Code of Practice

Irrigated Public Open Space

Contents

Acknowledgements

This revised Code of Practice – Irrigated Public Open Space (IPOS) was prepared with the generous and enthusiastic support of a wide range of organisations and people with an interest in open space water management. G&M Connellan Consultants and IPOS Consulting were engaged to be the Principal Consultants for the review process.

Funding for the review was provided by three organisations: Department of Water and Natural Resources (DEWNR), Adelaide Mount Lofty Ranges Natural Resource Management Board (AMLR) and Murray Darling Basin Natural Resource Management Board (MDB).

The project was managed by City of Marion on behalf the Local Government Turf and Irrigation Technical Group (LGTITG).

The review process was guided by a project steering committee, which included representatives from the following organisations:

- Adelaide Mount Lofty Ranges Natural Resource Management Board (AMLR)
- Adelaide University
- Bureau of Meteorology (BoM)
- Department of Education and Child Development (DECD)
- Department of Environment, Water and Natural Resources (DEWNR)
- Local Government Association of South Australia (LGA)
- Local Government Turf and Irrigation Technical Group (LGTITG)
- Murray Darling Basin Natural Resource Management Board (MDB)
- Office for Recreation and Sport (ORS)
- SA Water.

The support and contributions of the above organisations and their representatives is greatly appreciated.

Input from the many industry representatives who attended industry workshops is also greatly appreciated.

The Code of Practice and support tools are hosted by SA Water and can be accessed on its website at https://www.sawater.com.au/business/products-and-services/irrigated-public-open-spaces-ipos

Executive Summary

The Code of Practice – Irrigated Public Open Space (IPOS) provides a template that can be used by open-space managers to ensure the planning, management and reporting of water consumption in the urban environment is based on sound principles applied consistently at all levels of management.

The Code can be used by water providers, practitioners and regulating authorities to set policy, manage resources and regulate water use in the provision of open-space services.

The original Code was released in 2008, a period of drought, and since that time has been used widely and with considerable success in improving water use efficiency and contributing to a saving in potable water.

There have been significant changes to the overall water landscape and the management of water in South Australia in recent years. It was decided that a review and update of the Code was appropriate.

Funding became available from a number of sources including Department of Water and Natural Resources (DEWNR), Adelaide Mount Lofty Ranges Natural Resource Management Board (AMLR) and Murray Darling Basin Natural Resource Management Board (MDB). The project was managed by City of Marion on behalf the Local Government Turf and Irrigation Technical Group (LGTITG).

The main drivers for the review are:

- increased recognition of the contribution of green space to liveability
- potential climate change impact
- availability of alternative water sources
- need to expand the scope of the Code to cover trees and landscapes
- technology developments.

Following initial guidance from the steering committee, the consultants engaged with the water, open-space, recreation and sports and irrigation sectors in developing an updated Code.

The main consultation processes involved an online survey of the people involved in open-space irrigation and three workshops.

The feedback from the survey and workshops provided strong endorsement for the principles outlined in the Code and also for the need to amend and/or update elements of a code.

The key outcomes from the survey and workshop were:

- It is a valuable program with sound methodologies.
- A simpler or concise version would assist less experienced operators.
- The Code needs to be broadened to include non-turf landscapes, gardens and trees.
- Training in the use of the Code and irrigation management would be beneficial.
- Tools on the SA Water website are valuable.
- Increased exposure and adoption of the Code is required.

Feedback from the consultation process was incorporated into the revised Code.

The contents of the new Code are similar in structure to the original Code with significant additions and changes in climate change, water quality, landscape plant water requirements and updating of the climate data used in the model calculations. The core expressions used in the irrigation management calculations, as part of the model, have not been changed.

Structure of the Code

There are basically six steps to the process outlined within the Code of Practice, those being:

1. Implement a strategic approach to irrigation management underpinned by a policy statement and commitment by an organisation to appropriately resource and manage the irrigation of the sites under their control.
2. Ensure that systems are functioning to the appropriate performance standard with periodic system audits and ongoing regular maintenance to the physical infrastructure.
3. Ensure that an appropriate horticultural maintenance program is in place to maintain soil structures and turf nutrient requirements.
4. Determine the baseline irrigation requirement, which is based on long-term average climatic data, to set the monthly irrigation schedule.
5. Amend the base irrigation schedule on a regular basis to account for climatic variance in any given season to the long-term average. This will ensure that the turf is receiving the water requirement to maintain it at the appropriate quality level.
6. Monitor irrigation water consumption against irrigation requirements and report on irrigation efficiency and turf quality.

SA Water is the host organisation for the Code of Practice – Irrigated Public Open Space. The Code and support tools are accessible on the SA Water website at: https://www.sawater.com.au/business/products-and-services/irrigated-public-open-spaces-ipos

The adoption of the Code will provide significant benefits to the organisation and the broader community.

Increased water use efficiency will provide quality landscapes, including turf surfaces, with savings in potable water and contribute to the sustainability of irrigated sites.

1.0 Foreword

The development of Code of Practice - Irrigated Public Open Space was a strategic initiative of the South Australian Government's, Waterproofing Adelaide Strategy 2005 (WPA).

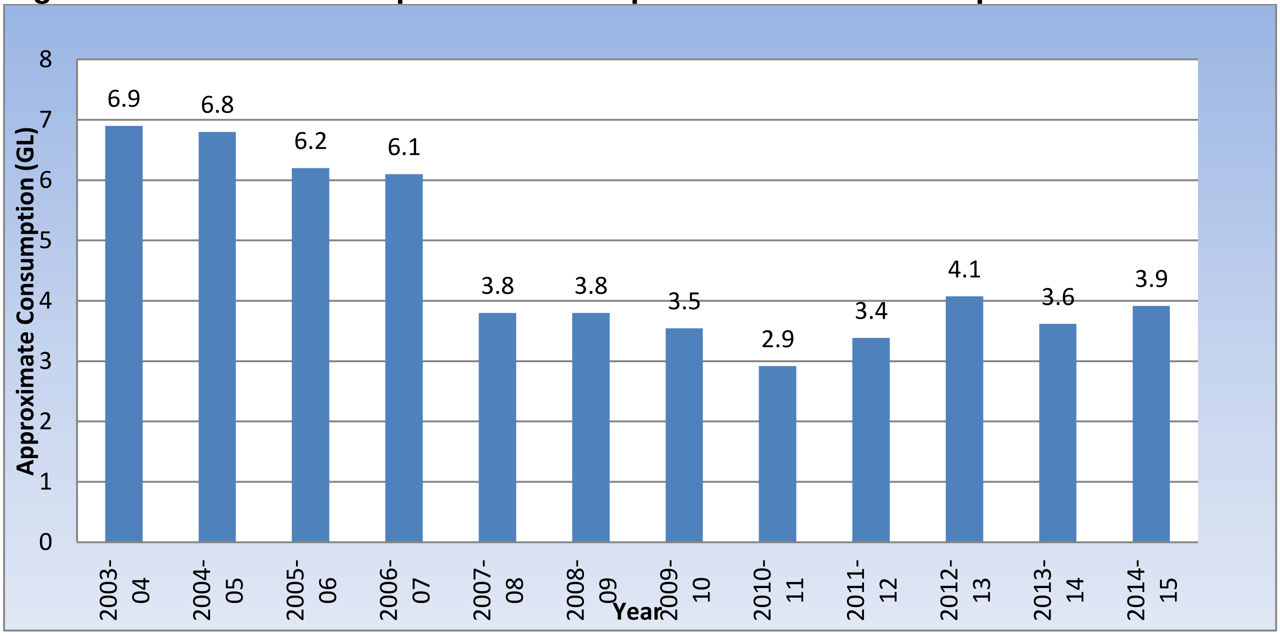
The WPA Strategy No. 33 states:
"A code of practice that encourages irrigation efficiency for public purpose water use will be developed by the SA Government in consultation with the Irrigation Association of Australia, Local Government Association of SA, Botanic Gardens and sporting associations."

The Code of Practice was first developed in 2007 primarily in response to drought Conditions, which limited access to SA Water potable water supplies across metropolitan Adelaide and regional areas of South Australia. The original aim of the Code was to provide managers with a resource that provided a framework and tools necessary to implement best practice in the provision and management of irrigated public open space. The objective was to provide 'fit for purpose' turf based on efficient irrigation management and sound horticultural practices. The emphasis was on turf due to the high water requirement and importance to the community.

The Code was administered by SA Water on behalf of the DEWNR. During the water restrictions of 2007 – 2010 it was mandatory for organisations responsible for irrigated public open space to report on water consumption monthly according to the models developed in the Code, as part of the conditions for exemption from water restrictions. It was the aim of the government to achieve a 20% reduction in water used for irrigated public open space.

During the drought period, local government responded by implementing drought management strategies that included turning off less-functional areas of irrigated turf, increased water use efficiency on sites of high community value such as sports grounds and improving the monitoring and reporting of water usage. The net result of these measures was a reduction of approximately 48% in water usage from 6.9 ML in 2003/04 to 3.6 ML in 2013/14.

Figure 1.1 Adelaide metropolitan council potable water use comparison



Source: SA Water (data based on 16 major South Australian metropolitan councils)

The Code of Practice has been acknowledged nationally as the recipient of the Irrigation Australia Limited, Innovation in Irrigation Showcase Award (2008) and the Parks and Leisure Australia National Award for Water Conservation and Management (2008). In 2010 the state government released *Water for Good – A Plan to Ensure our Water Future to 2050*. The *Water for Good Plan* acknowledged the success of the Code of Practice in improving water use efficiency for public open space and committed to "extend delivery of irrigation efficiency programs, such as the Irrigated Public Open Space program, to all local councils and schools." *(Water for Good 2010. P. 111)*

While the Code has been successful in achieving improved water use efficiency for irrigation in the public sector, much has changed since it was developed in 2007. Major changes that have occurred since 2007 include:

- The construction and operation of the Adelaide desalination plant, which is capable of providing 100 GL per annum. This is approximately 50% of Adelaide's domestic water requirement. The desalination plant has effectively secured Adelaide's water supply for the foreseeable future.
- The cost of SA Water potable water has risen by 205% since 2006 from $1.09 to $3.36 per kL. This has had a significant impact on the ability of local councils and schools to fund the cost of water used for irrigation.
- A significant increase in the development of alternative water supplies including Aquifer Storage and Recharge (ASR) projects and reclaimed sewerage treatment projects.
- The Central Adelaide Groundwater Region has been prescribed with water allocation plans being developed to ensure groundwater usage is sustainable into the future.
- The impact of warming as a result of climate change has resulted in an increased irrigation requirement for irrigated public open space.
- Recognition of the importance of the irrigated landscape as well as turf in providing benefits to the community.
- Increased awareness in the benefits of green space in urban environments including the urban heat island effect, improved physical and mental health and social benefits.
- Reduced amenity of open space within the community due to the 'browning off' of reserves and increased pressure on local government to return to pre-drought levels of irrigated public open space.

The review of the Code of Practice – Irrigated Public Open Space will explore the changes in the water environment since 2007. This includes:

- review of the aims and objectives of the Code
- review of the impacts of climate change on urban irrigation
- review of alternative water supplies for urban irrigation
- review and update of models, benchmarks and data used in the IPOS modelling
- development of a concise irrigated public open space support tool to assist less technical operations personnel in managing irrigated areas
- development of an Irrigated Public Open Space – Best Practice Checklist to assist organisations in achieving best practice in urban irrigation.

2.0 Introduction

2.1 What is a code of practice?
A code of practice is a written set of guidelines and information providing practical advice on how to achieve desirable standards in a particular profession or activity.

2.2 Why develop a code?
The Code of Practice – Irrigated Public Open Space provides a resource that can be used by open space managers to ensure the planning and management of irrigated green space in the urban environment is based on sound principles applied consistently at all levels of management. The Code can be used by providers, practitioners, and regulating authorities to set policy, manage resources and regulate water use in the provision of irrigated public open space.

The Code provides a management framework for best practice turf and landscape irrigation management for all irrigated public open space, including that managed by local government, the education sector and others. It forms the basis by which the industry can demonstrate efficient, effective resource management.

A commitment to managing irrigation to a high performance standard is the first and most critical step to realising water efficient irrigation practices.

2.3 What is the aim of this Code?
The principle aim of this Code is to achieve functional urban green space that provides benefits for the community and is sustainable.

Urban public green space consists of irrigated vegetation, such as sportsgrounds, golf courses, race tracks, reserves and parklands, streetscapes, urban forests and trees and formal and informal landscapes and gardens. In the urban context, these areas have high value and contribute to the amenity and liveability of urban environments providing a balance between the built and natural form.

Function
The function of an urban green space reflects the desired outcome to be achieved by the site. Landscape outcomes include:

- spaces for structured active recreation and sport – competitive sporting competition (football, soccer, rugby, athletics, etc.), fitness activities, community events
- spaces for unstructured recreation activities – play spaces and playgrounds, ball play areas, dog walking, exercise, picnics, relaxation
- micro-climate modification – urban green spaces to mitigate the urban heat island
- effect; shade spaces, refuge from radiant heat off the built environment
- environmental considerations such as habitat protection and biodiversity preservation in cases such as botanic gardens or urban forests
- contact with nature
- aesthetic considerations such screen plantings, formal gardens beds, lawn areas that provide balance between the built and natural form.

Prior to the development of irrigated green spaces, a clear identification of the functional objectives and desired outcomes is critical.

Community
As part of the planning of urban green space development, it is important to identify what segment of the community will be the principal user of the space. Community sectors or stakeholders in urban green space include:

- sporting clubs – junior and senior, elite to local competition
- general passive recreation groups – dog walkers, picnickers, playground users
- interest groups – flora / fauna groups, community gardens
- volunteer groups / education – students, teachers
- special need groups – equity of access and use is essential.

Different community groups have a variety of needs and outcomes.

Benefits
Benefits of urban green space are numerous and can be classified into four categories:

1. health – physical and mental
2. social
3. environmental
4. economic.

Health benefits - physical health
There is increasing evidence that the provision of open space encourages people to engage in physical activities. This is important in promoting healthy lifestyles. Studies have shown that obesity and physical inactivity were the third and fourth most significant risk factors associated with disease in Australia, following smoking and high blood pressure. Lack of quality public open space or reduced access to open space contributes to reduced physical activity and increased community health problems.

Health benefits - mental health
Parks and green spaces provide relaxing and peaceful environments, which are associated with positive mental health. Studies have shown that having trees and quality landscapes in public housing precincts reduces levels of fear, violent and aggressive behaviour and encourages relationships and interaction with neighbours. Studies of office workers found that a view of and access to natural parks creates a more productive work environment, reduces sick leave and results in higher job satisfaction. Natural settings have a restorative quality and offer an opportunity to become revitalised and refreshed. In addition to reducing stress and improving concentration, access to green space and natural settings can enhance general wellbeing by improving spiritual or existential wellbeing.

Social benefits
Access to green space provides opportunities for social interaction and provides a sense of community. Be it a sports ground, dog park, playground or park in the centre of the city, open spaces provide opportunities for social interaction and contributes to social cohesion. The impact of sports ground closures in Victoria as a result of water restrictions had a devastating impact on communities, particularly in regional areas.

Environmental benefits
There are many direct environmental benefits of urban green space.

The park design and layout may include systems such as swales and wetlands, which can reduce the cost of stormwater drainage infrastructure by capturing peak flows and slowing run-off while providing sustainable open space that requires reduced irrigation.

Urban green space can have significant positive environmental impacts including:

- reduction of erosion
- reduction of discharge of pollutants into marine environments
- greater natural infiltration and natural recharge of groundwater.

The creation of urban forests and parklands increases biodiversity and habitat and provides balance between the built and natural form in our cities and urban centres.

Vegetation also has the capacity to reduce air pollution by capturing air borne particles, dust and vehicle emissions. Vegetation can absorb carbon dioxide, nitrogen and other chemicals and particulate material. Trees and screen plantings can also mitigate the negative impacts of noise pollution by absorbing sound waves.

Urban environments with large buildings and extensive infrastructure constructed from concrete, steel and pavements store and radiate heat, which results in the urban heat island effect. Research in Adelaide has found that the parklands surrounding the city have a significant cooling effect. The difference in temperature between the CBD and parklands can be as great as 6^0C. The development of urban green space with a mixture of trees, gardens and lawn can create a microclimate where temperatures are reduced by between 2 - 8^0C providing refuge from radiant heat.

