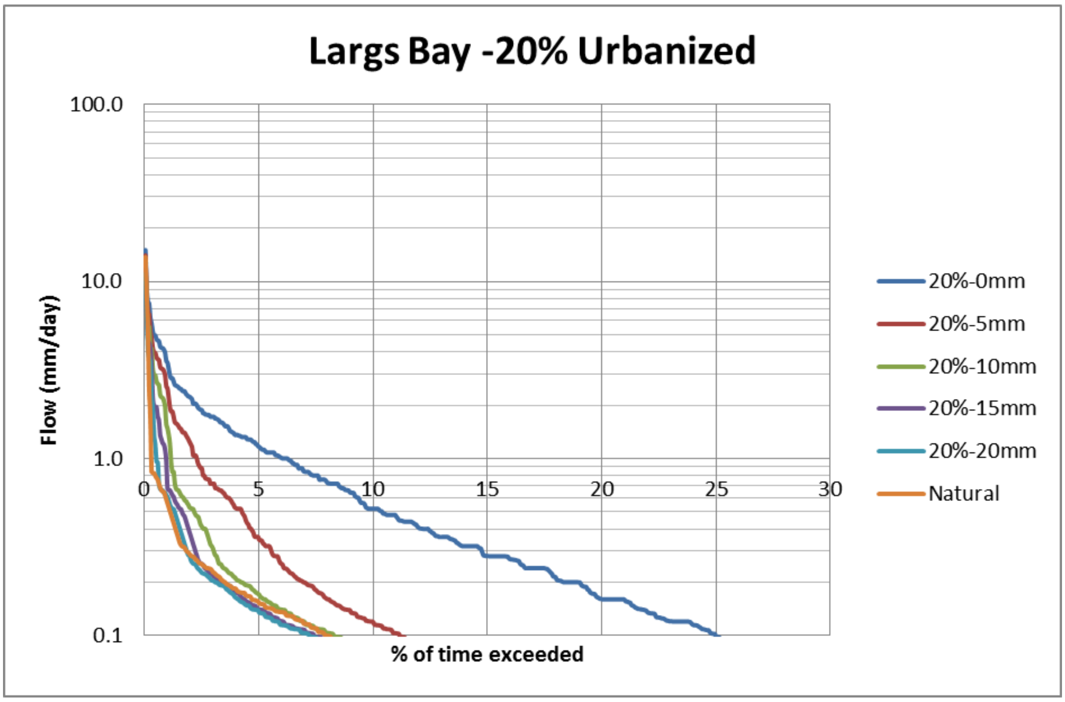


Figure 4-15 - Flow Duration Curve for Largs Bay – 20% impervious

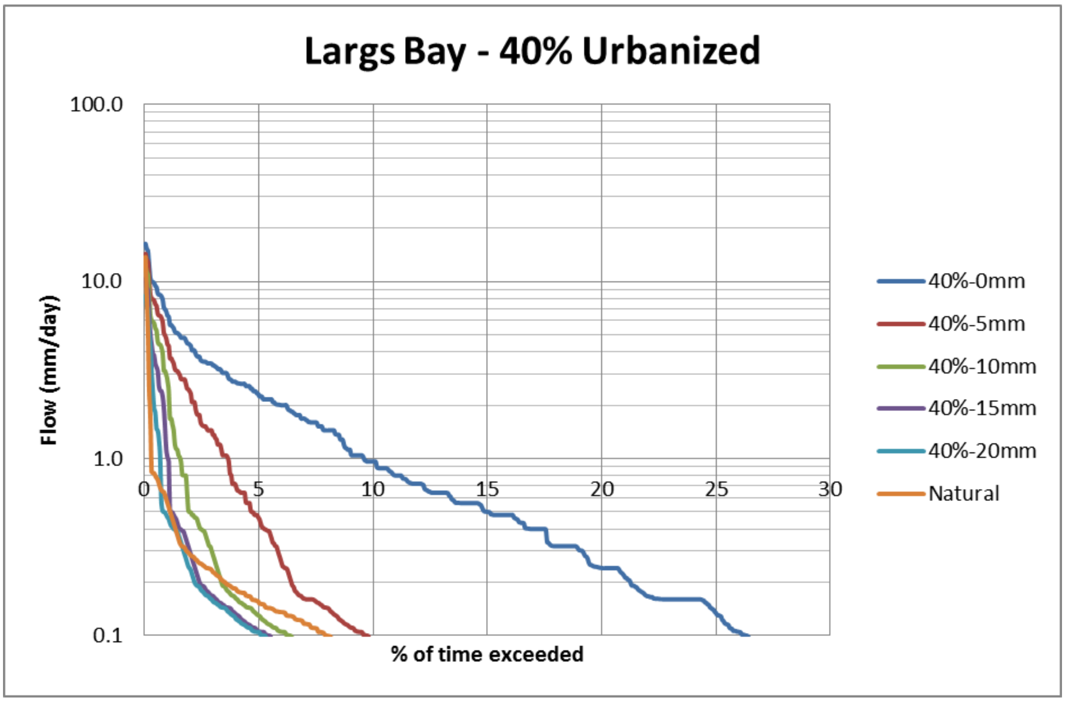


Figure 4-16 - Flow Duration Curve for Largs Bay – 40% impervious

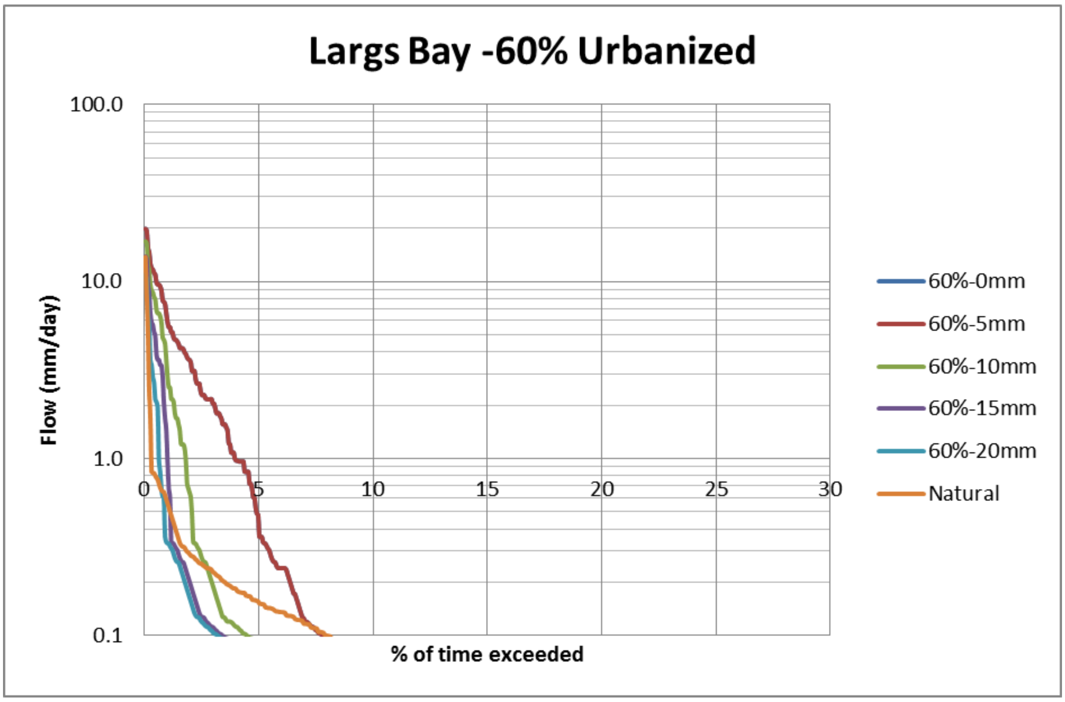


Figure 4-17 - Flow Duration Curve for Largs Bay – 60% impervious

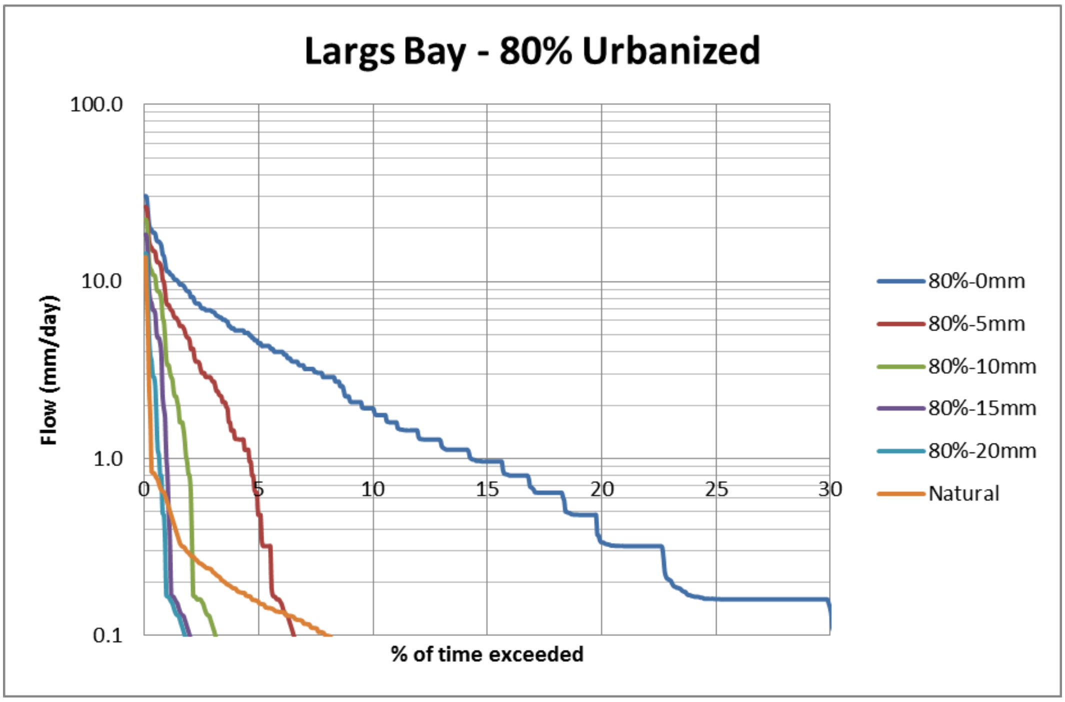


Figure 4-18 - Flow Duration Curve for Largs Bay – 80% impervious

## 4.5 Recommended Water Quantity Targets

The interim stormwater runoff quantity target aims:

- To minimise the change in frequency of disturbance to aquatic ecosystems by managing the volume and frequency of surface runoff resulting from small rainfall events (called "frequent flow management" objective)
- To minimise in-stream erosion to reduce nutrient and sediment transportation to coastal waters of the Greater Adelaide Region by limiting peak flows to channel-forming peak flow of the natural state (called "channel-forming flow management" or "waterway stability management" objective)

The recommended interim target for achieving both frequent flow management objective and the channel-forming (or waterway stability management) objective is to:

- Capture runoff equivalent to the volume generated from 5 mm of rainfall on connected impervious areas, for catchments with total impervious area up to 20%
- Capture runoff equivalent to the volume generated from 10 mm of rainfall on connected impervious areas , for catchments with total impervious area greater than 20%

The disposal of the captured runoff must be capable of drawing down the captured runoff within a day i.e. 24 hours. Capture of runoff can be achieved in a number of ways and consideration can be given to available storage in rainwater water tanks and surface depression storage.

It is recognised that there will be instances where quantity targets will not be necessary or applicable. Such instances could include when runoff from a development drains directly to either a stormwater harvesting schemes or large receiving water bodies (as opposed to either stream or a creek) via a lined or concrete drain. Such examples include the Grange Gulf Club stormwater harvesting scheme and natural outfalls along the Adelaide coast and the Port River. Where unlined drainage systems exist downstream of large water bodies such as wetlands and harvesting systems, meeting frequent flow management objectives should demonstrated. For practical reasons there may be cases where the quantity target may not apply, such as developments where topography is not favourable for gravity operated systems. It should be noted that stormwater quality and mains water conservation targets will still apply, together with local flood mitigation requirements as specified by the local council.

While it is possible to achieve water quantity targets at the allotment level, a considerable amount of work is required to demonstrate how on-ground measures can be implemented, together with consideration given to ownership, maintenance requirements and long term performance. Generally, at the cluster and development level suitable measures and management systems exist that can be adapted to meet the water quantity based targets. For this reason it is recommended that the quantity targets be applied to cluster and development scales.

Flow management could be achieved with large scale systems such as wetlands and ponds or more local systems such as bioretention systems and raingardens. Using these types of measures it would be possible to implement quantity management systems for developments with 10 or more dwellings. The scope of this study does not include an examination of the effectiveness of specific measures for managing target captured volumes, however the same methodology and principles used to derive the targets will apply.

If a flow management strategy is to be implemented at the allotment level, runoff may be captured at an allotment scale as per the recommended volumes specified above, but catchment scale hydrologic analysis must be performed to ensure flow characteristics at the discharge point comply with the recommendations given above. For example, for an allotment scale runoff capture system, consider a block of 500 $m^2$ with a 200 $m^2$ impervious area. For this block, the fraction of impervious area is 40% of the total area, and the interim targets require capture of up to 10 mm runoff from this impervious area. This is equivalent to a capture volume of 2 $m^3$ (10 mm X 200 $m^2$). Hence for an effective daily rainfall of 8 mm falling on this block of land, the amount of runoff that should be captured is 1.6 $m^3$. If the effective rainfall is 12 mm, the amount of runoff that should be captured will be 2 $m^3$. The captured runoff must be disposed/used within a day to allow capture of up to 10 mm of runoff that might occur on the following day.

## 4.6 Comment on Implementation of Runoff Quantity Management Targets

The proposed interim target is recommended based on an analysis carried out on a hypothetical catchment using climatic data specific to the Greater Adelaide Region and default characteristics for Adelaide in the MUSIC model (Version 4.10) for soil store capacity and field capacity. Hence it is recommended that the same model and parameters be used by the users of the interim target when demonstrating achievability of the interim targets.

Of the four climatic zones analysed, the annual volumetric runoff (AVR) and 1.5 year ARI flow analyses of the three climatic zones have indicated that capturing 5 mm runoff from impervious areas can restore the pre-development AVR and channel-forming flow if the total impervious area is less than or equal to 20%. In circumstances where the total impervious area is greater than 20%, a capture depth of 10 mm is required to restore the pre-development AVR and channel-forming flow rate. However, it should be noted that the flow duration curve analysis undertaken as part of the present study has indicated that these capture depths cannot restore low flow characteristics present in pre-development flow regimes to an adequate level. Therefore, the proposed interim target should be applied cautiously for catchments with large connecting groundwater systems, i.e. catchments with significant base flows. Gradual release of the captured runoff from impervious areas to pervious areas may result in restoration of base flows. This may be achieved with controlled infiltration. Further research is needed examine the effect of capturing runoff from impervious areas on low or base flows.

Of the four climatic zones analysed, Largs Bay had the lowest and most variable rainfall, which has resulted in low and highly variable runoff with cease-to-flow condition occurring 92% of the time over the simulation period. The runoff characteristics of other climatic zones do not exhibit cease-to-flow condition at all. Significant differences in runoff characteristics in Port Adelaide has resulted in a significant variance in the interim stormwater quantity targets in Port Adelaide, i.e. a daily capture depth of 20 mm irrespective of the total impervious area. However, considering the fact that it is not practical to implement different interim targets across the Greater Adelaide Region, it is recommended that the above-mentioned stormwater runoff quantity interim targets be adopted across the Greater Adelaide Region until further work is undertaken to provide enhancements to the proposed interim targets.

Further analysis is required to understand the applicability of the MUSIC model default parameters used to represent areas of the Greater Adelaide Region. To achieve this, the analysis undertaken in this study should be repeated using real and representative catchments in the Greater Adelaide Region. Such catchments should be replicated in the MUSIC model (or another equivalent tool) with the aid of observed data for calibration and validation of the results. The results of such an analysis can produce a robust set of outputs relevant to the Greater Adelaide Region.

Further work should also be undertaken to resolve issues surrounding the effects of runoff capture from impervious areas on base flow characteristics. The issue of replicating pre-development base flows would require exploration of alternative management measures to those adopted in the current study (i.e. capture and disposal of runoff from impervious areas within 24 hours). Alternative management measures would need to consider the capture of runoff from impervious areas and slow release of the captured runoff to parent soil in order to generate base flows.

It is important to understand that at this stage, the analysis has been carried out using increments of 20% for the total fraction impervious. Hence the capture depths that can replicate pre-development flow regimes when the total impervious area is less than 20% are not known. Thus, it is recommended that further analysis be carried out to understand the effect of capture depths for a number of scenarios with total impervious areas less than 20% (e.g. 5%, 10% and 15%).

With consideration given to the analysis in this section, it is strongly recommended that further analysis be undertaken to improve and test the validity and achievability of stormwater quantity interim targets using a catchment with relevant stream characteristics and measured flow data. Further analysis should focus on

- repeating the analytical procedure adopted in this report to a wide range of catchments in the Greater Adelaide Region with observed rainfall and runoff data
- examining ways of restoring low flow regimes to pre-development state; undertaking research to characterise healthy in-stream ecosystem of waterways in the Greater Adelaide Region
- understanding linkages between stream hydrology and ecology of waterways in the Greater Adelaide Region
- understanding the relationship between flow duration and stream forming flow hydrology
- the sensitivity of targets to soil characteristics and
- examining the effectiveness of alternative urban water management options and WSUD measures to protect in-stream ecology of urban waterways and reduce in-stream erosion to reduce sediment and nutrient transport to the coastal waters of the Greater Adelaide Region from a triple bottom line point of view.

It is strongly recommended that a whole-of-urban water physical systems analysis be undertaken by considering hydrologic connectivity of catchments across the Greater Adelaide Region to set appropriate runoff quantity and quality targets for each major catchment with the aim of achieving sustainable outcomes for the whole region.

## 4.7 References

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# Appendices

| | |
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| Appendix A | Comment from the South Australian EPA on development of interim WSUD targets for Greater Adelaide with respect to Water Quality policy |
| Appendix B | Rainwater tank harvesting curves |
| Appendix C | Summary table of proposed and existing water quality targets |
| Appendix D | Recommended runoff quality targets using MUSIC Version 5.01 |

# Appendix A – Comment from SA EPA

<u>Current Legislation and Definitions</u>

The EPA is responsible for administering the Environment Protection Act 1993 (EP Act). The Environment Protection (Water Quality) Policy 2003 (WQEPP) is subordinate legislation to the EPA Act.

The application of the policy is outlined in Clause 4 of the policy. In essence the WQEPP applies to all surface waters and underground waters including the water within a “public stormwater disposal system”. Therefore, for the purposes of the WQEPP the discharge or depositing of waste or a pollutant into the “public stormwater disposal system” is an offence. However the ultimate discharge of stormwater from the “public stormwater disposal system” into any waters by a government or public authority is exempt (i.e. the ultimate discharge into coastal waters for example).