Economic benefits

There are many direct and indirect economic benefits of urban green space. Direct benefits include the economic impact on industries and complimentary support sectors such as turf maintenance, nursery and landscape and arboriculture.

Indirect economic relationships include:

- retailers and suppliers of sporting and recreational goods and services
- enhancement of property values located close to quality green space
- reduced building energy consumption and costs of between 7% – 47% as a result the cooling effects of vegetation and trees.

Sustainability

A critical aspect of the provision of urban green space is sustainability. The three principle areas that need to be considered in the sustainability equation are economic, social and environmental sustainability.

A truly sustainable landscape is one where there are no human inputs such as energy, water and chemicals. Such an area of open space would be in harmony with the environment and be a naturally self-sustaining eco-system such as a national park. Urban green space on the other hand has been constructed to provide a service or outcome for the community. That could be for passive recreation, such as a parkland, or for active structured use such as a sportsground. There needs to be a balance between economic input, social benefit and environmental impact.

Economic sustainability involves the financial cost of inputs in achieving desired outcomes such as:

- capital cost of development
- water
- energy
- labour
- machinery

- chemicals.

The cost of provision of urban green space needs to be considered in relation to the outcome or service that it provides.

Social sustainability – the benefit to the community derived from the urban green space – means:

- the site is able to deliver the desired outcomes or services for the medium to long term (20 – 50 years)
- the site is accessible to the community
- the community benefits derived from the site are achievable within budget.

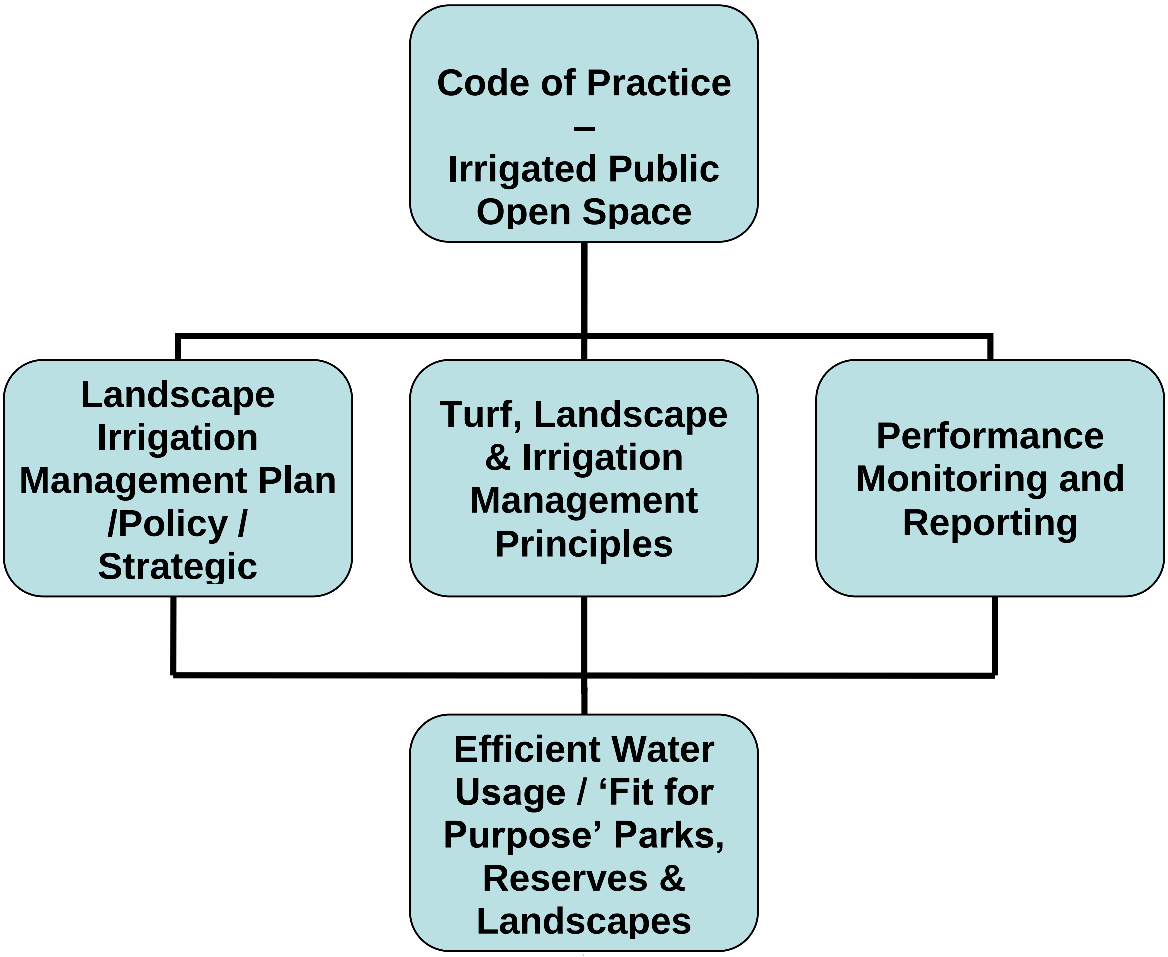
Environmental sustainability, the principle that sites should minimise environmental impacts, requires that:

- The principles of Water Sensitive Urban Design (WSUD) should be used to optimise the natural water flows and make use of rainfall as much as possible.
- Existing native vegetation should be preserved wherever possible.
- Plant selection should take into account drought tolerant/local native species that minimise water use.
- Potable water supplies are replaced with alternative water sources.
- The health of the alternative water source is maintained.
- Chemical inputs are minimised and do not threaten to health of the soil or water.

It is essential for every organisation involved in open space irrigation to have a plan that includes the objectives, policies and strategies required to manage site water sustainably. There are various plans currently in use including the Water Management Plan (WMP), Drought Management Plan (DMP), Drainage Plan and Landscape Irrigation Management Plan (LIMP).

The LIMP is considered to be the appropriate plan for use in this Code. Many organisations will also have a WMP that will cover whole water cycles and all of the water issues relevant to the site.

The Code explains how best to plan, manage and report water use for irrigated public open space, ensuring water use efficiency and fit-for-purpose sports turf, recreational parks and landscapes.



2.4 What are the benefits of using the Code?
Irrigators of urban green spaces who subscribe to the Code of Practice will realise significant benefits, not only to the organisation, but to the community and environment in a broader context. Benefits include:

- improved irrigation management translating into reduced watering costs
- community recognition of efficient watering practices employed
- improved outcomes and services to the community
- potential aversion of health and safety issues – particularly in the case of school ovals and sporting grounds
- increased amenity levels associated with appropriately irrigated public open space.

2.5 Who should use this Code?
This Code should be used by everyone involved in the management and operation of irrigation systems for urban green space. The Code covers all areas including policy, planning, operation and performance monitoring and reporting. Those who should use the Code are:

- open space planners
- managers of urban green space
- irrigation consultants and designers
- irrigation equipment suppliers
- irrigation installation and maintenance contractors
- irrigation technical officers
- horticulture and irrigation operations staff.

2.6 What is the legal status of the Code?
The Code provides advice on how to manage irrigation water use efficiently. It is a voluntary Code that is not linked to any regulation or legislation.

The Code sets out principles that can be implemented to ensure best practice turf and landscape irrigation management. Irrigation managers and consultants may already be operating at best practice and above. The methods described in the Code may be adapted or altered to suit individual organisations or as the circumstances require.

2.7 What other advice is available?
The Code has drawn on a wide range of technical documentation and sources in the public domain. A bibliography of reference material is included at the end of each section of the Code.

2.8 Glossary of terms and abbreviations
A glossary of terms and abbreviations is included as Appendix 7.

References / Further Information: Section Number 2 - Introduction

- Department of Environment, Water and Natural Resources (DEWNR) (2009) *Water for Good – A Plan to Ensure Our Water Future to 2050,* Office of Water Security, Adelaide South Australia: http://www.environment.sa.gov.au/managing-natural-resources/water-use/water-planning

- Schebella M, Weber D, Brown G, Hatton McDonald D. *The Importance of Irrigated Urban Green Space: Health and Recreational Benefits Perspectives (2014) Goyder Institute, Adelaide South Australia. The Importance of Irrigated Urban Green Space: Health and Recreational Benefits Perspectives (2014) Goyder Institute, Adelaide South Australia.*

3.0 Policy and Planning

3.1 Water use policy

In order to ensure that sustainable water management is a priority for the organisation, a clear policy statement is required to outline the commitment to sustainable water use in the management of irrigated public open space. The policy should be clear and succinct and be able to guide future decisions in relation to the provision and management of irrigated public open space.

The policy should be used in the planning and development of new sites and to assess the performance and sustainability of current irrigated sites.

The overall objectives of this policy are to:

- Achieve a balance between the provision of a high value amenity landscape that meets the needs of the community and is economically and environmentally sustainable.
- Implement the principles of Water Sensitive Urban Design (WSUD) to achieve integration of water cycle management into urban planning and design.
- Achieve a consistent and best management approach in the provision and development of the irrigated landscape.
- Provide a clear direction and framework for irrigation and water management strategies to enable water conservation and financial savings to be achieved.

A strong commitment to this policy is required. It should be endorsed by the organisation at the highest level.

3.2 Policy context – federal and state

The management of water resources has become a major focus for all governments and industry in recent years. The reasons for change include:

- demand for water is increasing – population growth
- increasingly stressed natural environment
- extended period of drought (more than 10 years in some cases)
- climate change adaptation – less rainfall, higher temperatures.

All Australian governments, federal and state, have adopted policies and legislation to deal with water resource management. In developing a water plan, reference should be made to the various Acts and associated legislation that establishes the umbrella framework within which water resources are managed.

Legislation at a South Australian state level that may be relevant includes:

- Water Industry Act 2012
- catchment and land protection acts
- natural resources management acts
- planning acts
- health acts.

For each organisation there will be a range of local policies and plans that will impact on a specific water plan covering the irrigated open space. These may include business plans, landscape master plans, environment and sustainability plans and open space plans.

Familiarisation with the policies and the regulatory framework is a starting point in water management planning.

3.3 Developing water plans for the organisation

A water plan clearly and precisely states the vision and goals of the organisation in terms of achieving sustainable use of water.

The commitment to sustainable water management can be demonstrated through individual or multiple plans. It is important that these plans outline the key principles that are to guide the development and ongoing management of irrigated sites. For each organisation, the scope of the various plans will vary and address different aspects of water management.

A water plan is essential. It outlines the pathway and processes that will be used to achieve the organisation's goals. A water plan identifies the works and practices that will improve all water management, including irrigation and water use efficiency, for the site or enterprise. It identifies how water can be conserved and what strategies need to be put in place to ensure sustainability of water use in the future.

Water Management Plans (WMP) are extensively used for a wide scope of water issues for an organisation or a site. These plans often include public open space as part of the overall water plan. Plans specifically dealing with irrigation and open space are called Landscape Irrigation Management Plans (LIMP).

IMPs review the current water management practices and identify opportunities for improvement in water use efficiency across the site. The plan clearly and precisely states the vision and goals of the organisation in terms of achieving sustainable use of water. It establishes the targets to be achieved and actions to be implemented that will produce sustainability of water use.

The structure, contents and development of water and irrigation management plans are outlined in *Water Use Efficiency: Irrigated Turf and Landscape* (Connellan, 2013). There is also an IMP information sheet included in the appendices.

3.4 Organisation water objectives for irrigated public open space

The development of specific objectives to achieve the organisation's water policy provides a framework within which priorities can be determined and appropriate actions identified. The objectives will reflect the water issues confronting the organisation and the outcomes that it is seeking. The vision of the organisation in terms of the nature and purpose of the site and the services to be provided will have a strong influence on the specific water objectives developed by the organisation.

In developing water objectives, recognition of objectives contained within other documents such as an environmental management plan or a business plan need to be taken into account.

An organisation's objectives may include:

- providing fit-for-purpose sports surface while achieving optimum water use efficiency
- investigating alternative water source options (replace potable water used for irrigation)
- improving water use efficiency
- introducing recycled water for irrigation

- undertaking a detailed review of all water (irrigation and non-irrigation) used on the site
- reviewing all existing plant species in the context of water use requirements and landscape outcomes
- maximising opportunities to use stormwater to reduce current irrigation water demand
- adopting practices that protect the quality of water in the natural environment
- adopting best management practice in all irrigation operations
- providing training for all staff in water management to ensure performance standards can be achieved
- benchmarking all water use within the responsibility of the organisation, setting targets and implementing strategies to achieve those targets
- developing an IMP
- ensuring that the organisation has adequate resources to achieve and maintain high efficiency standards.

3.5 Key guiding principles in this Code of Practice

The following principles provide guidance in the preparation and implementation of plans for irrigated open space:

- **Water supply**
  Where possible, sources other than potable mains water should be identified and investigated for use on irrigated public open space.

- **Environmental and water quality management**
  Steps must be taken at the planning and design stage to ensure irrigation has minimal negative affect on the surrounding environment and natural drainage systems. WSUD principles must be considered and implemented when planning the development of irrigated public open space.

- **Functional benefit of irrigated public open space**
  The provision of irrigated public open space should be based on an assessment of the functional benefit of the site. Irrigation should only be provided where there is a clear functional benefit (i.e. sportsground, picnic area, etc.) The area being irrigated should be the minimum required to achieve the functional objective, complimented by alternative landscape treatments.

- **Best practice irrigation management**
  All sites irrigated should adopt the principles of best practice in regard to design, installation, maintenance and scheduling.

- **Water efficiency management planning and reporting**
  All sites should have a documented reporting process that monitors water use efficiency and the quality and 'fit for purpose' standard of the turf or landscape.

References / Further Information: Section Number 3 – Policy and Planning
• Connellan, G. 2013. *Water Use Efficiency for Irrigated Turf and Landscape,* CSIRO Publishing, Victoria, Australia: http://www.publish.csiro.au/pid/5263.htm

4.0 Potential impacts of Climate Change

4.1 Overview – climate change and South Australia

Earth's climate has changed during the past century. The atmosphere and oceans have warmed, sea levels have risen and glaciers and ice sheets have decreased in size. The best available evidence indicates that greenhouse gas emissions from human activities are the main cause. Continuing increases in greenhouse gases will produce further warming and other changes in Earth's physical environment and ecosystems.

South Australia has always had a variable climate; however, we are now experiencing increased temperatures, sea level rise, changes to rainfall patterns and increased occurrences of extreme events such as heatwaves.

Average temperatures across the state have risen almost one degree Celsius during the past century. Since the 1990s, a decline in rainfall, particularly within the agricultural districts of the state between April and October, has been experienced, although trends are less clear than for temperature and sea level rise because of natural rainfall variability.

In summary, climate change for Southern South Australia is expected to be characterised by:

- increased CO_2 levels
- increased average and maximum temperatures
- reduced rainfall
- more frequent and severe extreme weather events – storms, floods, heat waves and drought
- sea level rise.

Open space managers need to plan for these changes. Examples of policies and strategies that are currently in place in South Australia are:

- *Prospering in a Changing Climate, A Climate Change Adaptation Framework for South Australia August 2012, Government of South Australia, DEWNR*
- *Climate adaptation planning guidelines prepared by the LGA SA - http://www.lga.sa.gov.au/webdata/resources/files/LGA%20CAPG%20Final%20Print%20Version.pdf*
- *CCIA website - http://www.climatechangeinaustralia.gov.au/en/*
- *SA Climate Ready Projections - https://data.environment.sa.gov.au/Climate/SA-Climate-Ready/Pages/default.aspx*
- *Climate Change Adaptation Plan 2013-2015, Adelaide City Council*
- *Local Government South Australia Climate Adaptation Programme Final Report, 2012, Local Government Association Mutual Liability Scheme (LGAMLS), LGA, Adelaide*
- *Resilient East Climate Projections Report, 2015, URPS, Rose Park, SA, in association with the Government of South Australia and the Australian Government.*

4.2 Climate projections for South Australia

Scientific assessment and research in relation to climate change for Australia is provided by collaboration between the Australian Government Department of the Environment, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the BoM. Climate Change in Australia (CCIA) has a comprehensive website hosting a suite of reports providing information about climate change projections across Australia.

The SA Climate Ready (SACR) project managed by the Goyder Institute for Water Research has undertaken research and modelling in relation to the impact of climate change across South Australia with a focus on the natural resources management (NRM) regions.

For each of the key climate parameters, projections have been made in relation to potential changes. These projections are based on models that tend to produce some variability in projection values. These models are continually being refined as more data become available.

In order to gain an appreciation of the likely changes, it is necessary to consider a range in greenhouse gas emission levels. A summary of the climate change projections is presented using intermediate (RCP4.5) and high (RCP8.5) greenhouse gas emissions scenarios. Two timelines have also been adopted in presenting this data: 2030 and 2070 with the average from 1986 – 2005 used as the reference period.

The tables below present data in relation to projected changes for rainfall, maximum temperature and potential evapotranspiration for South Australia. Each table displays the median projection in bold (50th percentile) and the range (10 – 90th percentile) below this figure, in brackets. The data compare projections nationally by CCIA with those done by SACR for the geographically corresponding South Australian NRM regions.

Table 4.1a and 4.1b is a summary of the modelling projections for Southern South Australia.

Table 4.1a Projected change by 2030 in temperature, rainfall and potential evapotranspiration for South Australia compared to the baseline period (1986 – 2005) using intermediate and high emission scenarios

Source	Region	Annual rainfall change (%) Median (range)		Annual maximum temperature increase (°C) Median (range)		Annual potential evapotranspiration increase (%) Median (range)	
		Intermediate emissions (RCP4.5)	High emissions (RCP8.5)	Intermediate emissions (RCP4.5)	High emissions (RCP8.5)	Intermediate emissions (RCP4.5)	High emissions (RCP8.5)
CCIA (CSIRO / BoM)	Southern and South Western Flatlands	-6.1 (-12.9 to -0.2)	-3.9 (-14.1 to 2.3)	0.9 (0.6 to 1.0)	0.9 (0.6 to1.2)	2.3 (1.5 to3.6)	2.9 (1.6 to 4.3)
SACR (Goyder Inst)	Adelaide and Mount Lofty Ranges	-4.7 (-8.9 to -1.0)	-4.8 (-7.9 to 3.4)	0.9 (0.7 to 1.1)	1.0 (0.9 to 1.4)	2.6 (2.2 to 3.5)	3.1 (2.1 to 4.0)
	Kangaroo Island	-3.6 (-8.3 to -2.3)	-5.9 (-8.8 to -3.1)	0.7 (0.6 to 0.8)	0.8 (0.6 to 1.1)	2.0 (1.8 to 2.8)	2.3 (1.5 to 3.3)
	Northern and Yorke	-6.5 (-15.9 to -4.0)	-9.6 (-14.3 to -3.0)	1.0 (0.8 to 1.1)	1.1 (1.0 to 1.5)	2.8 (2.5 to 3.8)	3.2 (2.6 to 4.4)
	Eyre Peninsula	-5.0 (-13.9 to -1.6)	-7.3 (-12.7 to -2.4)	0.8 (0.7 to 1.0)	1.0 (0.9 to 1.3)	2.2 (2.0 to 3.3)	2.6 (2.0 to 3.7)
CCIA (CSIRO / BoM)	Murray Basin	-2.5 (-8.6 to 5.5)	-1.4 (-11.4 to 4.9)	0.9 (0.6 to 1.3)	1.1 (0.8 to 1.4)	2.6 (1.0 to 4.5)	3.1 (1.9 to 5.1)
SACR (Goyder Inst)	SA Murray Darling Basin	-5.9 (-12.6 to -3.2)	-8.1 (-10.9 to -4.0)	0.9 (0.8 to 1.1)	1.0 (0.9 to 1.5)	2.6 (2.3 to 3.6)	3.0 (2.3 to 4.2)
	South East	-3.1 (-6.3 to -1.0)	-4.9 (-6.6 to -1.8)	0.8 (0.7 to 0.9)	0.9 (0.8 to 1.3)	2.3 (2.1 to 3.2)	2.9 (1.9 to 3.9)
CCIA (CSIRO / BoM)	Rangelands	-1.9 (-11.5 to 5.9)	-1.0 (-10.1 to 6.0)	1.1 (0.7 to 1.5)	1.1 (0.8 to 1.6)	2.4 (1.0 to 3.9)	3.0 (1.2 to 4.2)
SACR (Goyder Inst)	Alinytjara Wilurara and SA Arid Lands	-4.9 (-20.9 to -0.5)	-4.1 (-13.4 to -1.7)	1.0 (0.8 to 1.2)	1.3 (1.0 to1.6)	2.4 (1.9 to 3.8)	2.8 (2.4 to 4.3)

Table 4.1a - Climate change projections for South Australia to 2030 (Source: Goyder Institute for Water Research, 2014 and Climate Change in Australia, 2015)

Table 4.1b Projected change by 2070 in temperature, rainfall and potential evapotranspiration for South Australia compared to the baseline period (1986 – 2005) using intermediate and high emission scenarios

Source	Region	Annual rainfall change (%) Median (range)		Annual maximum temperature increase (°C) Median (range)		Annual potential evapotranspiration increase (%) Median (range)	
		Intermediate Emissions (RCP4.5)	High Emissions (RCP8.5)	Intermediate Emissions (RCP4.5)	High Emissions (RCP8.5)	Intermediate Emissions (RCP4.5)	High Emissions (RCP8.5)
CCIA (CSIRO / BoM)	Southern and South Western Flatlands	-8.0 (-18.8 to 0.0)	-15.4 (-28.5 to 3.4)	1.7 (1.1 to 2.1)	2.6 (2.0 to 3.1)	4.8 (2.8 to7.2)	7.6 (5.4 to 11.0)
SACR (Goyder Inst)	Adelaide and Mount Lofty Ranges	-5.7 (-12.9 to 4.7)	-11.0 (-21.0 to 8.7)	1.5 (1.3 to 1.8)	2.3 (2.2 to 3.3)	4.3 (3.8 to 5.5)	6.8 (6.1 to 9.3)
	Kangaroo Island	-7.9 (-13.2 to 6.2)	-12.5 (-22.2 to 9.7)	1.2 (1.0 to 1.5)	1.9 (1.7 to 2.6)	3.5 (2.8 to 4.8)	5.4 (5.0 to 8.2)
	Northern and Yorke	-10.8 (-21.0 to 7.7)	-18.4 (-31.6 to -12.8)	1.6 (1.5 to 2.0)	2.6 (2.3 to 3.5)	4.6 (4.2 to 5.7)	7.5 (6.3 to 9.8)
	Eyre Peninsula	-9.2 (-18.5 to 5.6)	-14.1 (-26.2 to -8.0)	1.5 (1.3 to 1.7)	2.3 (2.1 to 3.0)	4.0 (3.6 to 4.9)	6.4 (5.4 to 8.4)
CCIA (CSIRO / BoM)	Murray Basin	-3.9 (-17.7 to 7.7)	-4.5 (-22.4 to 7.6)	1.8 (1.3 to 2.4)	2.9 (2.2 to 3.6)	4.9 (3.0 to 8.6)	8.9 (5.4 to 12.6)
SACR (Goyder Inst)	SA Murray Darling Basin	-9.9 (-16.7 to 6.8)	-17.3 (-24.3 to 10.9)	1.6 (1.4 to 1.9)	2.5 (2.3 to 3.4)	4.4 (4.0 to 5.4)	7.2 (6.3 to 9.4)
	South East	-6.8 (-10.9 to 4.6)	-11.1 (-17.2 to -7.6)	1.4 (1.2 to 1.7)	2.1 (2.0 to 3.0)	4.0 (3.6 to 5.3)	6.4 (5.9 to 9.0)
CCIA (CSIRO / BoM)	Rangelands	-2.8 (-14.1 to 7.6)	-2.7 (-21.2 to 9.5)	2.1 (1.4 to 2.6)	3.2 (2.3 to 4.2)	4.9 (1.5 to 7.2)	8.7 (5.1 to 10.7)
SACR (Goyder Inst)	Alinytjara Wilurara and SA Arid Lands	-8.1 (-21.5 to 0.3)	-7.3 (-28.1 to -0.9)	1.8 (1.5 to2.1)	3.0 (2.4 to 3.7)	4.3 (3.7 to 5.8)	6.9 (5.8 to10.1)

Table 4.1b – Climate change projections for South Australia to 2070 (Source: Goyder Institute for Water Research[1], 2014, and Climate Change in Australia, 2015[2]) [1]http://www.goyderinstitute.org/uploads/CC%20Task%203%20CSIRO%20Final%20Report_web.pdf

[2] http://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/summary-data-explorer/#

The key messages to be taken from the combined CCIA and CRSA data in relation to managing irrigated open space are as follows:

- South Australia is likely to experience an increase in annual average maximum temperature under an intermediate emission scenario of between 0.6 – 1.5ºC by 2030 and 1.0 – 2.6ºC by 2070. Under a high emission scenario increases are projected to be between 0.6 – 1.6ºC by 2030 and 0.6 – 1.6ºC by 2070.
- Temperatures will continue to increase in all seasons with marginally higher increases in the central and northern areas of the state.
- There is significant variation in the rainfall projections across the different NRM regions with the Adelaide and Mt Lofty Ranges and South East projections lower than the Eyre Peninsula and Northern and Yorke and the north of the state, which are projected to experience higher reductions in rainfall. There was also a significant variation in seasonal changes with a higher reduction in rainfall projected for winter and in spring. While the average rainfall is expected to decrease, the incidence of extreme rainfall events is projected to increase.
- Annual average potential evapotranspiration is projected to increase under an intermediate emissions scenario of between 1.0 – 4.5% by 2030 and 1.5 – 8.6% by 2070. Under a high emission scenario, increases are projected to be between 1.2 – 5.1% by 2030 and 5.0 – 12.6% by 2070. Increases in evapotranspiration are consistent across all NRM regions with a higher increase expected in spring and summer.

CCIA (CSIRO/BoM) have carried out modelling projections for extreme heat events in Southern South Australia for the 2030 timelines. Projections are for the number of days annually over 35ºC and 40ºC for an intermediate (RCP4.5) emissions scenario with the median projection in bold (50th percentile) and the range (10 – 90th percentile) below this figure, in brackets.

Table 4.2 Projected extreme heat days compared to current using intermediate scenarios

Threshold	Current (days)	2030 (days)	Change (%)
Over 35ºC	20	26 (24 to 29)	30%
Over 40ºC	3.7	5.9 (4.7 to 7.2)	59%

Extreme heat days over 35ºC are projected to increase by 30% by 2030 with days over 40ºC increasing by 59%.

Overall, there is expected to be an increased deficit between rainfall and evaporation. This means that the amount of irrigation required will need to increase to satisfy this deficit.

4.3 Consequences of climate change

The main consequences of climate change for our communities and environment are:

- human health and wellbeing will be at risk due to increased thermal stress
- reduced life of infrastructure – storms, extreme temperatures
- stressed vegetation requiring increase supplementary water provided by irrigation
- potential flooding
- reduced rainfall water supplies available from catchments.

Climate change will impact on the management of urban open space in a number of ways:

- Amount of rainfall-harvested water for irrigation (and other purposes) will decrease. Reduced spring rainfall will potentially impact on harvested catchment yield.

- The demand for water by plants will be increase.
- With more frequent extreme temperatures some plant species will be at risk.
- Overall, there will be a greater demand for water by turf and landscape plants.
- There will be greater need for cooling of the urban built environment.
- More frequent and severe droughts will impact on plants/trees, water sources and plant irrigation demand.

Additional risks include potential damage to open space structures and trees as a result of an increase of intense storm activity. Also, with warmer conditions and generally lower yields from catchments, stagnant water storages will be more conducive to algal blooms.

4.4 Recent observations in climatic conditions

The BoM has been calculating daily reference evapotranspiration (ET_o) for the past nine years - since 2006/07. Reference evapotranspiration is the measure of plant water requirement (mm) used in agriculture and horticulture to determine specific plant water requirements. Reference evapotranspiration is explained in more detail in Section 8.

Data from the BoM have been compiled in the tables below comparing maximum temperature, rainfall and evapotranspiration using the long-term average and actuals for the period 2007 – 2015.

Table 4.3 Climate data comparison 2007-2015, BoM Adelaide Airport. Data displayed in columns broken down into long-term average, years and averages 2007-2015. The rows display climate data relevant to each year.

Year	Long-term avge	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	Avge 07-15
Average maximum temp. (ºC)	21.5	22.9	22.9	21.8	22.9	21.1	22.2	22.5	22.6	21.9	22.3
Variation (ºC)		1.4	1.4	0.3	1.4	-0.4	0.7	1.0	1.1	0.3	0.9
Rainfall (mm)	452	310	304	318	437	488	506	340	508	296	390
Variation (%)		-31%	-32%	-28%	-2%	8%	12%	-25%	12%	-35%	-14%
ETo (mm)	1376	1687	1702	1664	1740	1511	1599	1681	1684	1556	1647
Variation (%)		23%	24%	21%	26%	10%	16%	22%	23%	13%	20%

Source: Bureau of Meteorology (2015) *Reference Evapotranspiration for Australia* http://www.bom.gov.au/watl/eto/

Table 4.4 Maximum monthly temperature (temp) long-term average compared to average 2007-2015 along

Month	Long-term average temp (ºC)	2007 - 2015 average temp (ºC)	Difference (ºC)	Difference (%)
July	14.9	15.3	+0.4	3%
August	15.9	16.6	+0.7	4%
September	18.2	19.7	+1.5	8%
October	21.0	22.1	+1.1	5%
November	24.0	25.6	+1.6	7%
December	25.7	26.7	+1.0	4%
January	28.1	29.4	+1.3	5%
February	28.1	28.8	+0.7	2%
March	25.5	26.5	+1.0	4%
April	22.2	23.0	+0.8	4%
May	18.6	19.2	+0.6	3%
June	15.9	16.0	+0.1	1%
Average	21.5	22.4	+0.9	4%

Source: BoM (2015) *Reference Evapotranspiration for Australia*
http://www.bom.gov.au/watl/eto/

Table 4.5 Monthly rainfall (P) long-term average compared to average 2007-2015

Month	Long-term average P (mm)	2007 - 2015 average P (mm)	Difference (mm)	Difference (%)
July	59.4	53.1	-6.3	-11%
August	50.5	44.3	-6.2	-12%
September	45.1	31.7	-13.4	-30%
October	36.6	16.3	-20.3	-55%
November	24.8	20.0	-4.8	-19%
December	23.4	20.7	-2.7	-12%
January	17.5	15.6	-1.9	-11%
February	18.9	17.7	-1.2	-6%
March	21.8	25.9	4.1	19%
April	35.3	41.8	6.5	18%
May	54.1	50.3	-3.8	-7%
June	56.0	53.2	-2.8	-5%
Total	444.2	390.6	**-53.6**	**-12%**

Source: BoM (2015) *Reference Evapotranspiration for Australia*
http://www.bom.gov.au/watl/eto/

Table 4.6 Monthly evapotranspiration long-term average compared to average 2007-2015

Month	Long-term average ETo (mm)	2007 - 2015 average ETo (mm)	Difference (mm)	Difference (%)
July	42	57	+15	36%
August	59	76	+17	29%
September	85	118	+33	39%
October	127	160	+33	26%
November	157	192	+35	22%
December	186	216	+30	16%
January	201	234	+33	16%
February	171	193	+22	13%
March	147	166	+19	13%
April	99	110	+11	11%
May	61	74	+13	21%
June	41	50	+9	222%
Total	1376	1646	+270	20%

Source: BoM (2015) *Reference Evapotranspiration for Australia* http://www.bom.gov.au/watl/eto/

Average maximum temperature has increased by 0.9 ^{o}C with a maximum increase of 1.4^{o}C in 2006/07, 2007/08 and 2009/10 with a reduction of 0.4^{o}C in 2010/11. The highest increase in temperature occurred in spring and summer.