In terms of stormwater, pollution sources fall into 2 broad categories:

Point Source Pollution

Point Source Pollution relates to a discharge that comes from a readily defined or identifiable source or site. Many of these discharges are managed through EPA licences. The water quality criteria specified in schedule 2 apply to these point sources, particularly for licensed sites. Other point source pollutants, particularly those that generally contaminate stormwater are managed through the clause 17 and 19 and Schedule 4 of the WQEPP. These clauses are obligations not to discharge or deposit the listed pollutants of Schedule 4 into waters or land where it is likely to enter waters (See Appendix 1 and 2 respectively)

Diffuse or non point source pollution

Diffuse pollution is considered to occur when it is sourced over a wide area where the single source points are not easily definable. Pollutants may include (but are not limited to) litter, dust oil and grease from roads, leaf litter, herbicides and pesticides, animal faeces. It is this diffuse pollution that most commonly contaminates stormwater and ultimately receiving waters.

<u>WSUD targets and the WQEPP</u>

It is the EPA view that WSUD targets are required to drive behaviour change which requires capacity building and compliance to be successful. The water quality targets have been developed with reference to diffuse source pollution from a catchment or precinct.

Stormwater flows over a range of land uses (e.g. industrial, agricultural, commercial) picks up a range of diffuse pollutants before passing onto roads, into stormwater systems and ultimately into streams and the ocean. New urban development invariably releases large quantities of sediment into stormwater systems unless soil erosion and drainage management is applied. Additionally, urbanisation reduces infiltration and greatly increases runoff volumes, leading to scour and creek bed erosion which further contribute to stormwater pollution. WSUD has the potential to both treat stormwater and reduce flows through capture and reuse. The importance of reducing flows is critical to achieving improved water quality in urban waterways and receiving waters. Flows and water quality are inextricably linked and WSUD targets should capture this.

If a single point source (e.g. industrial or commercial facility) within a catchment or precinct can be identified then Schedule 2 and Clause 13 of the WQEPP can be applied to the stormwater leaving that site. However, upon leaving the site stormwater may drain onto a public road and pick up a range of pollutants from diffuse sources that need to be treated. WSUD targets are to capture diffuse pollution.

In summary, proposed baseline WSUD targets are considered compatible with the *Environment Protection (Water Quality) Policy 2003* because they will apply to diffuse pollution sources on a catchment or precinct basis while the WQEPP and the water quality criteria within this apply to point source pollution.

Revised WQEPP and ANZECC guidelines

The *Environment Protection (Water Quality) Policy 2003* is currently under review and is likely to be replaced with a 2011 version. The revised policy is not available as yet, however, it is likely that the numbers outlined in Schedule 2 of the current policy will be removed and replaced with a duty to take all reasonable and practicable measures to comply with ANZECC Guidelines for Fresh and Marine Water Quality. Complying with WSUD targets would demonstrate taking reasonable and practicable measures to not pollute and thus WSUD targets are unlikely to be in conflict with any revised WQEPP

# Appendix B – Rainwater Tank Harvesting Curves

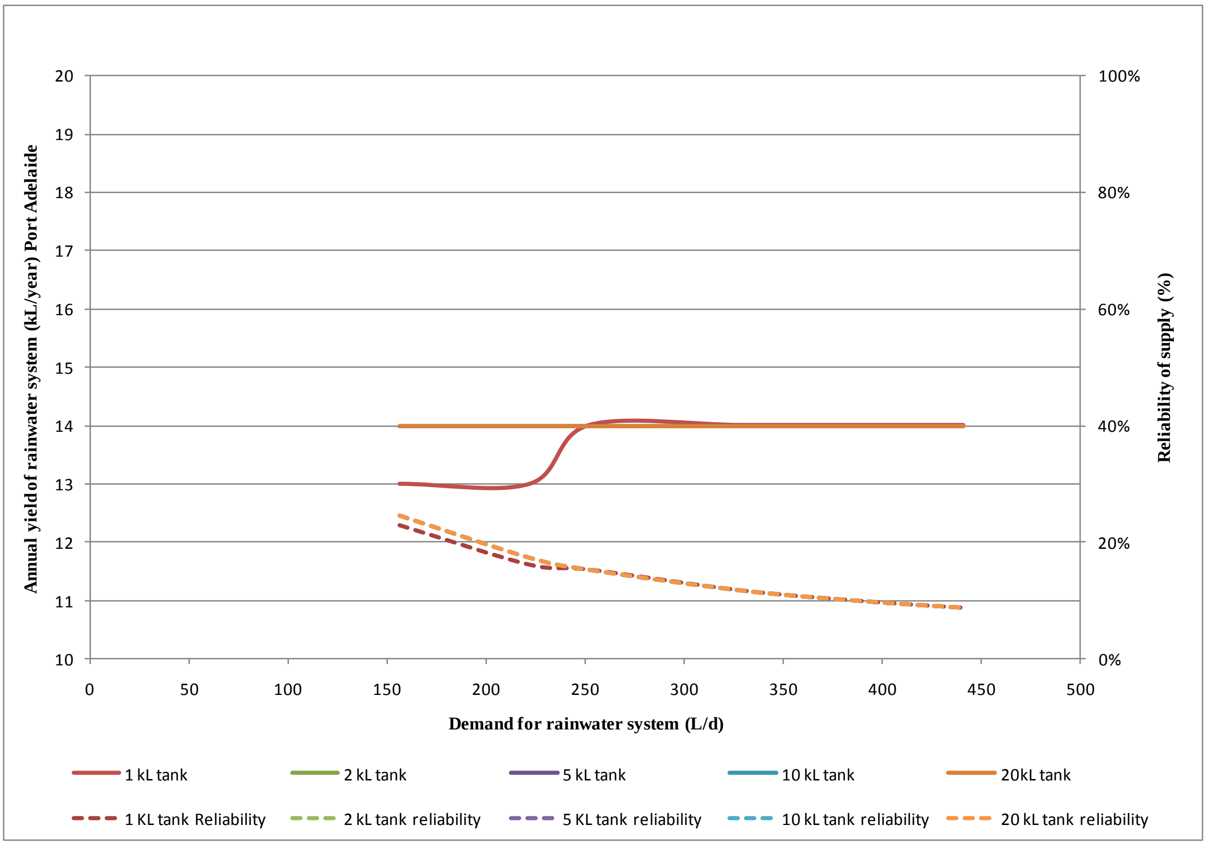


Figure B 1 - Rainwater system yield - 50 m2 roof area for low rainfall zone (Port Adelaide)

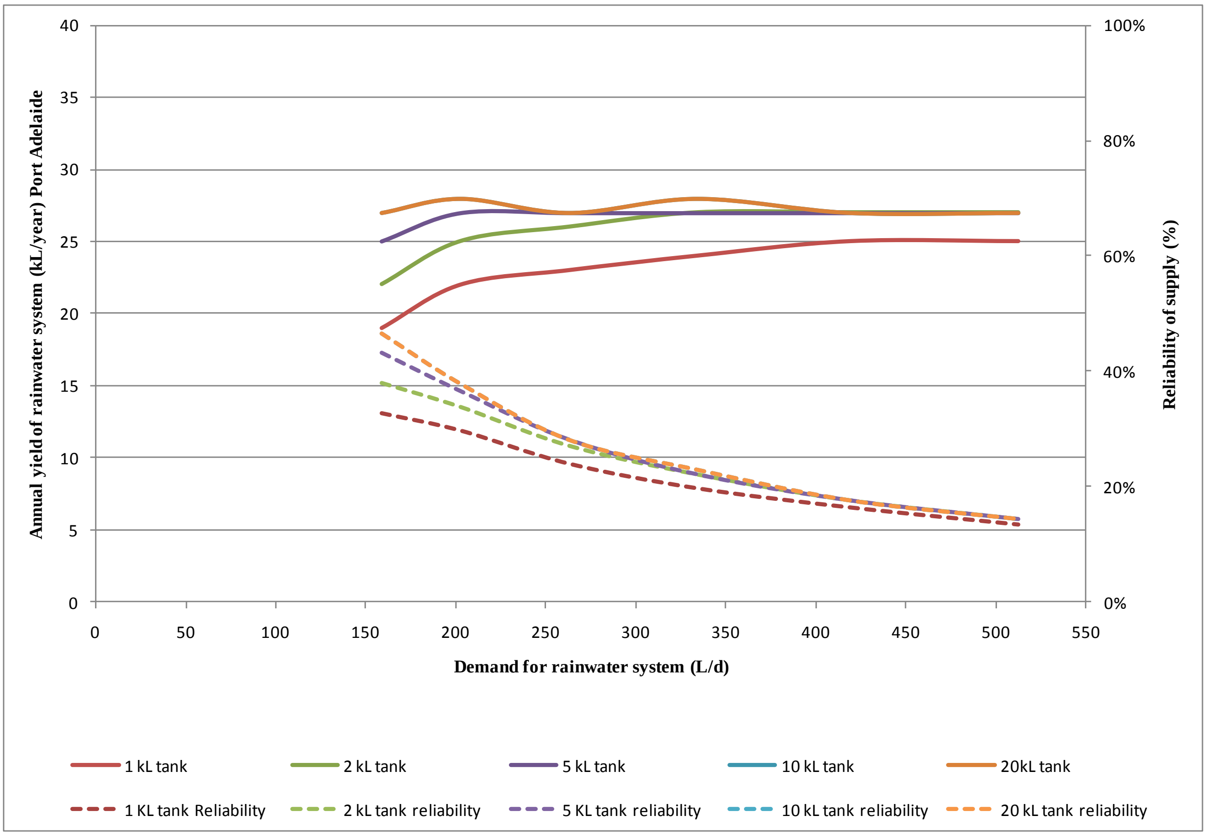


Figure B 2 - Rainwater system yield - 100 m$^2$ roof area for low rainfall zone (Port Adelaide)