There was a reduction of 14% in average rainfall, with significant variation, the highest reduction of 35% in 2014/15, with an increase of 8% in 2010/11. There was also significant seasonal variation with the highest reduction in rainfall occurring in spring and summer. There was an increase of 18% evapotranspiration, with significant variation, with the highest increase of 26% in 2009/10 and the lowest increase of 9% in 2010/11. There was no marked seasonal variation in ETo

While there is variation in both annual and monthly differences for these recent data, the changes in all parameters correlate closely to the long-term modelling projections for the future.

4.5 Preparing water budgets for future water demand

The impacts of climate change on plant water requirement for turf and landscape plantings are significant. Higher temperatures and reduced rainfall result in increased evapotranspiration for specific plant species. In the case of warm season turf grass (Kikuyu), used on local sports grounds, the plant water requirement has increased significantly during the past nine years (2007 – 2015).

Table 4.6 Plant water requirements for local sportsground (TQVS 3, warm-season turf, Kikuyu, Adelaide metropolitan area) between 2006 and 2015

Year	Long-term avge	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	Avge 07-15
Irrigation Requirement (kL/ha)	3,694	5,011	5,184	5,444	5,057	3,662	4,513	5,471	4,886	4,865	4,898
Variation (%)		36%	40%	47%	37%	-1%	22%	48%	32%	31%	33%

An average increase in plant water requirement of 33% has significant impact on water resource availability and cost. These issues are discussed more fully in Section 8.

4.6 Greening and climate change adaptation strategies

A key strategy to counter the impact of urban heating is through increased areas of vegetation.

Transpiring plants, which convert the energy of the sun into water vapour through evaporation, use up large amounts of energy that would otherwise cause heating of the air, as a result of absorption by hard surfaces, road, pavements and buildings.

Strategies such as tree planting to increase canopy area and irrigating grassed areas significantly improve the capacity of the urban areas to cope with the higher temperatures and continue to provide functional spaces during hot, dry conditions.

These strategies, which revolve around adapting or modifying the natural environment, are classified as being adaptation strategies. Other adaptation strategies include increasing biodiversity and the permeability of urban surfaces, WSUD elements, green roofs and green walls.

An alternative approach is to reduce the emission of greenhouse gases through strategies such as solar heating and solar electricity generation, energy conservation and alternative transport mediums such as cycling and walking. This type of approach is referred to as a mitigation strategy.

Pumping energy and greenhouse gases

Electrical energy consumption for pumping and water treatment is a source of production of greenhouse gases. Minimising greenhouse gases through maximising efficiency of pumping systems is a recommended strategy and is often part of environmental sustainability policies.

Irrigation system components including pipeline design, pump hydraulic efficiency and electric motor efficiency all contribute to the overall efficiency of the system.

The actual greenhouse gas production is dependent on the nature of the electrical generation facility. According to the Commonwealth of Australia (2009) National Greenhouse Accounts (NGA), the greenhouse gas emission factor for South Australia is 0.77 kg CO_2 -e per kWh.

Open space adaptation strategies
The following are strategies that may be adopted to reduce the impact of climate change on public open space:

- Select species that are better suited to future climate and also are more water efficient and drought tolerant.
- Reduce supplementary water demand/requirement through mulching, soil improvement.
- Increase the amount of green space, including tree canopy, to moderate high urban temperatures.
- Reduce dependence on potable water supplies.
- Develop alternative water sources including WSUD.
- The increased use of treated water will require consideration of water quality and its compatibility with urban horticulture. Sound water and soil management skills are required to manage this water effectively.
- Protect and improve water quality discharges to the environment/waterways/bays.
- Improve irrigation management practices to ensure efficient water use.

References / Further Information: Section Number 4 - Potential Impacts of Climate Change
• Climate Change in Australia website: http://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/summary-data-explorer/ • Goyder Institute for Water Resources (2014), SA Climate Ready: Climate Projections for South Australia. http://www.goyderinstitute.org/index.php?id=64 Charles SP, Fu G (2015) Statistically Downscaled Climate Change Projections for South Australia. Goyder Institute for Water Research Technical Report Series No. 15/1, Adelaide, South Australia. http://www.goyderinstitute.org/index.php?id=20#Climate • CSIRO (2006) Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance. CSIRO Marine and Atmospheric Research, Aspendale, Victoria http://ccsl.iccip.net/risk-scenarios.pdf • Bureau of Meteorology (2015) *Reference Evapotranspiration for Australia.* http://www.bom.gov.au/watl/eto/ • Bureau of Meteorology (2015) *Climate change and variability. http://www.bom.gov.au/climate/change/* • The Centre for Australian Weather and Climate Research (CAWCR) http://www.csiro.au/en/Research/OandA/Areas/Assessing-our-climate/CAWCR

5.0 Water Supply Options

5.1 Water scene in South Australia
Traditionally South Australia's water supply has been rain dependent and subject to climatic variations. Principle water sources include:

- River Murray
- local catchments
- groundwater
- recycled stormwater
- treated wastewater
- local rainfall
- desalination (2013).

The drought of 2004 – 2010 exposed the vulnerability of South Australia's water security. Lack of available water led to water restrictions and significant reduction in water use. In order to secure Adelaide's water supply, a 100 GL desalination plant was constructed and commissioned in 2013, which is able to supply approximately half of Adelaide's potable mains water demand.

SA Water potable mains water supplies have traditionally been the principle source of water for urban irrigation, followed - to a much lesser extent - by groundwater. Prior to the drought there had been unlimited access to cost effective mains water. Limited availability of mains water and water restrictions during the drought demonstrated the lack of sustainability of potable water for irrigation. Since the construction of the desalination plant in Adelaide, water security is no longer a problem; however, the cost of potable mains water has increased significantly - again making its use for irrigation unsustainable. Alternative water sources include groundwater bores, stormwater harvesting and treated wastewater. A discussion of these water supply options follows.

5.2 SA Water potable mains water
Potable mains water is highly treated water designed for human consumption. It meets stringent quality standards and is a highly valuable resource. It is only in recent years of drought, water restrictions and periods of limited availability that urban irrigators have come to realise the true value of this resource. The cost of mains water has been heavily subsidised in the past by the state government, keeping the price down as it is an essential service.

Sources of potable mains water include the River Murray and local catchments supplying a network of reservoirs. Water is treated and distributed through a network of pipes from Mannum in the Riverland to reservoirs surrounding Adelaide and to as far away as the Upper Eyre Peninsular and the West Coast. In an average year, 40% of Adelaide's water is supplied by the River Murray; however, this percentage increased to 90% during the drought due to lack of rain in the local catchments. Generally, a localised drought will not affect Adelaide's water security, as water can be sourced from the River. However, when a drought extends across the entire Murray-Darling Basin catchment, as was experienced in 2004 – 2010, Adelaide's water security was at risk whereby water may only be available for critical human needs. To ensure water security into the future, the state government developed the *Water Proofing Adelaide Strategy* in 2005 and the subsequent *Water for Good Plan* in 2010. Strategies to secure water supplies in these plans include infrastructure upgrades to reduce leakage, water use efficiency programs, improved management of groundwater and development of alternative water supplies including stormwater harvesting and treated wastewater and the construction of a 100 GL desalination plant. The implementation of these strategies will secure Adelaide water supplies until at least 2050. Significant progress has been made on the actions outlined in the *Water for Good Plan* and the state government is now developing an *Integrated Urban Water Management Plan for Greater Adelaide*. An issues paper, *Transitioning Adelaide to a Water Sensitive City,* was released in October 2014 with consultation taking place in 2015.

However, security of water supply does come at a cost and as a result there has been a 205% increase in the price of potable mains water since 2006. The higher cost of water has meant that local government is not able to return to pre-drought levels of irrigated open space due to budget constraints. The cost increases and financial impact on irrigating a local sports ground are detailed in Tables 5.1 and 5.2.

Table 5.1 Increase in cost of SA Water potable mains water 2006 – 2015

Year	**06/07**	**07/08**	**08/09**	**09/10**	**10/11**	**11/12**	**12/13**	**13/14**	**14/15**
Cost ($/kL)	1.09	1.16	1.38	1.88	2.48	2.75	3.45	3.23	3.32
Variance ($)		0.07	0.22	0.50	0.60	0.27	0.70	-0.22	0.09
Variance (%)		6%	19%	36%	32%	11%	25%	-6%	3%
						Variance 2006 – 2015 ($)			2.23
						Variance 2006 – 2015 (%)			205%

Table 5.2 Impact of increased cost of potable water on sports ground irrigation

Mains water cost (Adelaide) – local football oval (16,000m2)					
Year	Irrigation requirement (kL/ha)	Site area (ha)	Total water requirement (kL)	Water cost ($/kL)	Total cost ($)
2006	5,000	1.6	8,000	$1.09	$8,720
2015	5,000	1.6	8,000	$3.32	$26,560
			Variance 2006 – 2015 ($)		$17,840
			Variance 2006 – 2015 (%)		205%

Future increases in the cost of SA Water potable mains water will be subject to the recommendations of the Essential Services Commission of South Australia (ESCOSA). Pricing will be reviewed and modelled to reflect the full cost of production and supply.

5.3 Groundwater

The geology of South Australia supports the storage and movement of groundwater through aquifers. Ground water is an important non-potable water supply for the Greater Adelaide region including the Northern Adelaide Plains, Western Mount Lofty Ranges and Central Adelaide Plains. In regional South Australia it is the principal water resource in the South East, Eyre Peninsula and the more isolated northern regions of South Australia.

Managing and protecting South Australia’s groundwater aquifers has become increasingly challenging as:

- Climate change and reduced rainfall reduces natural recharge of aquifers.
- Over extraction threatens the sustainability of ground water resources.
- Groundwater levels decline resulting in increased salinity in some aquifers, particularly in coastal regions.

In order to ensure the sustainability of groundwater aquifers, there are eight Natural Resources Management Boards across the state with responsibility for preparing, reviewing and amending Water Allocation Plans (WAP) for prescribed water resources in each region. The WAPs control and manage the use of the water from the prescribed water resource. It is a legal document that sets out the rules for managing a prescribed water source through a system of water licences, authorisations and permits. There are currently 27 prescribed water resources for which 23 have WAPs developed or in development. The remaining four are covered by special regulation. The Adelaide and Mount Lofty NRM Board is currently preparing the Adelaide Plains WAP, which will incorporate the Central Adelaide, Dry Creek and Northern Adelaide Plains Prescribed Wells Areas.

Groundwater will continue to be an important alternative to potable water for the irrigation of urban green space. This resource, however, is not unlimited and will be closely managed into the future through a regulatory framework managed by the appropriate NRM Board.

5.4 Stormwater harvesting

Stormwater harvesting projects range from small, localised sites such as large buildings and carparks where water is stored above ground in tanks or dams to large regional schemes where stormwater is harvested and treated in wetlands and stored in underground aquifers. The water requirement for commercial irrigation is generally high requiring in excess of 1,000 kL per annum. For this reason, underground aquifer storage is preferred. Managed Aquifer Recharge (MAR) and Aquifer Storage and Recovery (ASR) are the terms used for capturing, treating and injecting stormwater into suitable aquifers. Adelaide is fortunate that its geology is suited to these processes.

Development of stormwater harvesting projects is a principle strategy of the *Water for Good Plan*. Federal, state and local governments, together with private investors, have contributed financially to the development of stormwater harvesting projects. Adelaide's stormwater harvesting capacity has grown from approximately 1 GL in 2000 to more than 20 GL in 2014. Large stormwater harvesting schemes have been developed across Adelaide with projects in the north, south, east and west largely managed by local government. There are also many smaller schemes operating across regional South Australia. Major stormwater harvesting projects either completed or under construction in the Greater Adelaide region are detailed in Table 5.3.

Table 5.3 Major stormwater harvesting projects in the Greater Adelaide Region

Project	**Local government authority**	**Total yield (GL)**
Waterproofing Northern Adelaide	Cities of Salisbury, Playford and Tea Tree Gully	8.2 GL
Waterproofing Southern Adelaide Stage 1	City of Onkaparinga	3.6 GL
Waterproofing Southern Adelaide Stage 2	City of Onkaparinga	8.0 GL
Waterproofing the West Stage 1	City of Charles Sturt	2.4 GL
Waterproofing Eastern Adelaide	Cities of Burnside, Norwood, Payneham, St Peters, Campbelltown, Tea Tree Gully and Walkerville	0.5 GL
Oaklands Wetlands	City of Marion	4.0 GL

Stormwater that has been treated, generally through natural processes in constructed wetlands, to appropriate standards is injected and stored in aquifers. The use of this water is regulated in the same way as natural groundwater and is subject to controls set out in the WAPs for the prescribed water resource.

The development of constructed wetlands, stormwater harvesting and aquifer injection and recovery infrastructure provides access to a significant water resource. The benefits also include:

- reduced output of polluted storm water into the marine environment
- enhancement of the urban environment and biodiversity
- recharge of aquifers and reduction in salinity of groundwater
- less reliance on potable water supplies.

Case Study Number 1
City of Charles Sturt – Aquifer Storage and Recovery

Water Proofing the West – Stage One project is creating the first stage of a region-wide system that harvests, treats and stores stormwater and distributes recycled water through western Adelaide, sustaining a growing economy and enhancing the natural environment.

The project will result in sound water management and will treat 2,400 megalitres of recycled water each year. The stormwater collected would otherwise drain untreated into the West Lakes, Port River Estuary, Barker Inlet and metropolitan Adelaide coast further degrading seagrass meadows and polluting Gulf St Vincent's coastal marine environment.

Potential users of the recycled water include irrigation for ovals and reserves managed by the City of Charles Sturt Council, West Lakes Golf Club and the new developments of St Claire, Cheltenham and Woodville West.

For further information refer to the full case study in the appendices or visit the City of Charles Sturt website: http://www.charlessturt.sa.gov.au/wpw

5.5 Treated wastewater

Currently Adelaide recycles 33% of its wastewater, which is more than any other capital city. Regional centres also process and recycle a significant percentage of their wastewater.

Major wastewater treatment schemes include the extension of Bolivar Virginia Pipeline, Glenelg Adelaide Pipeline, Christies Beach and Aldinga Beach Wastewater Treatment Plants. Regional water treatment plants in the Riverland, Victor Harbor, Adelaide Hills, West Coast and smaller isolated communities all contribute to alternative water supplies available for irrigation of urban green space.

There are some barriers to the use of recycled water. High salinity in some areas means that water must be mixed with either potable mains, groundwater or stormwater, although Adelaide treated wastewater is suitable for irrigation at generally <1000 ppm salts. Treated wastewater is primarily used for irrigation, which only occurs during the warmer summer months. This means that this water is unable to be used for a major part of the year in winter.

The use of treated wastewater is subject to compliance with regulations and guidelines that mitigate risks and ensure safe usage for humans. There are national guidelines for the use and management of recycled water: *Australian Guidelines for Water Recycling: Managing Health and Environment Risks, Phase 1* published by NRMMC, EPHC, NHMRC (2006). There are also state guidelines developed by the SA Department of Health: *South Australian Recycled Water Guidelines (2012)*.

Classes of recycled water, general description of treatment and suitability for irrigation usage is detailed in Table 5.4.

Table 5.4 Class and usage of recycled water

Indicative log removal (Virus, Protozoa, Bacteria)	**Microbiological criteria: E.Coli (median org/100mL)**	**Typical treatment process train**	**Scheme class/ type**
Dual reticulation	< 1	Full secondary treatment plus tertiary filtration plus disinfection	Class A
Unrestricted municipal irrigation	< 10	Full secondary treatment plus tertiary filtration plus disinfection	Class A
Municipal use with restricted access and application	< 100	Full secondary treatment plus disinfection	Class B
Municipal use with enhanced restrictions on access and application	< 1,000	Primary sedimentation plus lagooning or full secondary treatment (disinfection if required to meet microbiological criteria)	Class C
Landscape irrigation	< 1,000	Secondary treatment or primary treatment with lagoon detention	Class C
Non-food crops e.g., tress, turf, woodlots	< 1,000	Primary sedimentation plus lagooning or full secondary treatment	Class D

Source: South Australian Recycled Water Guidelines, Department of Health SA. 2012

5.6 Water quality

Where alternative water supply to mains water is being used, it is important to ensure that water quality is acceptable and that Department of Health and Environment Protection Authority requirements are met.