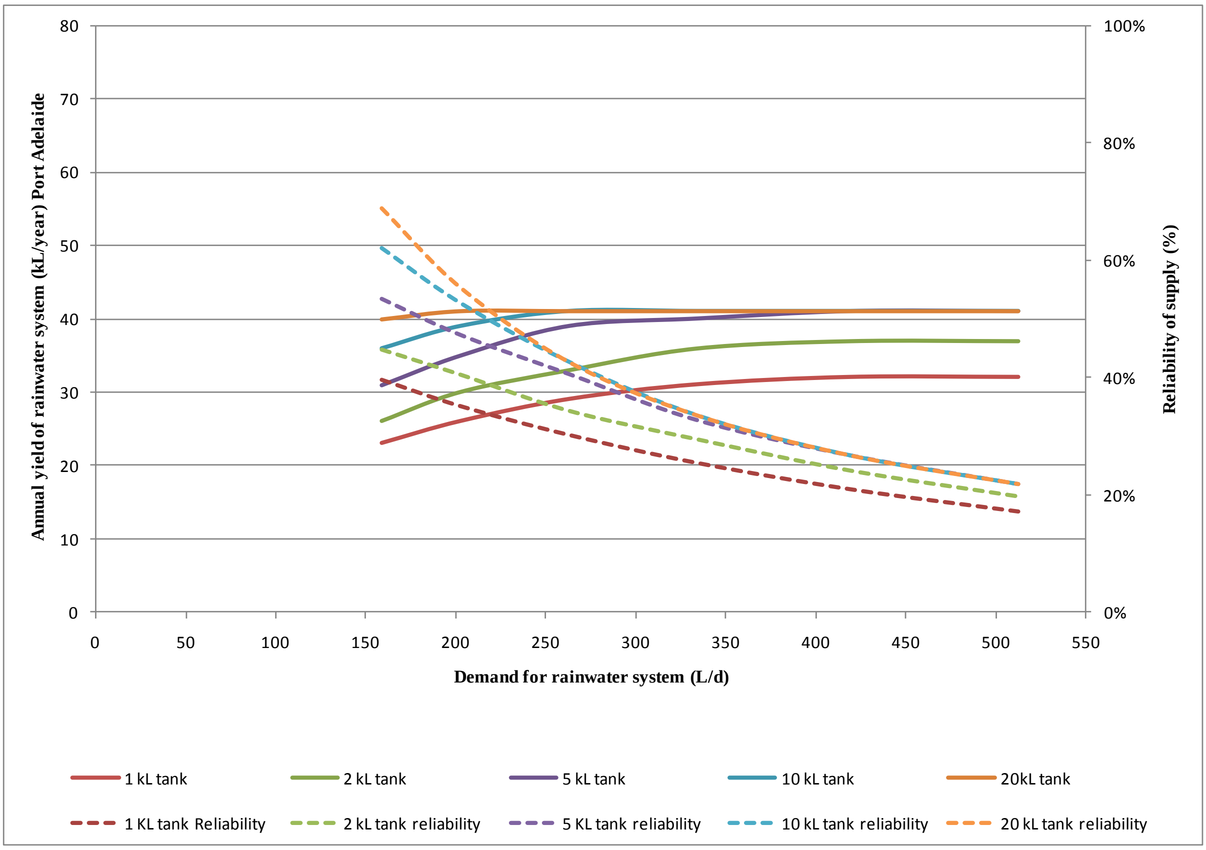


Figure B 3 - Rainwater system yield - 150 m$^2$ roof area for low rainfall zone (Port Adelaide)

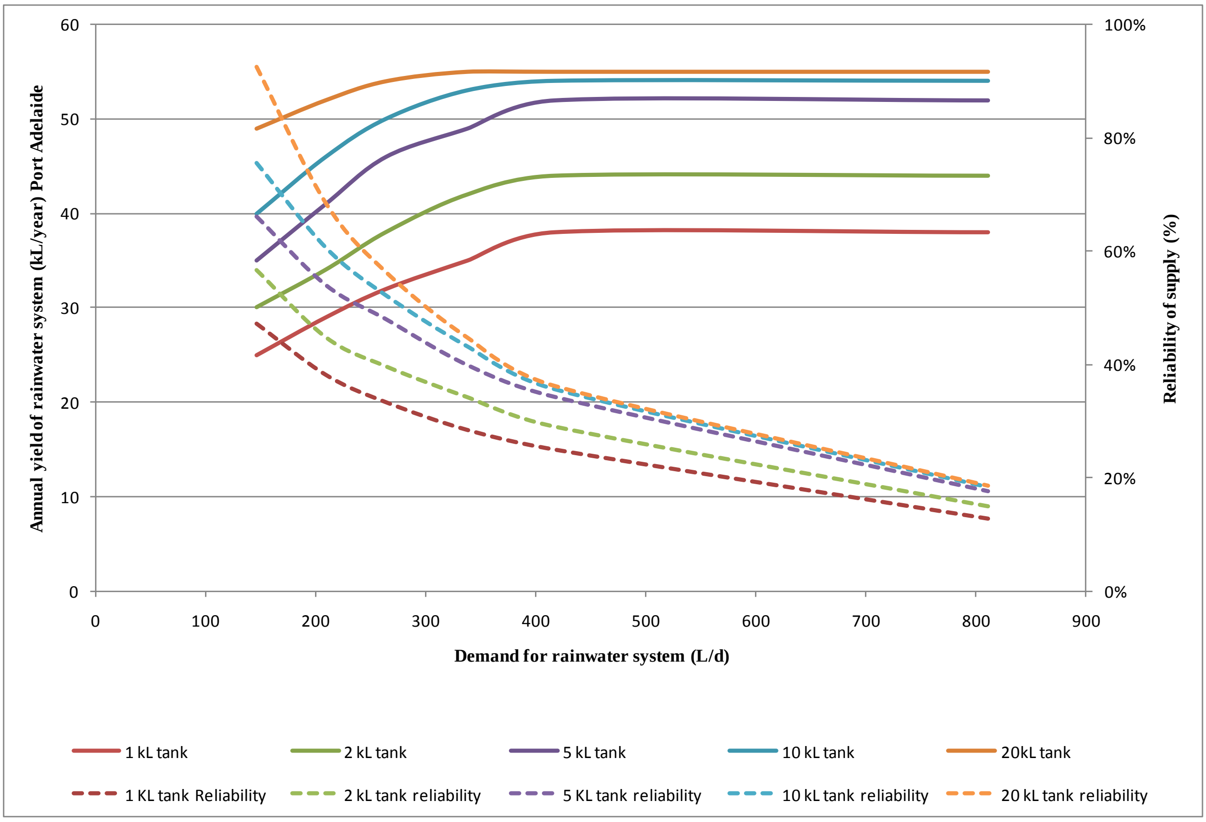


Figure B 4 - Rainwater system yield - 200 $m^2$ roof area for low rainfall zone (Port Adelaide)

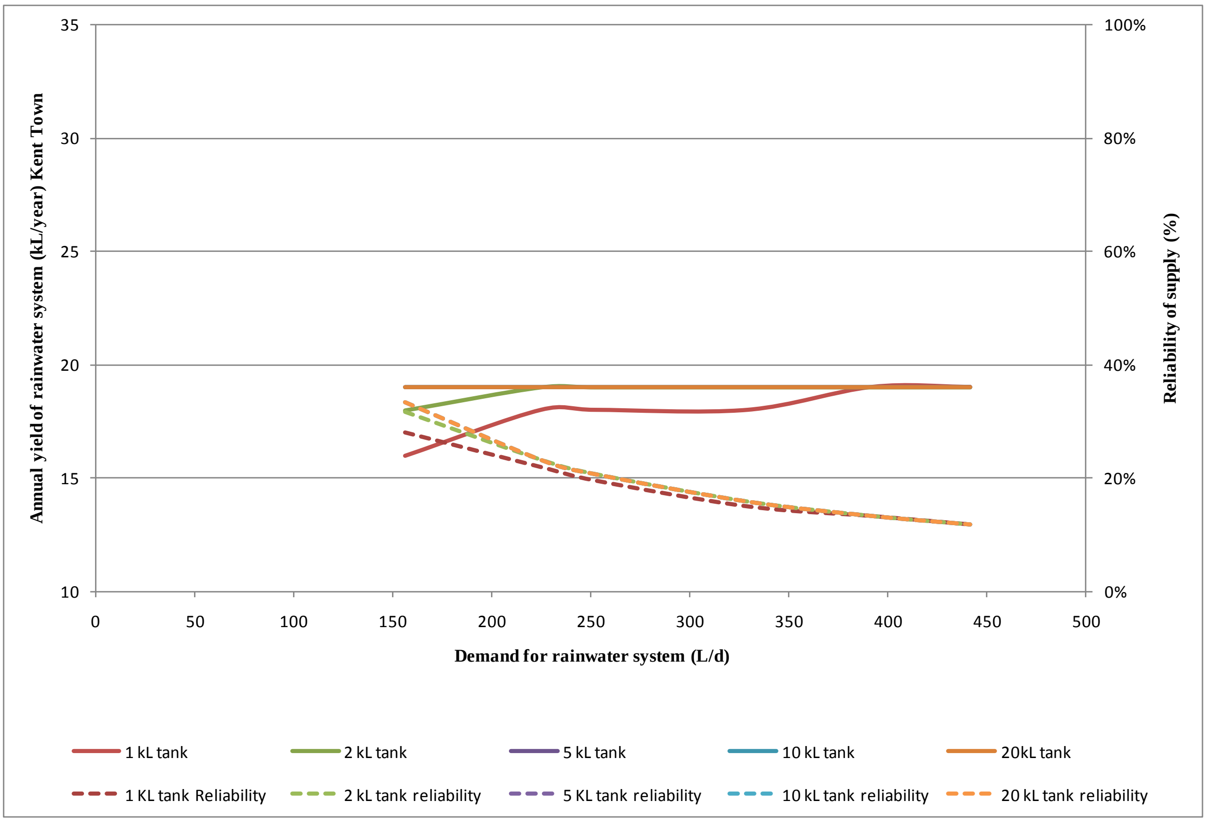


Figure B 5 - Rainwater system yield - 50 $m^2$ roof area for moderate rainfall zone (Kent Town)