The quality of water used for irrigation will have an impact not only on the plant but also on the soil. The principal considerations in relation to water quality for irrigation are that it:

- is suitable for growing healthy plants
- is suitable for maintaining a healthy soil environment
- is suitable for using in irrigation infrastructure including pumping, treatment, control and application
- is safe for human health
- does not pollute or contaminate the environment including water bodies.

The properties of water listed in Table 5.5 need to be assessed to determine suitability for irrigation.

Table 5.5 Desirable properties of water used for irrigation

Water quality property	Measure	Ideal range
pH		6.0 – 8.0
Salinity (Electrical Conductivity)	dS/m	< 0.8
Salinity (Total Dissolved Salts)	ppm	< 500
Nitrogen	mg/L	< 10
Phosphorous	mg/L	< 0.2
Potassium	mg/L	0.5 - 20
Calcium	mg/L	20 - 60
Magnesium	mg/L	10 - 25
Sulphur	mg/L	10 - 30
Iron	mg/L	2 - 4
Boron	mg/L	< 2.0
Copper	mg/L	< 0.2
Zinc	mg/L	< 2.0
Manganese	mg/L	< 0.2
Aluminium	mg/L	< 5.0
Carbonate	mg/L	< 10
Bicarbonate	mg/L	< 100
Sodium	mg/L	< 70
Sodium Absorption Ratio (SAR)		< 6.0
Residual Sodium Carbonate (RSC)	mq/L	< 1.25
Chloride	mg/L	< 100
Suspended Solids	mg/L	< 50
Turbidity	NTU	< 5.0
Water Hardness	mg/L	< 150

Source: Landschoot P. (2000) *Irrigation Water Quality Guidelines for Turfgrass Sites.* Penn State University – Centre for Turfgrass Science

In addition to the horticultural practices mentioned previously, it is necessary to carry out a range of other practices in order to keep the landscape performing and ensuring resources are used efficiently.

5.7 What water source should be used for irrigation?

Deciding what water source to use for irrigation requires an assessment of the site requirements and availability and suitability of the water. The following characteristics of the water supply options need to be assessed from the perspective of financial, environmental and social sustainability:

- volume of supply
- source water quality
- flow rate
- supply pressure
- availability – timing and duration
- reliability of supply – is a back-up supply required?
- storage requirements
- conditions of use – licence, permit requirements
- regulatory considerations
- human health issues
- impact on the environment
- cost.

Given that all other issues have been considered, cost may be a critical factor in deciding the preferred water source. Capital costs include the development of infrastructure such as storage facilities (wetlands, tanks), pumping stations and delivery systems (pipework). These may be high and in many cases are offset by government funding grants. The initial capital cost is recoverable, where appropriate, over the life of the system, which may be many decades, and is built into the unit cost for the supply of water. In the case of groundwater, there is a minimal unit cost for the access and use of the water and the main costs are ongoing power for pumping and maintenance of bore infrastructure. A guide to the unit cost of each water source is detailed in Table 5.6.

Table 5.6 Comparative unit cost of water supply options

Water source	**Unit cost / kL (2014)**	**Comment**
SA Water potable mains	\$ 3.32 (2014/15)	Includes water from AMLR catchments, River Murray and Adelaide Desalination Plant.
SA Water treated wastewater	\$ 2.10 - \$2.50	Includes water from Bolivar, Glenelg and Christies Beach Sewerage Treatment Plants.
Stormwater recharge and recovery water	\$ 2.10 - \$2.70	Prices vary depending upon local government authority managing the system.
Groundwater bores	\$ 0.50 - \$0.70	Includes nominal NRM charge, operating and maintenance costs.

Note: Unit costs are estimates only and may vary according to supplier.

References / Further Information: Section Number 5 – Water Supply Options

Department of Environment, Water and Natural Resources (2012) *Water Sensitive Urban Design – Creating more liveable and water sensitive cities in South Australia,* DEWNR Adelaide SA
http://www.environment.sa.gov.au/Home/Search_Results?dlv_Site%20Wide%20Search%20Results=%28keyword=Water%20Sensitive%20Urban%20Design%20%29

Department of Environment, Water and Natural Resources (2014) *Transitioning Adelaide to a Water Sensitive City – Towards an Urban Water Plan for Greater Adelaide*. Issues Paper DEWNR Adelaide SA
http://www.environment.sa.gov.au/Home/Search_Results?dlv_Site%20Wide%20Search%20Results=%28keyword=Water%20Sensitive%20Urban%20Design%20%29

Department of Environment, Water and Natural Resources (2011) Stormwater Strategy – The Future of Stormwater Management, DEWNR Adelaide SA
http://www.environment.sa.gov.au/Home/Search_Results?dlv_Site%20Wide%20Search%20Results=%28keyword=Stormwater%20Strategy%20%29

SA Health (2014) *Australian Drinking Water Guidelines (2011) incorporating all updates as at December 2014*. SA Health Adelaide SA
http://www.sahealth.sa.gov.au/wps/wcm/connect/Public+Content/SA+Health+Internet/Protecting+public+health/Water+quality/

SA Health (2012), *South Australian Recycled Water Guidelines*. SA Health Adelaide SA.
http://www.sahealth.sa.gov.au/wps/wcm/connect/Public+Content/SA+Health+Internet/Protecting+public+health/Water+quality/

Environmental Protection Authority South Australia (2003) Environment Protection (Water Quality) Policy 2003 Version: 2.9.2010 EPA Adelaide SA.
http://www.epa.sa.gov.au/environmental_info/water_quality/legislation_and_programs/environment_protection_water_quality_policy

Landschoot P. (2000) *Irrigation Water Quality Guidelines for Turfgrass Sites.* Penn State University – Centre for Turfgrass Science. Pennsylvania USA.

6.0 Best Practice Irrigation Systems

6.1 Statutory requirements
Irrigation systems must comply with the South Australian Water Industry Act and Regulations (2012), which define licensing, technical and safety requirements for water industry entities. The regulations also address protection and use of water infrastructure and equipment.

Considerations include compliance with:

- backflow prevention requirements
- Australian standards for materials and components
- licensing requirements for installation and maintenance personnel.

It is essential that the level of hazard associated with various types of irrigation system installation is assessed and that a registered plumber installs the appropriate backflow prevention device. Hazard levels required backflow prevention devices and installation guidelines are detailed in Australian Standard AS 3500.1.

Consideration needs to be given to the hydraulic properties of the various devices, in particular reduced pressure zone devices (RPZ), which can result in significant pressure losses. The resulting supply pressure losses can adversely affect the performance of irrigation systems.

The Office of the Technical Regulator (OTR) is responsible for compliance with legislation and applicable standards in the water industry to ensure the safety of workers, consumers and property.

Further Information can be accessed at www.sa.gov.au/otr

6.2 Irrigation system design
Irrigation systems must be designed to ensure the efficient, uniform application of water to the site. Design should be aimed at conserving and protecting water resources and take into consideration agronomic, climatic and water supply issues to ensure that the system operates effectively and water is applied efficiently.

Guidelines for the design of urban irrigation systems have been developed by Irrigation Australia Ltd and can be accessed in the IAL publication, *Urban Irrigation Best Management Practice Guidelines (2006).*

It is desirable that the design component is separated from the installation of the system. An irrigation design brief should be prepared to ensure the designer meets all appropriate requirements of the *Urban Irrigation Best Management Practice Guidelines*.

Issues considered in the design should include:

- soil type and structure
- soil infiltration rate and water holding capacity
- plant species
- root zone depth
- average and forecasted climatic data (ETo/rainfall)
- water quality, pressure and flow rate parameters
- scheduling restrictions
- use of technology to enhance water management such as, weather stations, moisture sensors, rain sensors and computerised irrigation management systems.

New irrigation systems should be designed to meet the following irrigation standards:

- A system application rate of between 10 – 20 mm per hour depending on soil properties.
- Lower quarter Distribution Uniformity (DU) measure of > 85%, which must equate to a field DU > 75%. DU is the unit of measure used to determine the performance of turf irrigation systems. DU is defined as the average water applied in the 25% of the area receiving the least amount of water, regardless of location within the pattern, divided by the average water applied over the total area.

Design documentation should include:

- irrigation plans
- design parameters (flow, pressure, DU, precipitation rate)
- installation specifications including component specifications to meet appropriate Australian standards
- quality control inspection procedures
- water budget
- irrigation schedule.

Irrigation systems should be designed by qualified irrigation designers (refer to Section 13.0 – Training and Certification).

6.3 Importance of high-quality design and uniformity of application
The capacity to apply water precisely, according to plant demand, is essential.

Some of the consequences of poorly designed irrigation systems include:

- uneven grass and/plant growth
- bare patches
- poor playability – uneven, bare ground
- increased risk of weed infestation
- leaching of nutrients in over-watered areas
- groundwater contamination risks through overwatering in parts
- wastage of water
- loss of visual amenity
- lack of control of water application.

The consequences of poor performance have significant resource implications for the management of the site, including:

- increased time to maintain the area
- reduced usability of the space
- increased water costs
- increased time to manage/service clients – due to unsatisfactory site performance
- reduced revenue from use and events.

Examples of poor design are:

- excessive sprinkler spacing
- inadequate pipe sizes
- insufficient capacity
- inadequate zoning.

6.4 Tender evaluation
Following approval of the irrigation system design, tenders should be called for the installation of the system. The tender evaluation process should consider both non-financial and financial aspects of the proposal. A potential consequence of adopting a lowest-cost tender for an irrigation system is that some aspects of performance will be sacrificed. This is false economy.

Non-financial considerations include:

- contractor's skill and experience; reference checks should be made to ensure the contractor has a history of high-quality work at a commercial level
- all workplace safety requirements are met
- materials and products to be used meet the appropriate standards as specified and are not replaced with cheaper alternatives.

Where organisations have many sites requiring irrigation upgrades or new installations, it is good practice to have a list of pre-qualified irrigation installation contractors with demonstrated performance in the areas previously listed.

6.5 Irrigation system installation
Correct installation of an irrigation system is critical to ensure optimum performance and the achievement of design objectives. Guidelines for the installation of urban irrigation systems have been developed by Irrigation Australia Limited(IAL) and can be accessed in the IAL publication *Urban Irrigation Best Management Practice Guidelines* (2006).

Installation should be carried out by experienced, qualified irrigation installation contractors or personnel (refer to Section 13.0 – Training and Certification).

Supervision should be carried out by a suitably experienced and qualified supervisor or project manager (refer to Section 13.0 – Training and Certification).

Installation should be in accordance with the irrigation design and technical specification. All components and fittings must meet specified standards. Quality of installation should be checked with stop points signed off at specified stages of the project.

Installation inspection points to include checks of:

- materials and fittings comply with specified Australian standards and codes of compliance
- trench alignment, depth and pipe coverage prior to backfill
- valve and valve box installations
- extra low voltage wiring (24 volt) meets specification
- sprinkler installation and placement
- construction and installation of all thrust blocks
- pressure test all mainlines according to the specification.

At completion of installation, the contractor should provide:

- a system compliance report detailing any deviations from the original design specification
- a constructed irrigation system plan detailing any changes to original design layout
- all product operating manuals and warranties.

Prior to final handover, the project supervisor or an independent third party should provide an irrigation audit report in accordance with Certified Landscape Irrigation Audit standards. Critical factors include:

- system compliance reports detailing sprinklers, valves and components
- installation conforms to design and technical specification
- operating pressures and flows
- field operational DU > 75%
- a water budget and irrigation schedule to meet average climatic conditions.

Any faults identified should be rectified by the contractor prior to handover of the system.

6.6 Irrigation system maintenance

In order for the irrigation system to continue to perform to design standards in relation to distribution uniformity, application rates and overall irrigation efficiency, it is critical that effective maintenance practices are put in place. Guidelines for the maintenance of urban irrigation systems have been developed by IAL and can be accessed in the publication *Urban Irrigation Best Management Practice Guideline*s (2006).

Irrigation system maintenance must be undertaken by suitably experienced and qualified irrigation maintenance personnel (refer to Section 13.0 – Training and Certification).

Maintenance should be programmed to ensure the system operates to design specifications and should include:

- periodic checks of pressure and flows to ensure they are within acceptable ratings for system operation
- periodic checks of system components, i.e., sprinklers, valves, controller, pumps, filters, sensors, to ensure they operate to manufacturer and design specifications
- periodic lifting and adjustment of sprinkler heads to ensure they are set and aligned as specified
- periodic clearance of vegetation around sprinkler heads
- replacement of all worn parts with those matching system requirements in accordance with the original design specifications
- operation during the non-irrigation season, periodically for a short duration, to flush system and operate components.

6.7 Irrigation system performance and auditing

An irrigation audit in accordance with Certified Landscape Irrigation Audit standards should be undertaken every three to five years to ensure efficient system performance, distribution uniformity and irrigation application rates are as originally specified.

The plant water requirement will be the same for similar sites in similar locations; however, the performance of the irrigation system may vary significantly. Actual system performance could be as low as DU 40 – 50%. This could result in the need to apply up to twice as much water than required, to account for system inefficiencies and ensure the driest sections of turf receive adequate irrigation.

In reality, due to low application rates and restricted timing of irrigation events, it is often not possible to compensate for poor system efficiency by applying the additional water required. This results in poor turf condition and may jeopardise the fit-for-use quality standards of the sports turf.

No allowance has been made for poor system application efficiency in the benchmarks developed in the Code, as it is considered fundamental that systems should be designed, installed and maintained to high standards. Where systems have a DU < 75%, an upgrade or replacement is advised.

References / Further Information: Section Number 6 – Best Practice Irrigation Systems

Connellan, G. 2013. *Water Use Efficiency for Irrigated Turf and Landscape,* CSIRO Publishing Victoria Aust. http://www.publish.csiro.au/pid/5263.htm

Cape, J. *Urban Irrigation, Best Management Practice Guidelines,* Irrigation Association limited, NSW, 2006. www.irrigation.org.au

Cape, J. 2004. *Certified Landscape Irrigation Auditor Resource Manual.* Irrigation Association of Australia, NSW. www.irrigation.org.au

Information on Certified Irrigation Designer, Certified Irrigation Operator / Installer and Certified Irrigation Agronomist accreditation can be found at www.irrigation.org.au

Water Industry Act 2012 SA / Office of the Technical Regulator www.sa.gov.au/otr

7.0 Turf and Landscape Outcomes

7.1 Landscape outcome approach

The starting point when considering the development or ongoing maintenance of any urban landscape area that is to be irrigated is the identification of the function or outcome to be provided by that space. This outcome may be aesthetic, functional (shade), active use (sports ground), passive recreation (picnics, playgrounds), environmental modification (urban heat island effect mitigation), preservation of cultural or heritage values or conservation of botanical collections.

Clear identification of the landscape outcome, including detailing of the standards, qualities and properties to be achieved, is the first step. This requires extensive consultation with all stakeholders including urban planners, landscape architects, horticulturalists, service managers, asset managers, maintenance personnel, sports and recreation management professionals and site users. Examples of landscape outcomes include:

- the provision of a safe turf playing surface for contact sport
- a floral display planting of high aesthetic quality
- street trees that provide high aesthetic quality, shade and microclimate cooling
- border plantings that provide a visual barrier
- treed parkland with grass of good aesthetic quality, suited to passive recreation use
- a cemetery garden that provides a space for reflection, a sense of peace and high overall amenity.

In determining the landscape outcome, the principles of WSUD should be a fundamental consideration so that the design and planning takes into account the issues of sustainability and an integrated approach to water-cycle management, where rainfall and runoff is an integral part of the landscape planning.

Having determined the landscape outcome of the site, the landscape design including plant selection is undertaken to deliver the required outcome. Once design is completed, the ongoing maintenance inputs including the amount of water required by the plants to achieve the required outcome can be determined. The driver of the process is the required performance or outcome of the site.

To determine the turf and landscape outcome in general terms we need to revisit the original aim of this Code, which is to achieve functional urban green space that provides benefits for the community and is sustainable.

The important elements in this aim are that the space is functional, it delivers the desired outcome, it provides benefits to the community and it is sustainable in the long term. A clear identification of the functional objectives and desired outcomes of the site is critical.