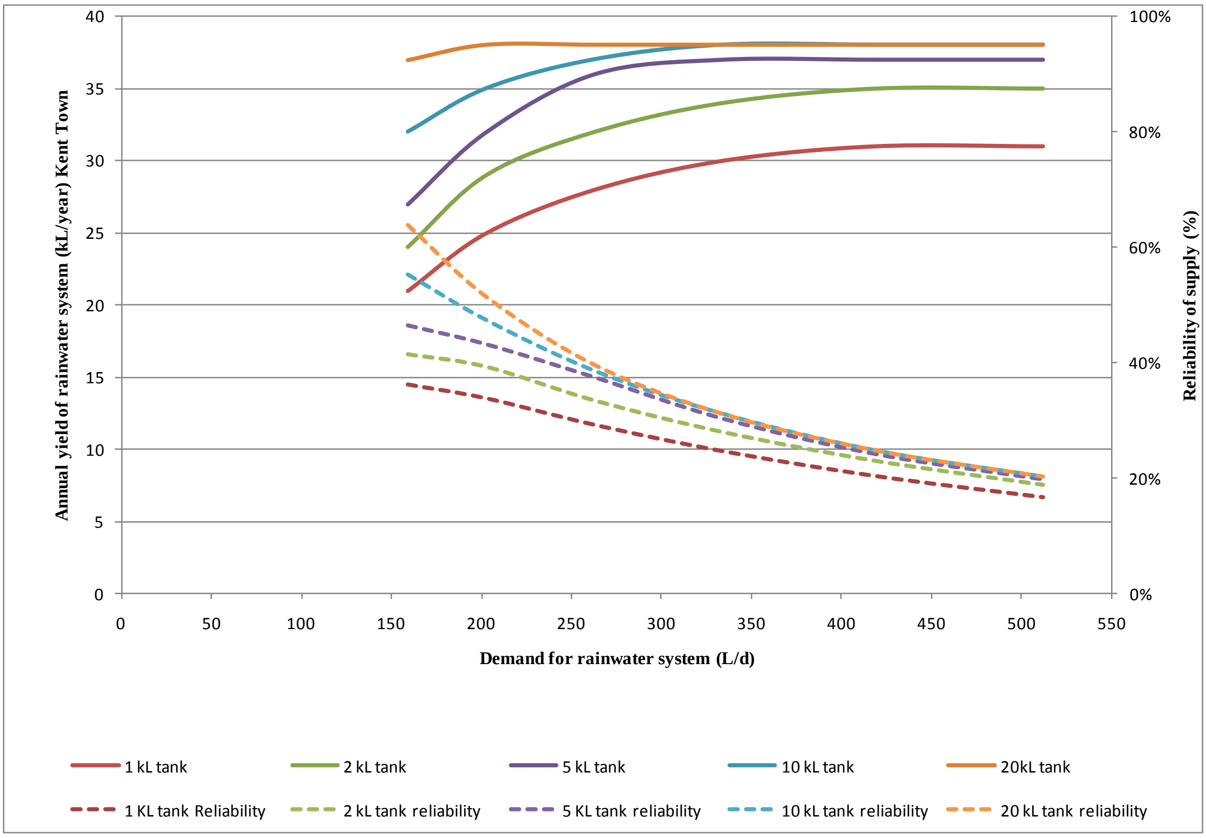


Figure B 6 - Rainwater system yield - 100 $m^2$ roof area for moderate rainfall zone (Kent Town)

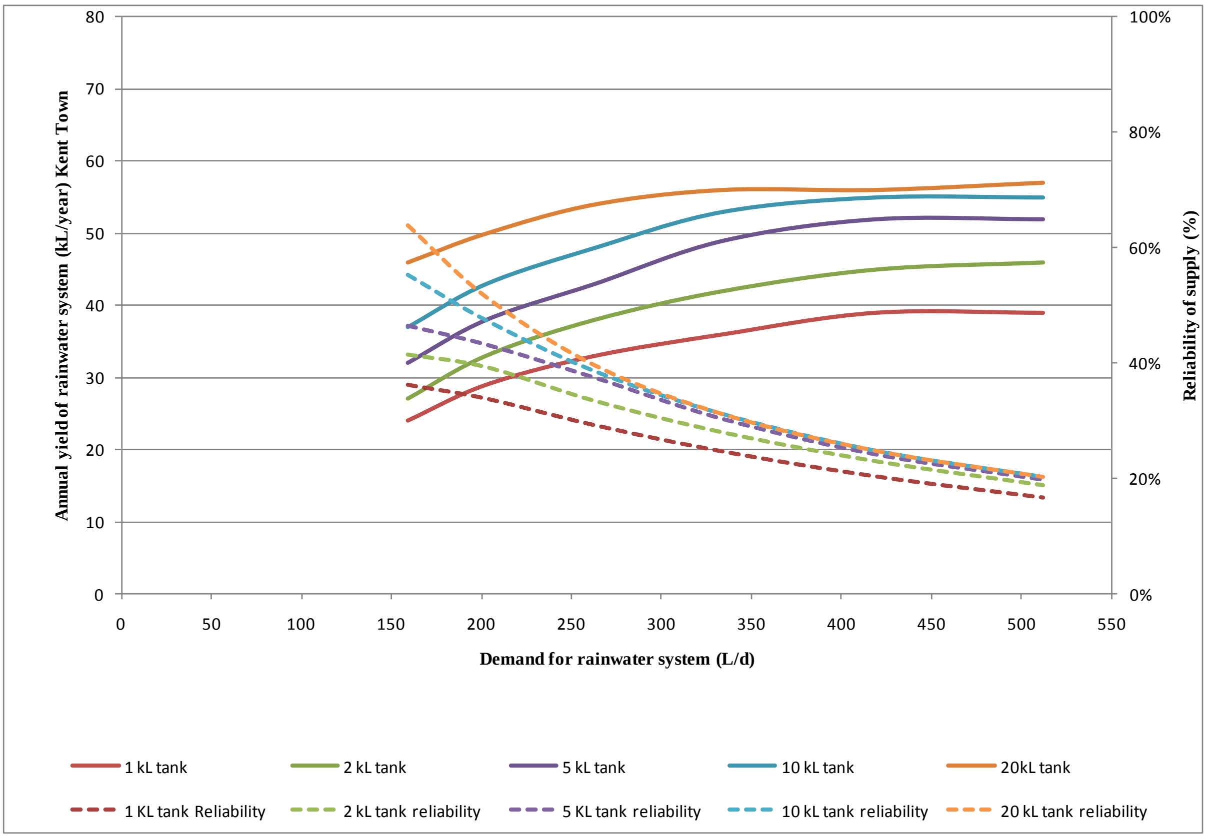


Figure B 7 - Rainwater system yield - 150 $m^2$ roof area for moderate rainfall zone (Kent Town)

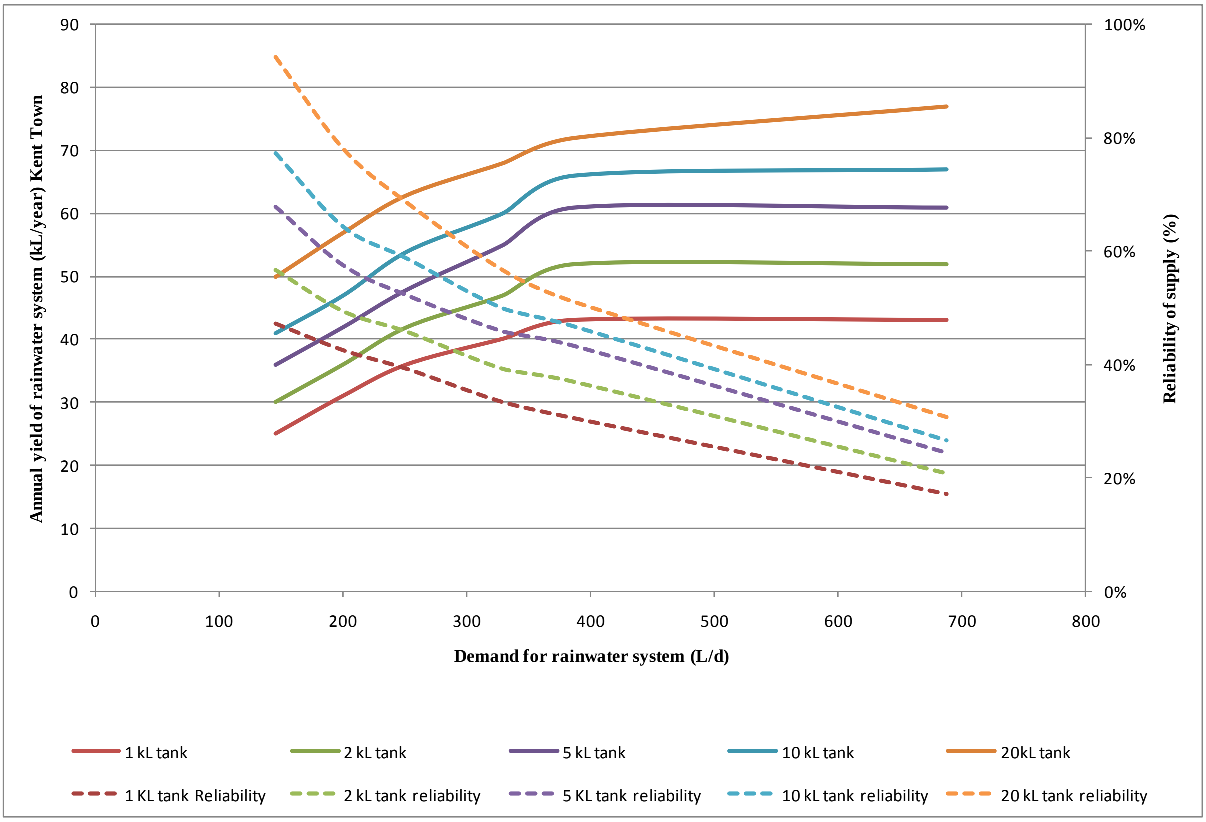


Figure B 8 - Rainwater system yield - 200 m2 roof area for moderate rainfall zone (Kent Town)