7.2 Turf quality – fit for purpose

Turf should be maintained to meet quality and risk management standards appropriate for its intended use. Sporting club administrators and ground managers have a duty of care to all persons using these facilities. This means that sports facilities, including the turf surface, must not present an unacceptable risk of injury to those using the facilities. Sports turf surface outcomes can range from very high quality sites hosting elite competition to sites hosting local level senior and junior competition. All sites need to be safe and fit for purpose; however, standards and the cost of construction and maintenance will vary. Sites hosting elite sporting competition, such as the Adelaide Oval, must adhere to the highest surface standards appropriate for elite athletes, a high speed and high intensity competition and international media exposure. Local level competition venues, managed largely by local government or sporting clubs, need to be safe, but do not require the same quality standards as the elite venues, as the intensity of competition is less and the usage is often very high with large numbers of the community participating and using the facilities.

Passive turf areas have different risk and quality standards than active sports grounds. The standard of turf and surface for the desired outcome can be very high, as in the case of sites of national or state tourism significance such as the Botanical Gardens or standards can be reduced in the instance of a local neighbourhood park.

The standard to which turf is maintained has significant impact on water usage, maintenance inputs and overall budget requirements. Turf must be maintained at a level that ensures safety for users and meets the functional objective or desired outcome of the site.

7.3 Turf species selection

Warm-season turf grasses (Kikuyu or Couch) use from 30% – 50% less water than cool-season turf grasses (Fescues, Ryes). The drought tolerance of warm-season grasses is significantly higher than the cool-season grasses. Turf species should be selected to meet the functional objective while minimising water use. Table 7.1 summarises the characteristics of various turf-grass species.

Table 7.1 Turf grass characteristics including information on climate tolerance and usage

Turf grass	Turf type	Water use	Drought tolerance	Wear tolerance	Shade tolerance	Salinity tolerance	Fertiliser requirement	Use
Couch	Warm season	Low	Excellent	Good	Poor	Very good	High	Sports grounds, parks, lawns
Kikuyu	Warm season	Medium	Good	Excellent	Fair	Good	Low	Sports grounds, parks
Buffalo	Warm season	Medium	Fair	Poor	Good	Good	Medium	Lawns
Seashore Paspalum	Warm season	Low – medium	Good	Fair	Fair	Excellent	Medium	Foreshore, parks, lawns
Ryegrass	Cool season	Very high	Poor	Good	Fair	Fair	Medium – high	Over sowing, sports grounds, lawns
Bentgrass	Cool season	Very high	Poor	Fair	Fair	Good	High	Golf greens
Tall Fescue	Cool season	Very high	Poor	Fair	Fair	Good	Medium	Lawns

Source: Ruscoe P, Johnson K, McKenzie G (2004)

Warm-season turf grasses (Kikuyu or Couch) should be used as the predominant turf grass species for irrigated turf in South Australian conditions.

Where turf is subject to intensive winter activity such as football, over sowing warm-season turf grass in autumn with a cool season turf species, such as a transitional ryegrass, will improve wearability and recovery during the cooler months. It is important to eradicate ryegrass using a selective herbicide in spring prior to the break of dormancy of the warm-season turf to assist in the recovery of the warm-season turf grass and to reduce the water requirement during the summer period.

7.4 Turf standards/risk management
Different uses for turf require different quality standards. The requirements for active competitive sport are different from passive recreational turf. While some sporting associations have guidelines for turf construction and maintenance standards, these vary significantly between grades of competition and sporting codes. There are pre-match checklists available for active sports turf, which provide guidance in relation to appropriate standards and risk management assessments.

Ground management authorities must ensure that they have met their duty of care in the provision of safe turf surfaces used by the community. Turf quality and risk management standards should be developed and include the following criteria:

- the desired turf outcome (refer to TQVS Classification Section 7.5)
- turf grass vigour and density
- evenness of turf surface
- presence of divots, pot holes
- presence of sunken or raised sprinkler heads
- traction and shear strength of the turf
- ground hardness and impact severity
- cutting height of turf
- presence of weed species or pest infestation
- associated infrastructure such as goal posts, coachs' boxes, fences, etc., should also be assessed for safety.

The quality and risk standards should be detailed in a quality and risk audit checklist, which is used by the organisation and the users to ensure risks have been identified and appropriate controls have been put in place. A risk assessment of the turf surface should be undertaken weekly for active sports and a quality audit undertaken monthly to monitor wear trends and turf quality.

The risk management process is as important as the assessment criteria. While the criteria may change the process by which hazards are identified and risks rated must be consistent across all codes of sport, the Australian Standards *AS / NZS ISO 31000:2009 Risk Management – Principles and Guidelines* and *HB 246:2004 Guidelines for Managing Risk in Sport and Recreation* provide a framework for risk management.

7.5 Turf classification system – turf quality visual standards
In order to determine the required outcome for a turf surface, the Turf Quality Visual Standard (TQVS) Classification System has been developed. This system classifies turf sites according to the intended function and the fit-for-purpose outcome. Each site is classified according to its intended use, the turf, surface and aesthetic quality required.

Classification of sites is not prescriptive and is subject to management discretion. It can be influenced by management priorities or community pressure to raise standards; if this is appropriate, a management decision can be made in relation to the desired outcome of a site and its appropriate classification.

The TQVS classification matrix in Table 7.2 details the description, example sites and applicable quality standards of each turf classification.

Table 7.2 TQVS classification matrix

TQVS classification	Description	Example	Turf quality	Aesthetics	Surface quality	TQVS example
TQVS 1	Elite sports turf Passive recreation/tourism sites of national or state significance	Adelaide Oval Botanic Gardens Veale Gardens Victoria Square	Highest turf quality High vigour and turf health	Highest visual quality Suitable for televised events	Highest surface quality Even coverage and density with no depressions or divots	
TQVS 2	Premier sports turf Passive recreation/tourism sites of state or regional significance	SANFL Oval A-grade cricket ground Premier-league soccer Glenelg foreshore	High turf quality High vigour and turf health Turf quality may be reduced with winter wear	Medium - high visual quality	High surface quality Even coverage and density Surface quality may be reduced with winter wear	
TQVS 3	Local sports turf Passive recreation sites of local community significance	Local sports ground Community park	Medium turf quality Medium vigour and turf health Turf quality may be reduced with winter wear	Medium visual quality Aesthetics have less importance Must be fit for purpose	Medium surface quality Even coverage and density Surface quality may be reduced with winter wear	
TQVS 4	Passive recreational turf	Local neighbourhood park Playground Surrounds Local picnic area	Low - medium turf quality Low - medium vigour and turf health	Lower visual quality Aesthetics have less importance Needs to be attractive to visit and use	Low surface quality Variable coverage and density but free from trip hazards	

7.5 Landscape quality

A landscape planting site may be a combination of turf, trees, shrubs and gardens beds. The turf outcome and quality has been discussed. In relation to the trees and plants as elements of the landscape, there can be a variety of desired outcomes. Examples of landscape outcomes have been outlined in Section 7.1.

The core quality requirement is for healthy vegetation that meets the desired outcome, be it shade, high aesthetic appearance of formal gardens beds, effective screen for visual amenity or noise reduction or a low maintenance native bushland. Some landscapes may need high irrigation and maintenance inputs to achieve acceptable plant health and vigour while others may need only establishment irrigation and little ongoing maintenance. The level of inputs and costs of ongoing maintenance of the landscape must be relative to the desired outcome and community benefit.

From a risk management perspective, use of the space must be safe and not pose a health or property risk to the community. Generally, feature gardens or shrubs pose little health risk; however, trees have the potential to cause major health trauma or property damage and must be managed to ensure risks are minimised. Tree management is a specialised area that requires specific policies and risk management systems that are not addressed in this Code of Practice; suffice it to say that a sound risk management process should be implemented to ensure trees are healthy and all reasonable steps are taken to mitigate risk to health or property. Further information in relation to tree management can be accessed through Arboriculture Australia Ltd at www.arboriculture.org.au or Treenet at www.treenet.org

7.6 Landscape species selection

Landscape plant species can be classified into a number of categories in relation to their botanical attributes, provenance, floral attributes, size, salt tolerance, water requirement and drought tolerance. When selecting a species of plant it is important to consider the desired landscape outcome and the site conditions in which the plant will grow. Factors that need to be considered include:

- climate of the area
- micro-climate of the site
- site soil and geology
- topography – site aspect and drainage
- surface treatments – pavement, mulch, etc.
- site use – wear factors, desire lines, compaction, risk of injury or damage.

Floral displays such as rose gardens or annual beds may require high inputs of water and maintenance, while shrub screens or street trees may only require establishment watering with little ongoing maintenance. Water use efficiency is a principal consideration in the selection of plants for a sustainable landscape.

The primary requirement is that the landscape provides the desired performance or outcome. If this can be achieved with species that have a low water requirement, then this contributes to the sustainability of the landscape. The selection of plants that satisfy both the low water requirement criteria and specific site conditions may involve professional horticulturalists, landscape designers and water-use experts to develop a sustainable solution.

There are broad guidelines for the selection of plants with low water requirements and drought resistance. This includes the selection of native plants indigenous to the area and plants that have inherent low water use and drought-tolerant characteristics.

There are plant lists available from the Adelaide Botanic Gardens, various plant societies and associations (Society for Growing Australian Plants, Sustainable Gardening Australia, Greening Australia), nursery associations (Nursery and Garden Industry Association) and SA Natural Resource Management and State Flora.

The University of California developed the Water Use Classification of Landscape Species (WUCOLS), which classifies more than 3500 plant species in relation to water requirements to maintain acceptable health and vigour. Categories are as follows:

- high - species require the greatest amount of supplementary water in summer
- moderate - species require lesser amount of supplementary water in summer
- low - species perform well with small amount of supplementary water
- very low - species require no supplementary water except in years of significant below-average rainfall.

While the WUCOLS system is specific to Californian climate and conditions, it serves as a valuable reference guide for plants in similar climatic regions such as Adelaide. A plant list for Australian conditions based on the WUCOLS system has been developed using the University of Melbourne, Burnley plant database.

A selection of urban plants, approximately 200, is available in the publication *Water Use Efficiency – for Irrigated Turf and Landscape* authored by Connellan, G, published by CSIRO Publishing (2013).

References / Further Information: Section Number 7 – Turf and Landscape Outcomes
• Connellan, G. 2013. *Water Use Efficiency for Irrigated Turf and Landscape,* CSIRO Publishing Victoria, Australia. http://www.publish.csiro.au/pid/5263.htm • Ruscoe P, Johnston K, McKenzie G (2004) *TurfSustain: A Guide to Turf Management in Western Australia* Sports Turf Technology, Como, WA • Costello LR and Jones KS (2000) *Water Use Classification of Landscape Species – A Guide to the Water Needs of Landscape Plantings in California – The Landscape Co-efficienct Method and WUCOLS III.* Department of Water Resources. Sacramento, California, USA http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.water.ca.gov%2Fwateruseefficiency%2Fdocs%2Fwucols00.pdf&ei=QoVQVYybCo_78QW3i4GwAw&usg=AFQjCNFlb1Hz0rlA-9R0w2u4_wgPSeL0JA&bvm=bv.92885102,d.dGc • Aboriculture Australia Ltd website: www.arboriculture.org.au • Treenet website: www.treenet.org • South Australian native plants: http://www.naturalresources.sa.gov.au/adelaidemtloftyranges/plants-and-animals/native-plants-animals-and-biodiversity/native-plants • State Flora: http://www.stateflora.sa.gov.au/home

8.0 Plant Water Use/Water Budget

8.1 Plant water use knowledge is essential
Knowing the amount of water used by plants is fundamental to the sound management of landscapes in the urban environment. Without this knowledge irrigation management is a matter of guesswork rather than informed decision making. Landscape irrigation managers need to be knowledgeable about the amount of water used, the factors that influence plant water use and the landscape performance of the site.

The reasons for knowing the amount or volume of water required include:

- the irrigation design must match the peak water demand for the site
- irrigation scheduling should match the site water budget
- reporting on the water use efficiency requires the actual water used and the plant irrigation requirement to be known
- financial budgeting and reporting requires knowledge of the amount of water required, actual usage and the cost of this water.

Knowledge of landscape water requirement and consumption is not an option. It is a necessity for sound site water and financial management.

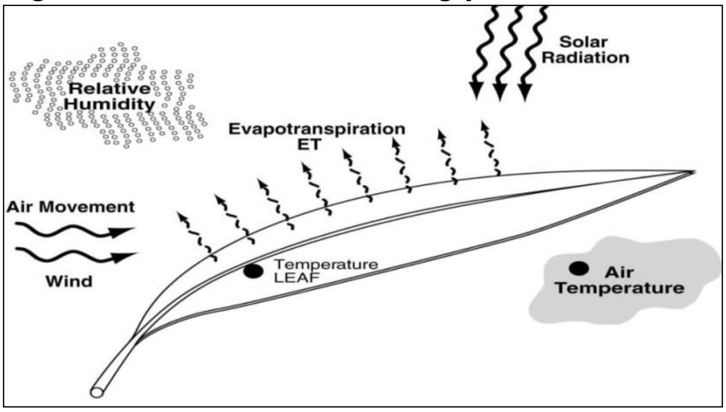
8.2 Plant water use
The movement of water from the soil through the plant to the atmosphere is a complex process. The basic principles are that water is used by plants to transport nutrients from the soil water throughout the plant where they combine with carbon dioxide and sunlight to produce sugars essential to plant growth. This process is called photosynthesis. Evaporation of water via the leaf stomata cools the plant. The process by which plants use water is referred to as transpiration. The water use or transpiration rate varies for different plant species and under different environmental conditions.

Water also evaporates from the soil surface around and in between the plants. The combined process of plant water use and evaporation from the soil is called evapotranspiration (ET). ET is expressed as millimetres per a given time period (e.g., mm/year, mm/month, mm/week or mm/day).

The main driving force that determines plant water use is the evaporation potential of the atmosphere surrounding the plant foliage. The following climatic factors directly influence the rate of ET:

- air temperature
- relative humidity
- solar radiation
- wind speed.

Figure 8.1 Factors influencing plant water use



(Source: G&M Connellan Consultants)

While ET - mm/day is the measure of plant water use, different plants use water at different rates depending on the growth phases. Warm-season turf grasses use less water than cool-season turf species. Drought tolerant landscape plants use less water and are more efficient in water use than many exotic species.

8.2.1 Reference evapotranspiration (ETo)

A reference evapotranspiration (ETo) value has been developed to which varying crop co-efficient values are applied to determine specific plant water use (ETc) rates.

The methodology for calculating ETo is detailed in the *FAO Irrigation and Drainage Paper No 56 – Crop Evapotranspiration* (Allen 1998). This methodology uses a hypothetical reference crop of a cool-season pasture grass growing in an open area to a height of 12 cm, which covers the ground and is supplied with adequate water. ETo is calculated by the BoM and is published on its website (http://www.bom.gov.au/watl/eto/) or can be accessed from private weather stations in regional areas where the BoM does not have stations. A table of monthly ETo data for Adelaide Airport BoM weather station from 2007 to 2015 is available in the appendices.

8.2.2 Crop evapotranspiration (ETc)

The water requirement for a specific crop or plant species is called the crop evapotranspiration (ETc). The reference crop used to calculate ETo is a high water usage species; other plant species will use water at a lower or proportional rate to the reference crop so it is necessary to apply a co-efficient value to the ETo to calculate the proportion of water used by a specific plant species compared to the reference crop. The ETc is calculated using specific crop or species co-efficient (Kc) values, which reflect the influence of different crop specific factors that impact on plant water use (e.g., crop height, ground cover, leaf area, stomata behaviour).

The calculation to determine the crop evapotranspiration (ETc) rate is:

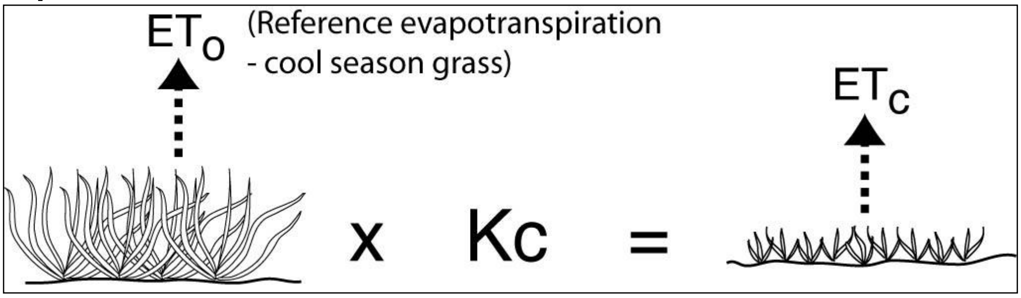
ETc = ETo x Kc

Where:

- Etc = crop or plant species evapotranspiration
- ETo = reference evapotranspiration
- Kc = crop or species co-efficient used to adjust the ETo rate.

The crop evapotranspiration for turf species (ET_T) and for mixed landscape plantings (ET_L) is calculated in different ways. These are described below:

Figure 8.2 The reference evapotranspiration (ETo) and crop co-efficient (Kc) expression



(Source: G&M Connellan Consultants)

8.2.3 Turf Evapotranspiration (ET_T)

The calculation for the Turf Evapotranspiration (ET_T) is:

ET = ETo x Tscx Tws

Where:

- ET_T = turf evapotranspiration (mm)
- ETo = reference evapotranspiration (mm)
- Tsc = turf species co-efficient (decimal factor)
- Tws = turf water stress factor (decimal factor).

Reference evapotranspiration (ETo) is calculated according to FAO-56 and is available from the BoM web site (http://www.bom.gov.au/watl/eto/) or private weather stations.

As the water requirement varies for different turf species under different growth conditions, the ETo must be converted to evapotranspiration for a specific turf species (ET_T). A turf species co-efficient (Tsc) is required to covert ETo to ET_T.

Turf species co-efficient values (Tsc) are different for warm- and cool-season turf grass species. Field trials have been conducted that show that warm-season turf grasses use approximately 60 – 80% and cool-season turf grasses use 80 – 95% of ETo depending on the growth phase of the plant.

Table 8.1 Turf species co-efficient values (Tsc)

Turf Type	**Warm-season turf grass Couch sp. / Kikuyu**	**Cool-season turf grass Rye sp. / Bluegrass / Fescue**
Turf species co-efficient (Tsc)	0.6 - 0.8	0.8 - 0.95

A Tsc of 0.7 has been used in calculations in the Code; however, this can be altered by the irrigation manager where it is deemed that there is less water use on the fringe of the irrigation season (spring and autumn) or for different growth phases of the plant. Monthly Tsc values have been calculated for a variety of turf species by the Centre for Irrigation Technology, University of California. These values are detailed in Table 8.2.

Table 8.2 Variable turf species co-efficient values for turf-grass species to account for seasonal and growth phase water use

Turf	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Couch (WS)	0.55	0.54	0.76	0.72	0.79	0.68	0.71	0.71	0.62	0.54	0.58	0.60
Kikuyu (WS)	0.55	0.54	0.76	0.72	0.79	0.68	0.71	0.71	0.62	0.54	0.58	0.60
Buffalo (WS)	0.55	0.54	0.76	0.72	0.79	0.68	0.71	0.71	0.62	0.54	0.58	0.60
Bentgrass (CS)	0.61	0.64	0.75	1.04	0.95	0.88	0.94	0.86	0.74	0.75	0.69	0.60
Bluegrass (CS)	0.61	0.64	0.75	1.04	0.95	0.88	0.94	0.86	0.74	0.75	0.69	0.60
Tall Fescue (CS)	0.61	0.64	0.75	1.04	0.95	0.88	0.94	0.86	0.74	0.75	0.69	0.60
Ryegrass (CS)	0.61	0.64	0.75	1.04	0.95	0.88	0.94	0.86	0.74	0.75	0.69	0.60

- CS = cool season turf; WS = warm season turf
- The values have been transposed to reflect seasonal months in the Southern Hemisphere

Source: Adapted from CIT (2011)

Variable Tsc values can be used in the fine tuning of irrigation scheduling so that the water requirements for each growth phase is represented with a specific value for each month or period of the irrigation season. Generally, a Tsc of 0.7, which is maintained constant for the irrigation season, is acceptable for warm-season turf but can be altered at the discretion of the irrigation manager.

A turf water stress factor (Tws) is applied where a management decision has been made to reduce the vigour and quality of the turf grass according to the use of the area to promote efficient use of water. As detailed previously, irrigated public open space can be classified into four TQVS standards depending upon the function and required standard of the turf surface. The Tws effectively reduces the irrigation requirement to achieve the appropriate functional outcome of the turf. Turf water stress factors for turf are listed in Table 8.3.

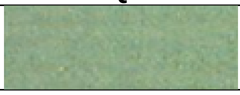
Table 8.3 Turf grass crop stress factors (Tws)

TQVS Cat.	**TQVS 1**	**TQVS 2**	**TQVS 3**	**TQVS 4**
TQVS example				
Turf water stress factor (Tws)	1.0	0.6	0.5	0.4

The Tws factors are a guide only and can be altered at the discretion of the irrigation manager to achieve the desired turf outcome.

When the Tsc is multiplied by the Tws, a combined turf co-efficient (Tcws) value is the result. Combined turf co-efficient values for warm-season grass (Kikuyu) for all TQVS categories are detailed in Table 8.4.

Table 8.4 Turf co-efficient values for turf quality visual standards (warm-season grass)

TQVS Cat.	TQVS 1	TQVS 2	TQVS 3	TQVS 4
TQVS Example				
Description	• Elite sports turf • Passive recreation/tourism sites of national significance	• Premier sports turf • Passive recreation/tourism sites of state or regional significance	• Local sports turf • Passive recreation sites of local community significance	• Passive recreational turf • Local neighbourhood park
Warm-season turf co-efficient (Tsc)	0.7	0.7	0.7	0.7
Turf water stress factor (Tws)	1.0	0.6	0.5	0.4
Combined turf co-efficient (Tcws)	0.70	0.42	0.35	0.28

The calculation for a plant water use or evapotranspiration (ET_T) for turf grass is:

ET_T = ETo x Tc x Tws

Below are examples of the calculation of water requirement for different turf sites:

Example 1 – AFL football/cricket oval used for state level competition (TQVS 2 - SANFL/A-Grade Turf Cricket)

ETo for January – 52.5 mm/week (BoM average 2007 – 2015 Adelaide Airport)

ET_{TQVS2} = ETo x Tsc x Tws
= 52.5 x 0.7 x 0.6
= 22 mm/week

Example 2 – AFL football/cricket oval used for local-level competition (TQVS 3 – Local football/hard wicket cricket)

ETo for January – 52.5 mm/week (BoM average 2007 – 2015 Adelaide Airport)

ET_{TQVS3} = ETo x Tsc x Tws
= 52.5 x 0.7 x 0.5
= 18.4 mm/week

8.2.4 Landscape evapotranspiration (ET_L)

Landscape evapotranspiration (ET_L) is the expression used for the evapotranspiration rate for the plant water use of a mixed landscape planting. The calculation of ET_L is more complex than that for a single species crop or monoculture of turf grass. The factors that need to be considered include:

- plant species: landscape planting may be mixture of species including ground covers, shrubs and trees with a variety of water use characteristics

- planting density: the influence of the foliage coverage of the site and the degree of multi-tiered plantings such as trees or shrubs with understorey plantings; the density of planting can vary from sparse, open plantings that leave a high proportion of the soil surface exposed to dense multi-tiered plantings that cover the entire soil surface
- microclimate: the influence of site-specific conditions such as shade, wind, exposure or thermal radiation from buildings or surrounding concrete surfaces.

To account for these variables, a number of factors are used to calculate the proportion of ETo used by a mixed landscape planting. There has been significant research into the appropriate plant species co-efficient values used in agriculture and turf; however, due to the diversity of landscape plantings there is limited information available.

The *Water Use Classification of Landscape Species – A Guide to the Water Needs of Landscape Plants (Costello and Jones 2000)* has developed a methodology for the calculation of landscape co-efficient (K_L) values that can be applied to ETo to calculate the proportion of water used by a mixed landscape planting compared to the reference crop. The landscape co-efficient is made up of a combination of factor values that account for all the variables that influence the water requirement of a group of plants.

The calculation of the landscape evapotranspiration (ET_L) is: $ET_L = ETo \times K_L$.

Where:

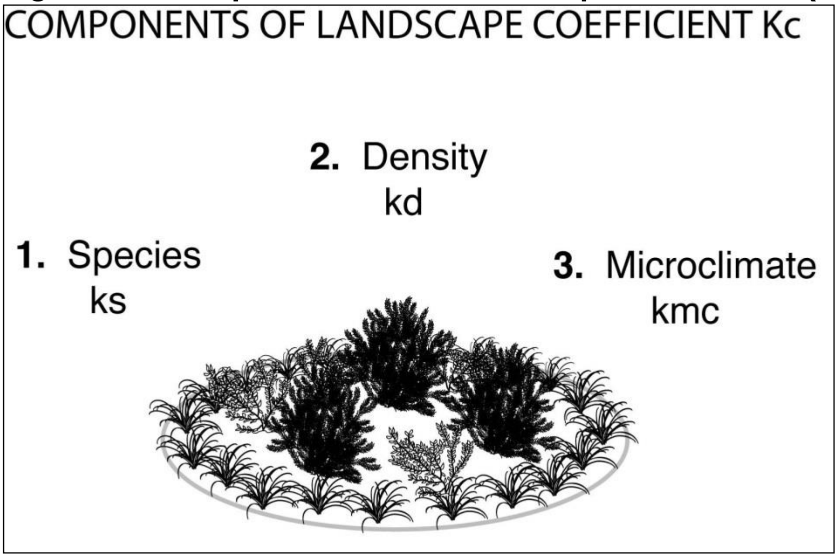
- ET_L = landscape evapotranspiration (mm)
- ETo = reference evapotranspiration (mm)
- K_L = landscape co-efficient (decimal factor).

The calculation of the landscape co-efficient (K_L) is: $K_L = Ks \times Kd \times Kmc$.

Where:

- K_L = landscape co-efficient (decimal factor)
- Ks = species factor (decimal factor)
- Kd = density factor (decimal factor)
- Kmc = microclimate factor (decimal factor).

Figure 8.3 Components of the landscape co-efficient (K_L)



(Source: G&M Connellan Consultants)

Species factor (Ks)
The species factor accounts for the differences in water needs of plant species. Water needs may range from low for drought tolerant plants to high for plants that require large amounts of water for healthy growth. Species factor values have been assigned to different water-need categories of plants through an evaluation based on field observations.

Table 8.5 Plant species factor (WUCOLS)

Plant water use category	Species factor (Ks)
Very Low (VL)	0.0 - 0.1
Low (L)	-0.3
Moderate (M)	0.4 - 0.6
High (H)	0.7 - 0.9

To determine the water-use category of a particular plant species, refer to plant list resources in Section 7.6. Table 8.6 provides an example of plant water use categories of a selection of commonly used plants.

Table 8.6 Examples of specific plant water use categories and corresponding species factors

Common name	Botanical name	Plant type	Water use rating	Species factor (Ks)
Ash (golden)	*Fraxinus excelsior*	Tree	M - H	0.7
Bottlebrush (weeping)	*Callistemon viminalis*	Tree	L - M	0.4
Abelia (glossy)	*Abelia x grandiflora*	Shrub	L - M	0.4
Correa (white)	*Correa alba*	Shrub	VL	0.75
Hydrangea (oakleaf)	*Hydrangea quercifolia*	Shrub	H	0.8
Gardenia	*Gardenia augusta*	Shrub	M	0.5
Pittosporum (diamond leaf)	*Pittosporum rhombifolium*	Shrub	L - M	0.4
Star Jasmine	*Trachelospermum Jasminoides*	Groundcover	L - M	0.4
Convolvulus (morning glory)	*Convolvulus sabatius*	Groundcover	L	0.3

The allocation of species factor values is at the discretion of the irrigation manager with local knowledge of specific plant water needs. Where there is little or no experience of a plant species, the mid-range value would be selected and adjusted in response to plant performance.

Where there is a landscape planting, with mixed species in the same irrigation zone, the species factor (Ks) for the highest water use rating plant must be used to ensure that all plants have adequate water for healthy growth. In this situation, if some of the plants are low water use species, then there is the risk of over watering resulting in plant damage. It is important to match the plant species used in a mixed planting to ensure that the water needs of the various plants are compatible.

Density factor (Kd)

The density factor adjusts the estimated water demand, where the demand is significantly increased or reduced due to the density of the plantings and foliage coverage. This considers the collective canopy cover or leaf area of all plants in the landscape and the impact of multiple tiers of vegetation including ground covers, shrubs and trees in a mixed planting. The more dense the canopy cover and the more tiers of vegetation, the higher the water use and corresponding density factor.

A guide to landscape density factors developed by WUCOLS is detailed in Table 8.7.

Table 8.7 Plant density factors (WUCOLS)

Density rating	Description	% of cover	Density factor
Low	Sparse leaf coverage of the area or less % cover than for average rating	Shrubs/groundcovers < 90% Trees < 70% Mixed plantings < 70%	0.5 – 0.9
Average	High percentage of leaf coverage of the area Generally one plant type with moderate tiers of vegetation	Shrubs/groundcovers 90-100% Trees 70–100% Mixed plantings 70–100%	1.0
High	Full canopy cover with multi-tiers of dense vegetation	100% canopy cover with multi-tiers of vegetation	1.1 – 1.3

The allocation of a density factor value is at the discretion of the irrigation manager. The density factor will generally be at an average rating of 1.0 unless there are obvious variations in density cover and tiers in the vegetation. The Irrigation Association USA has developed density factors for different plant types using an adaption of the WUCOLS rating system.

Table 8.8 Density factor (Kd) for different plant types

Plant type	25 – 50% ground cover	50 – 75% ground cover	Greater than 75% ground cover
Low-growing plants <400 mm	0.35 – 0.45	0.60 – 0.75	0.80 – 0.95
Small shrubs approx. 1 m high	0.35 – 0.50	0.70 – 0.80	0.85 – 0.95
Large shrubs / trees <4 m	0.40 – 0.55	0.75 – 0.95	0.95 – 1.00

Source: Irrigation Association (2011)

Microclimate factor (Kmc)

The microclimate factor adjusts the estimated water demand for site conditions where there is a significant increase or reduction due to siting and physical features or structures that alter the solar, thermal and atmospheric properties impacting on the vegetation. Roof overhangs that shade plants, courtyards that reduce wind or plantings on the south side of buildings create a microclimate where water use is decreased. Increased water demand is created where plants are surrounded by heat radiating surfaces such as pavements and roads or exposed to particularly windy sites. An average microclimate is equivalent to reference evapotranspiration conditions in an open field subject to natural atmospheric conditions. A guide to landscape microclimate factors developed by WUCOLS is detailed in Table 8.9.

Table 8.9 Plant microclimate factors (WUCOLS)

Microclimate rating	Description	Microclimate factor
Low	Excessive shade or wind reduction	0.5 – 0.9
Average	Normal atmospheric conditions	1.0
High	Excessive reflected heat or significant wind	1.1 – 1.4

The allocation of a microclimate factor value is at the discretion of the irrigation manager. The microclimate factor will generally be at an average rating of 1.0 unless there are significant variations in atmospheric conditions due to siting or physical features. The Irrigation Association USA has developed microclimate factors for different plant types using an adaption of the WUCOLS rating system.

Table 8.10 Microclimate factor (Kmc) for different plant types

Vegetation type	High (exposed, windy)	Average (open, sunny)	Low (protected, shaded)
Trees	1.2 – 1.4	1.0	0.5 – 0.8
Shrubs	1.2 – 1.4	1.0	0.5 – 0.8
Ground covers	1.2 – 1.4	1.0	0.5 – 0.8
Mixed plantings	1.2 – 1.4	1.0	0.5 – 0.8

Source: Irrigation Association (2011)

Below are examples of the calculation of water requirement for two different landscape plantings.

Example 3: A dense mixed garden bed with an upper story of weeping bottlebrush over a mid-storey of glossy abelia and gardenia with a groundcover of star jasmine.

Species factor Ks - 0.5 (Medium - highest water use species gardenia is a medium water use rating all others are low – medium)

Density factor Kd - 1.1 (High - full canopy cover with multi-tiers of dense vegetation)

Microclimate factor Kmc - 1.0 (Average – open position with normal atmospheric conditions)

K_L = Ks x Kd x Kmc
= 0.5 x 1.1 x 1.0
= 0.55

ETo for January – 52.5 mm/week (BoM average 2007 – 2015 Adelaide Airport)

ET_L = ETo x K_L
= 52.5 x 0.55
= 28.8 mm/week

Example 4: An established garden bed of hydrangeas planted at 1m spacings.