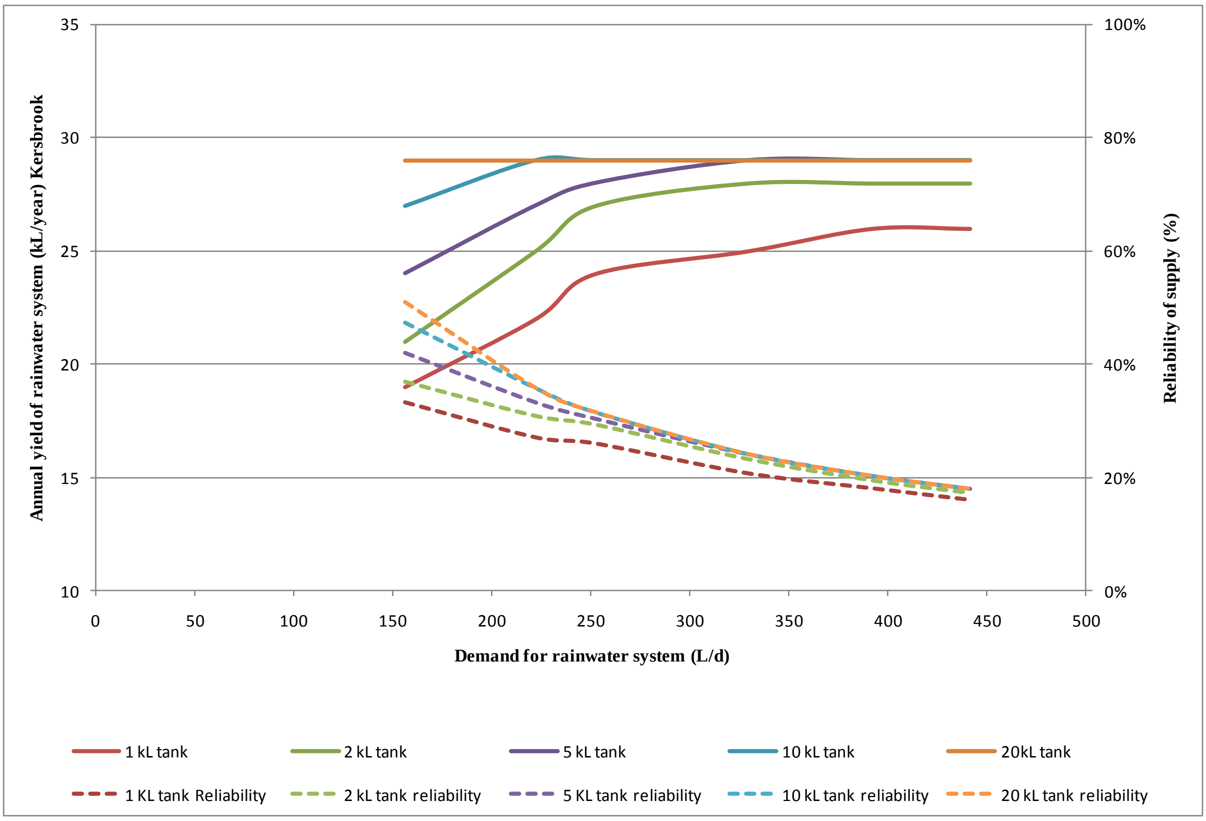


Figure B 9 - Rainwater system yield - 50 $m^2$ roof area for high rainfall zone (Kersbrook)

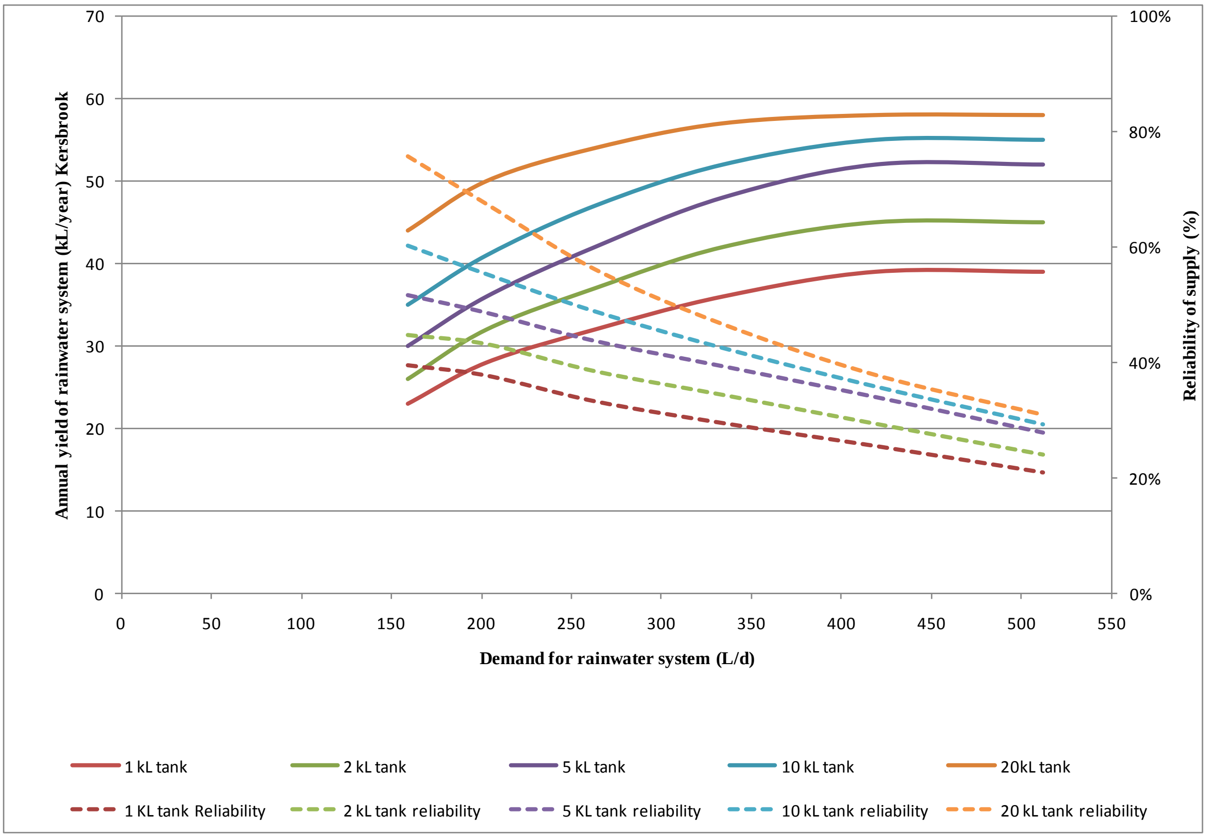


Figure B 10 - Rainwater system yield - 100 m$^2$ roof area for high rainfall zone (Kersbrook)

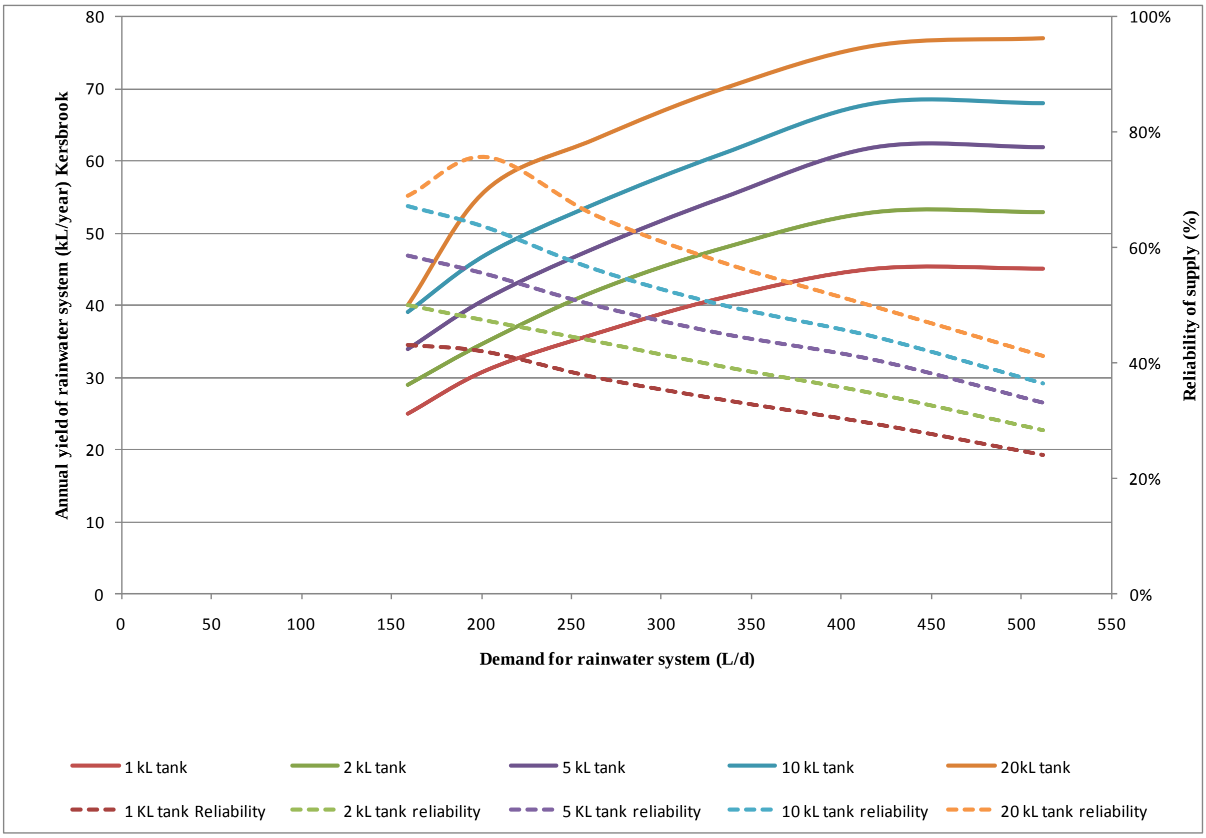


Figure B 11- Rainwater system yield - 150 m$^2$ roof area for high rainfall zone (Kersbrook)

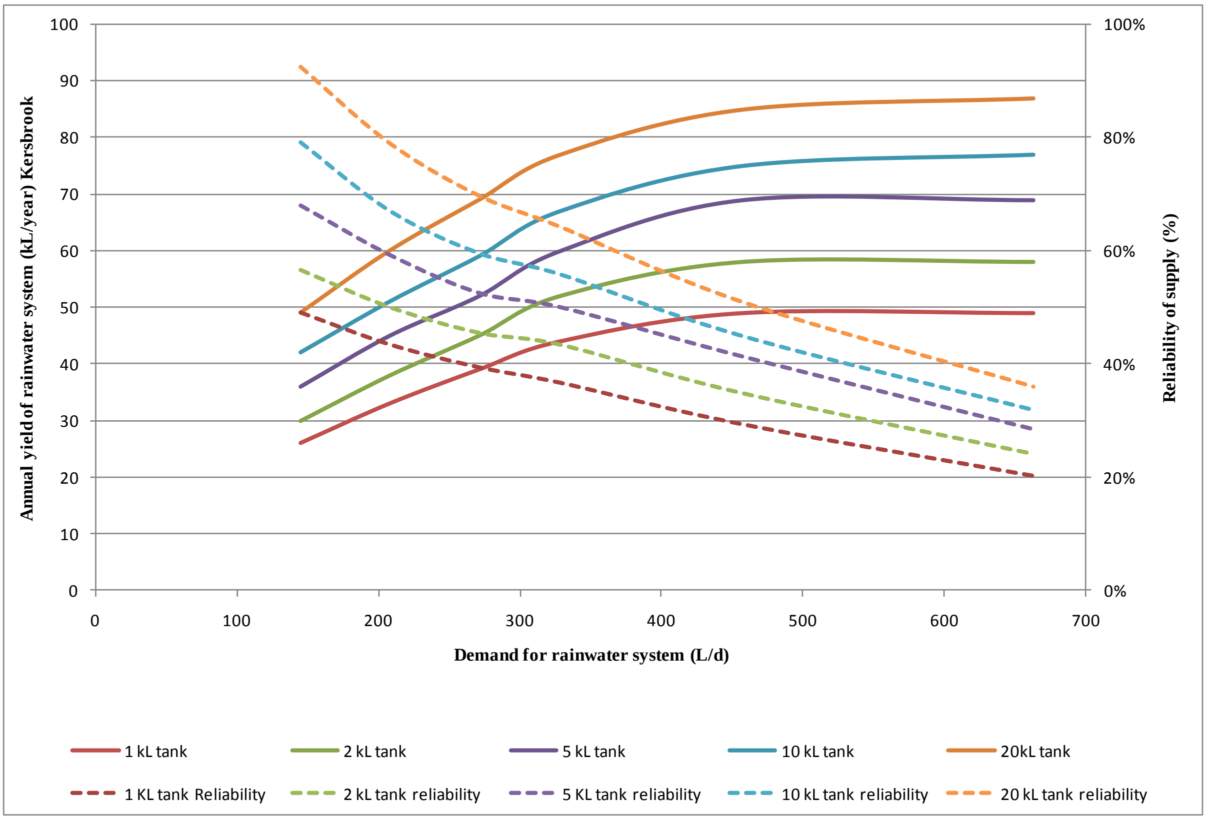


Figure B 12- Rainwater system yield - 200 $m^2$ roof area for high rainfall zone (Kersbrook)

# Appendix C – Summary of Stormwater Runoff Quality Targets

The runoff quality improvement targets recommended in this report are provided in Table C 1 for ease of comparison with targets from other states or state capitals. References within the table are provided in Section 3.6.

Table C 1 – Summary of stormwater runoff targets proposed and targets applied in other states and/or state capitals (references provided in Section 3.6)

| | |
|---|---|
| **GREATER ADELAIDE – Proposed interim targets (from this report)** | |
| Suspended solids | 80% retention of annual load |
| Total phosphorous | 60% retention of annual load |
| Total nitrogen | 45% retention of annual load |
| Gross pollutants | 90% retention of annual load |
| | |
| **NATIONAL – Example guidelines (BMT WBM, 2009)** | |
| Suspended solids | 80% retention of annual load |
| Total phosphorous | 60% retention of annual load |
| Total nitrogen | 45% retention of annual load |
| Gross pollutants | 90% retention of annual load |
| | |
| **MT GAMBIER (SA EPA, 2007)** | |
| Suspended solids | 80% retention of mean annual load |
| Total phosphorous | 45% retention of mean annual load |
| Total nitrogen | 45% retention of mean annual load |
| Litter | Retention of litter greater than 50 mm for flow up to the 3-month average recurrence interval (ARI) peak flow |
| Coarse sediment | Retention of sediment coarser than 0.125 mm for flows up to the 3-month ARI peak flow |
| Oil and grease | No visible oils for flow up to the 3-month ARI peak flow |
| | |
| **QUEENSLAND – South East (incl. Brisbane) (EDAW/AECOM, 2009)** | |
| Suspended solids | 80% retention of mean annual load |
| Total phosphorous | 60% retention of mean annual load |
| Total nitrogen | 45% retention of mean annual load |
| Gross pollutants | 90% retention of mean annual load |
| | |
| **VICTORIA – Post-construction (Victorian Stormwater Committee, 1999)** | |
| Suspended solids | 80% retention of mean annual load |
| Total phosphorous | 45% retention of mean annual load |
| Total nitrogen | 45% retention of mean annual load |
| Litter | 70% retention of mean annual load |
| | |
| **VICTORIA – Construction Phase (Victorian Stormwater Committee, 1999)** | |
| Suspended solids | Treatment of 90% daily runoff events (< 4 month ARI) |
| Litter | Prevent litter from entering stormwater system |

| | |
|---|---|
| Other pollutants | Like the application, generation and migration of toxic substances to maximum extent practicable |
| | |
| **SYDNEY REGION – Interim Targets (SMCMA, 2010)** | |
| Suspended solids | 80% reduction in mean annual load |
| Total phosphorous | 65% reduction in mean annual load |
| Total nitrogen | 45% reduction in mean annual load |
| Gross pollutants | 90% reduction in mean annual load greater than 5 mm |
| | |
| **ACT – DEVELOPMENT/REDEVELOPMENT SITES (ACT Planning and Land Authority, 2009)** | |
| Suspended solids | 60% reduction in mean annual load |
| Total phosphorous | 45% reduction in mean annual load |
| Total nitrogen | 40% reduction in mean annual load |
| | |
| **ACT – REGIONAL/CATCHMENT WIDE (ACT Planning and Land Authority, 2009)** | |
| Suspended solids | 85% reduction in mean annual load |
| Total phosphorous | 70% reduction in mean annual load |
| Total nitrogen | 60% reduction in mean annual load |
| | |
| **TASMANIA (DPIWE, 2010)** | |
| Suspended solids | 80% reduction in mean annual load |
| Total phosphorous | 60% reduction in mean annual load |
| Total nitrogen | 45% reduction in mean annual load |
| Gross pollutants | 90% reduction in mean annual load |
| | |
| **DARWIN (McAuley and McManus, 2009)** | |
| Suspended solids | 80% reduction in mean annual load |
| Total phosphorous | 60% reduction in mean annual load |
| Total nitrogen | 45% reduction in mean annual load |
| Gross pollutants | 90% reduction in mean annual load |
| | |
| **WESTERN AUSTRALIA (WAPC and WADPI, 2008)** | |
| Suspended solids | 80% reduction in mean annual load |
| Total phosphorous | 60% reduction in mean annual load |
| Total nitrogen | 45% reduction in mean annual load |
| Gross pollutants | 70% reduction in mean annual load |

# Appendix D – Recommended Runoff Quality Targets using MUSIC Version 5

The stormwater runoff quality improvement targets proposed in Section 3 of this report were based on modelling undertaken in MUSIC Version 4.01, produced and supported by the eWater CRC[15]. However, as noted in Section 3.3.3, eWater CRC released MUSIC Version 5 during the completion phase of this research. MUSIC Version 5 includes several changes to the model including a revision to the algorithm for bioretention treatment, which was an important treatment mechanism in the development of recommended targets. Based on this, research was conducted to compare the water quality treatment outcomes of identical models in MUSIC Version 4.01 and MUSIC Version 5.

The results of this comparative analysis indicated that, for any development involving a bioretention treatment system, the results of an identical model in MUSIC Version 5 will yield different results to MUSIC Version 4.01. Based on this finding, the analyses conducted in Sections 3.3.2 and 3.3.3 was repeated to provide treatment curves based on bioretention treatment in MUSIC Version 5. These treatment curves were used to derive recommended stormwater runoff quality improvement targets based on the treatment algorithm in MUSIC Version 5. It should be noted that the procedure to develop the treatment curves and the recommended levels of treatment is *identical in every way* to the procedure outlined in Section 3.3.2, except that the model was run in MUSIC Version 5.

The stormwater quality treatment curves developed using the methods outlined in Section 3.3.2 are shown in Figures D1 to D4. For comparison purposes, these figures correspond with Figure 3-5 to Figure 3-8 (Pages 75 to 76) of this report. The point of diminishing performance identified in each case is indicated by a bold vertical line in each figure. It should be noted that the nature of treatment curves was different to those developed in analyses for other Australian states and regions. This is because the bioretention treatment algorithms have been adjusted in MUSIC Version 5 to reflect research into bioretention system performance.

[15] For more information visit http://www.ewater.com.au/

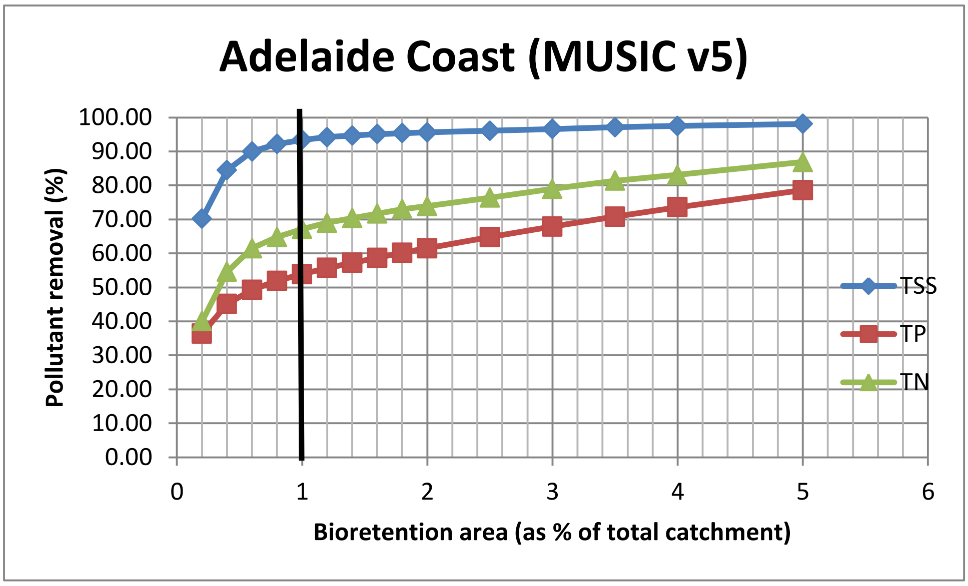


Figure D 1 - MUSIC Version 5 bioretention system treatment performance curve for Adelaide Coast (Largs Bay, 523000)

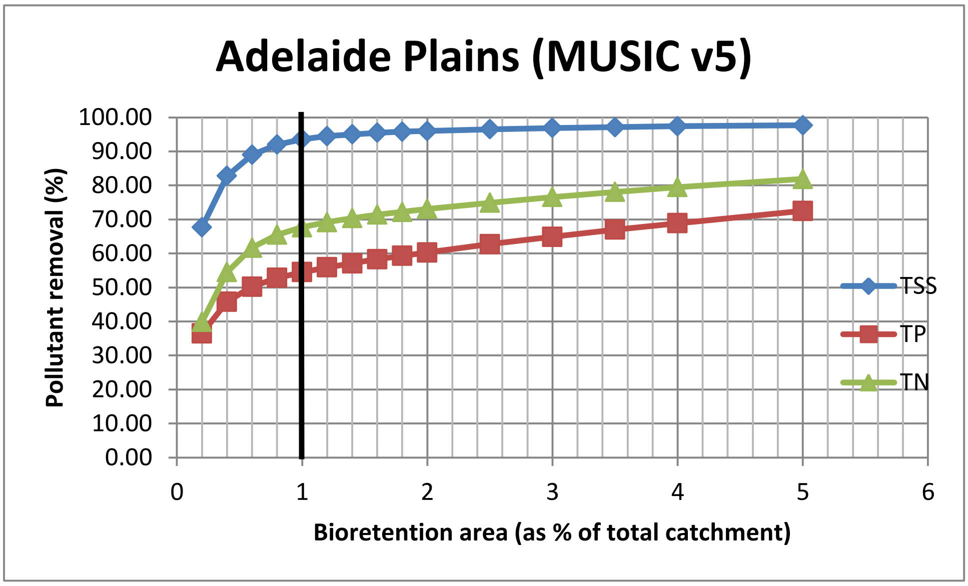


Figure D 2 - MUSIC Version 5 bioretention system treatment performance curve for Adelaide Plains (Adelaide airport, 023034)

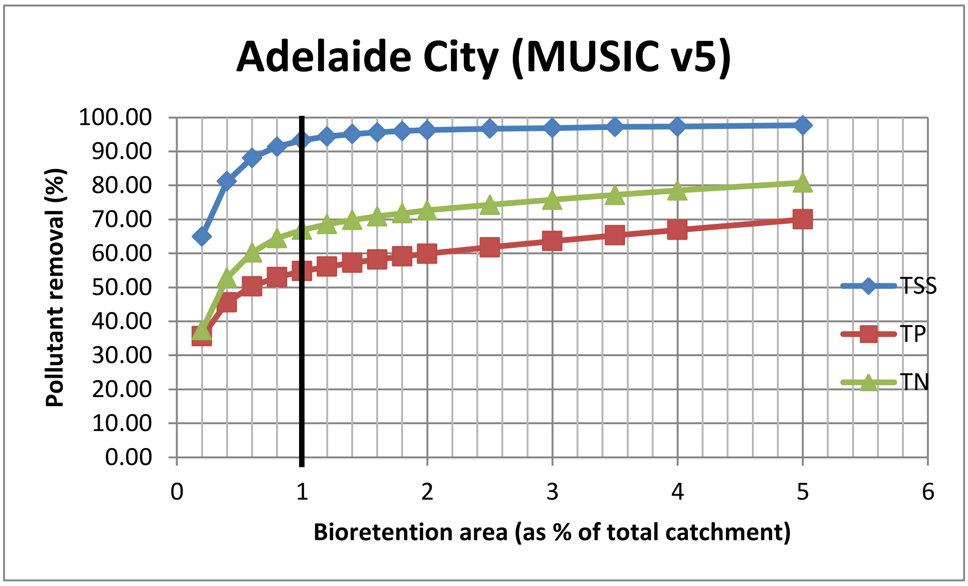


Figure D 3 - MUSIC Version 5 bioretention system treatment performance curve for Adelaide City (Kent Town, 023090)

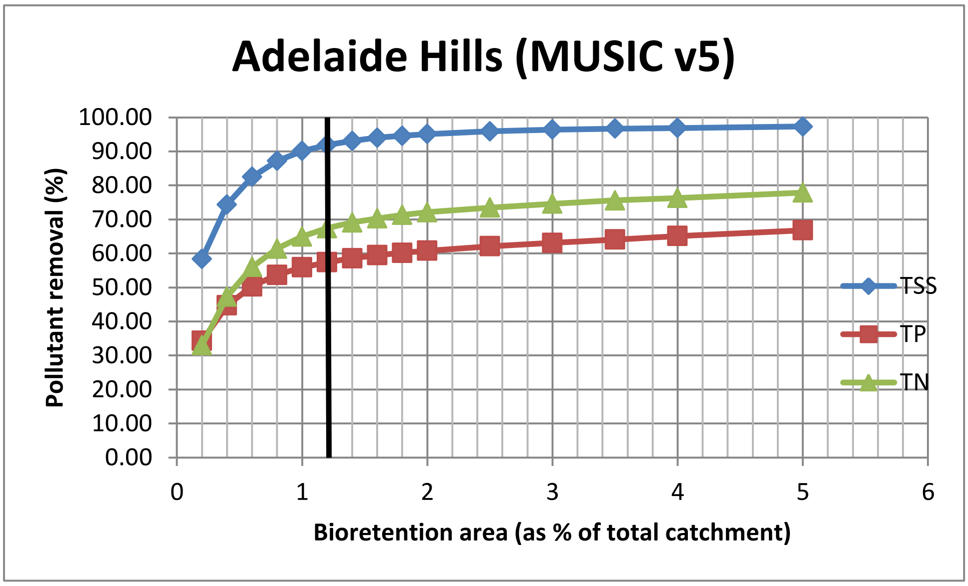


Figure D 4 - MUSIC Version 5 bioretention system treatment performance curve for Adelaide Hills (Kersbrook, 023877)

A summary of recommended treatment performance based on Figures D1 to D4 is presented in Table D 1. It is notable that, according the results derived from MUSIC Version 5, there is a significant change in the treatment performance, where in all geographic regions nitrogen removal outstrips phosphorous removal (with respect to percentage removal based on inlet and outlet concentration). These results have not been found using previous versions of MUSIC during this research. The results are however attributable to changes in the TN treatment algorithm, and improved levels of filtration due to a revised assessment of saturated flows through filter media (pers. comm., eWater CRC). These changes are based around research conducted by the Facility for Advanced Water Biofiltration (FAWB) which conducted extensive laboratory studies into bioretention treatment performance.

Table D 1 - Recommended water quality improvement targets for the Greater Adelaide Region based on modelling in MUSIC Version 5

| **Pollutant** | **Stormwater treatment objective*** |
|---|---|
| Suspended solids (SS) | 85 % retention of the average annual load |
| Total phosphorous (TP) | 50 % retention of the average annual load |
| Total nitrogen (TN) | 65 % retention of the average annual load |

The Goyder Institute for Water Research is a partnership between the South Australian Government through the Department for Water, CSIRO, Flinders University, the University of Adelaide and the University of South Australia.