Species factor Ks - 0.8 (High - high water usage species)

Density factor Kd - 1.0 (Average - 90 - 100% canopy cover)

Microclimate factor Kmc - 1.0 (Average - open position with normal atmospheric conditions)

K_L = Ks x Kd x Kmc
= 0.8 x 1.0 x 1.0
= 0.8

ETo for January – 52.5 mm/week (BoM average 2007 – 2015 Adelaide Airport)

ET_L = ETo x K_L
= 52.5 x 0.8
= 42 mm/week

Case Study Number 2
Royal Botanic Gardens, Melbourne
Stormwater Optimisation and High Irrigation Efficiency

The landscape plantings and lawn areas of the Melbourne Gardens of the Royal Botanic Gardens Victoria are maintained to a very high standard with high efficiency of water use. Multiple strategies, including soil moisture sensing and adaptive management, are being used to achieve precision irrigation. The sustainability of the site is being enhanced through stormwater harvesting to reduce the dependence on potable mains supply.

Figure: Ornamental Lake and landscape, RBG Vic Melbourne Gardens

For further information refer to the full case study in the appendices or contact Peter Symes, Curator, Environmental Horticulture, Royal Botanic Gardens Victoria.

8.3 Water budget

Good water management requires knowledge of the amount of water used and the amount required to maintain a healthy, fit-for-purpose landscape. The amount of water required by the turf or landscape should be estimated on a monthly and annual basis. The monthly estimate is used to guide and monitor irrigation management. The annual estimate is used for planning and overall evaluation. Annual water use estimates are also used to determine water allocations and financial budgets.

A water budget should be developed to set irrigation water consumption targets. A water budget calculates the irrigation requirement of the site for a given period based on climatic, agronomic, turf or landscape quality and system performance factors. The outcome is monthly and annual water consumption targets based on average or forecast climatic conditions, in millimetre depth of water, which can be converted to kilolitres per hectare.

From the water budget a financial budget for water cost can be developed to enable the management of both water and financial resources.

Irrigation requirement (Ir)
In order to determine how much water to apply to the turf or landscape and monitor water where:

- In - net irrigation requirement (mm)
- PWR - plant water requirement (mm)
- Peff - effective rainfall (mm).

Effective rainfall (Peff)
The calculation for effective rainfall is: Peff = P x Pf.

Where:

- Peff - effective Rainfall (mm)
- P - total rainfall (mm)
- Pf - effective rainfall factor (decimal factor).

Rainfall or precipitation (P) replaces water lost from the soil by evapotranspiration and thereby reduces the plant water requirement (PWR). Rainfall (P), during the irrigation season, can be variable and is not always effective. Small rain events are lost by evaporation and do not soak into the soil, whereas large events may deliver more water than the soil can hold and can be lost either through drainage or run off. The rainfall that can effectively be used by the plant is called effective rainfall (Peff). A general rule, for a shallow-rooted turf grass, is that only half the rainfall that occurs in the irrigation season is effective and actually replenishes soil to the root zone of the plant.

The effective rainfall factor (Pf) used in the Code is 0.5 or 50%. The Pf can be altered at the discretion of the irrigation manager. In a situation where an extreme rainfall event in summer delivers up to 100mm, it would be prudent to reduce the Pf to a value of 0.2 where only 20% of the rainfall can effectively be used by the plant. In this case 80% of the rain would be lost to deep drainage or surface runoff. Rainfall data can be accessed from the BoM web site (http://www.bom.gov.au/watl/eto/) or from local rain gauges. A table of monthly rainfall data for Adelaide Airport BoM weather station from 2006 to 2015 is available in the appendices.

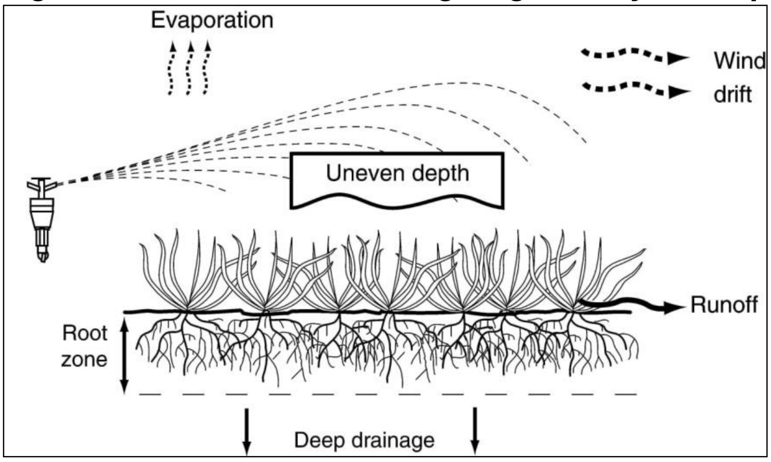
Irrigation requirement (Ir)
The irrigation requirement (Ir) is the amount of water (mm) to be applied by irrigation, with allowance for irrigation system application efficiency. That is the net irrigation requirement divided by the system application efficiency.

The calculation of the irrigation requirement is: Ir = In / Ea.
Where:

- Ir - irrigation requirement (mm)
- In - net irrigation requirement (mm)
- Ea - irrigation system application efficiency (decimal).

Irrigation system application efficiency (Ea)
Irrigation systems do not apply water at 100% efficiency. The optimum performing irrigation system is subject to inherent system inefficiencies. Factors such as wind, misting, poor sprinkler spacing, nozzle loss and other system performance faults impact on the uniformity of water application. Therefore, a factor must be applied to account for inefficient irrigation system performance.

Figure 8.4 Factors influencing irrigation system application efficiency



(Source: G&M Connellan Consultants)

A field irrigation audit, conducted by an experienced irrigation auditor, is required to determine the performance of the irrigation system. The DU is one measure of irrigation system application efficiency. However, this can vary with conditions such as high wind or system pressure fluctuations. A high performing pop-up sprinkler system will achieve a field DU of between 75% and 85%. In practice, many systems fall short of this figure and may achieve between 55% and 65% DU or lower.

An application efficiency factor of 80% or 0.8 has been used in the Code as this represents a high performing system.

Ea - irrigation system application efficiency (0.8)

No allowance has been made for poor DU in the benchmarks developed in the Code, as it is considered fundamental that systems should be designed, installed and maintained to high standards. Where systems have a DU < 75%, maintenance, upgrade or replacement is advised.

Converting irrigation depth (mm) to volume (kL per Ha)

Irrigation requirement (Ir) refers to the depth of water (mm) that needs to be applied by the irrigation system to replace soil water used by the plant. Each millimetre of water applied refers to one millimetre depth of water over the entire irrigated area. One millimetre depth of water over an area of one square metre equals one litre of water. Subsequently an irrigation depth of one millimetre per hectare (10.000 m^2) is equal to 10,000 litres or 10 kilolitres of water. To convert mm depth of water applied to kilolitres per hectare, a multiplier factor of 10 is used. The calculation is: kL per ha= mm x 10.

Where:

- kL - kilolitres (1,000 litres)
- ha - hectares (10,000 square metres)
- mm - millimetre depth of water
- 10 - conversion factor (mm to kL per ha).

Calculating water cost

The cost of mains water is set by the SA Water Corporation and is adjusted annually. The cost of SA Water mains water in 2014/15 financial year was $3.32 per kilolitre. The cost of water for irrigation is calculated by multiplying kilolitres used by the water cost. The cost of alternative water sources is used where appropriate.

Total water cost = kL used x water cost per kL (SA Water Potable Supply)
= kL x 3.32 (2014/15)

Given the above information, the irrigation requirement can be calculated, as in the following examples.

Turf Irrigation Water Requirement (IWR) / Water Budget - Example 1
Site: SANFL/A-grade turf cricket oval Area: 1.6 hectare Location: Adelaide metropolitan area Turf species and quality standard: Kikuyu, TQVS Cat 2 Irrigation season: October - April inclusive BoM weather station: Adelaide Airport Climate period (ETo/P): Average 2007 - 2015 Irrigation water requirement (Ir) = net irrigation requirement (In) / application efficiency (Ea) **Ir = In / Ea** Net irrigation requirement (In) = Turf evapotranspiration (ET_T) – Effective rainfall (Peff) In = ET_T - Peff Turf evapotranspiration (ET_T) = reference evapotranspiration (ETo) x turf species co-efficient (Tsc) x turf water stress factor (Tws) ET_T = ETo x Tsc x Tws = 1388 x 0.7 x 0.6 = 583 mm Effective rainfall (Peff) = rainfall (P) x effective rainfall factor (Pf) Peff = P x Pf = 189 x 0.5 = 95 mm Net irrigation requirement (In) In = ET_T – Peff = 583 - 95 = 488 mm Application efficiency Ea = 0.80 Irrigation requirement (Ir) Ir = In / Ea = 488 / 0.80 = 610 mm Irrigation requirement volume (kL per ha) $Ir_{(kL/ha)}$ = Ir(mm) x 10 = 610 x 10 = 6,100 kL/ha Site irrigation requirement $Ir_{(site)}$ = $Ir_{(kL\ per\ ha)}$ x site area = 6,100 x 1.6 = 9,760 kL Water Cost = $Ir_{(site)}$ x Water cost ($/kL) = 9,760 x 3.32 = $32,403

Landscape Irrigation Water Requirement (IWR) / Water Budget - Example 2
Site: A dense mixed species garden bed with an upper story of weeping bottlebrush over a mid-storey of glossy abelia and gardenia with a ground cover of star jasmine. Area: 500 m2 (0.05 ha) Location: Adelaide metropolitan area Irrigation season: September – April inclusive BoM weather station: Adelaide Airport Climate period (ETo/P): Average 2007 - 2015 Irrigation requirement (Ir) = net irrigation requirement (In) / application efficiency (Ea) Ir = In / Ea Net irrigation requirement (In) = landscape evapotranspiration (ET_L) – Effective rainfall (Peff) In = ET_L - Peff Landscape evapotranspiration (ET_L) = reference evapotranspiration (ETo) x landscape co-efficient (K_L) K_L = species factor (Ks) x density factor (Kd) x microclimate factor (Kmc) ET_L = ETo x K_L (Ks x Kd x Kmc) = 1388 x 0.55 (0.5 x 1.1 x 1.0) = 763 mm Effective rainfall (Peff) = rainfall (P) x effective rainfall factor (Pf) Peff = P x Pf = 189 x 0.5 = 95 mm Net irrigation requirement (In) In = ETc – Peff = 583 - 95 = 668 mm Application efficiency Ea = 0.80 Irrigation requirement (Ir) Ir = In / Ea = 668 / 0.80 = 836 mm Irrigation requirement volume (kL per ha) $Ir_{(kL/ha)}$ = Ir(mm) x 10 = 836 x 10 = 8,360kL/ha Site irrigation requirement $Ir_{(site)}$= $Ir_{(kL\ per\ ha)}$ x site area = 8,316x 0.05 = 418kL Water cost = $Ir_{(site)}$ x water cost ($/kL) = 418 x 3.32 = $1,388

8.4 Adaptive irrigation management

The co-efficient and factor values used to estimate plant water use and irrigation budgets are generally given in a range and there is not one value that applies to all turf or landscape species. To optimise water use efficiency, the irrigation manager should select a value that will provide adequate water for healthy plant growth and then monitor the response of the turf or landscape planting. The outcome should be strong healthy plant growth. It may be appropriate to reduce the vigour of the plant growth to an outcome that is of a lower quality but still fit for purpose. Where this is the case, the value can be adjusted down and the plant response monitored until the desired outcome is achieved. This will reduce water use while still achieving the desired outcome. This process is referred to as adaptive irrigation management.

To implement adaptive irrigation management effectively, the irrigation manager should have sound horticultural skills and experience and the irrigation system should perform at a high level with uniform application, precise flexible control and water use must be monitored closely.

Values selected in the development of plant water use estimates and benchmarks in the Code are generally mid-range values. These values can be adjusted at the discretion of the irrigation manager using the adaptive irrigation management approach.

8.5 Base irrigation requirement (BIr)

The irrigation requirement (Ir) is calculated using reference evapotranspiration (ETo) and rainfall (P) data available from the BoM. The base irrigation requirement (BIR) is the water requirement for a site based on average climatic conditions and forms the monthly and annual water and financial budget. Generally, long-term (30^+ years) average data is used; however, the impact of climate change during the past decade and predicted changes into the future, mean that long-term averages are not an accurate indication of expected weather patterns now and into the future. Table 8.11 details the turf IWR using long-term average climate data, actual data for the period 2006/07 through to 2014/15 and average data for the period 2007 to 2015.

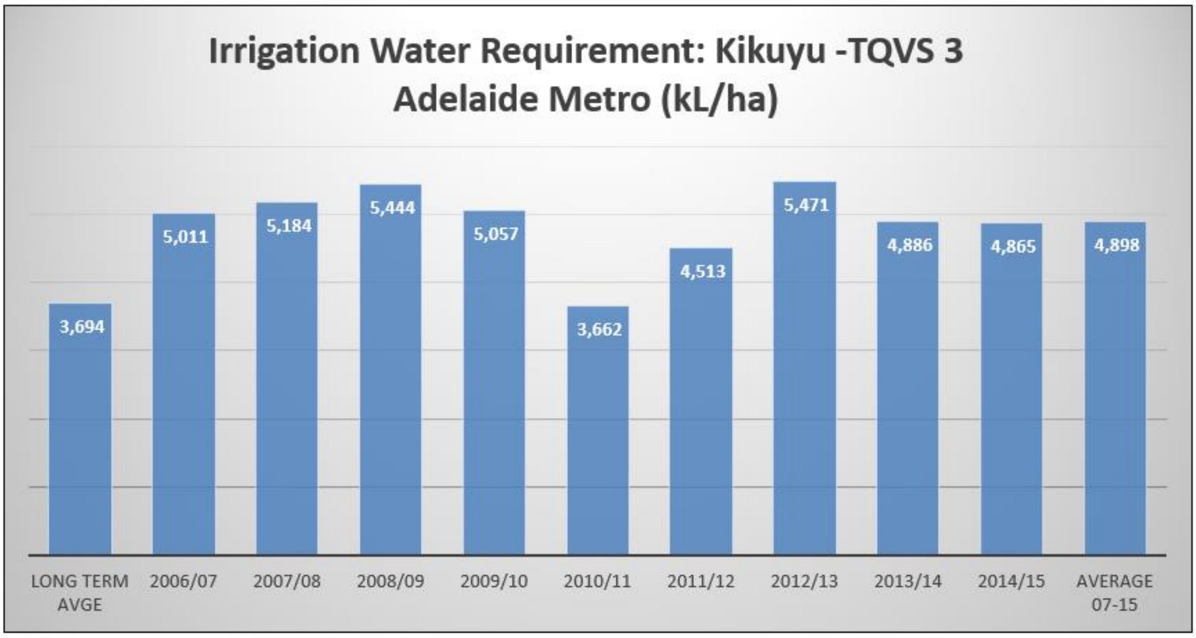
Table 8.11 Irrigation requirement (Ir): Couch / Kikuyu, Adelaide metro

TQVS Cat.	**TQVS 1**	**TQVS 2**	**TQVS 3**	**TQVS 4**
Year	**Ir (kL/ha)**	**Ir (kL/ha)**	**Ir (kL/ha)**	**Ir (kL/ha)**
Long-term average (30yr)	**8,826**	**4,721**	**3,694**	**2,668**
2006/07	11,271	6,263	5,011	3,759
2007/08	11,449	6,437	5,184	3,931
2008/09	11,656	6,686	5,444	4,201
2009/10	11,458	6,337	5,057	3,777
2010/11	9,149	4,749	3,662	2,632
2011/12	10,419	5,694	4,513	3,331
2012/13	11,679	6,712	5,471	4,229
2013/14	11,116	6,132	4,886	3,640
2014/15	10,605	6,013	4,865	3,717
2007 – 2015 average	**10,978**	**6,114**	**4,898**	**3,682**

There is significant variation in the Ir for the different TQVS categories due to the turf water stress factors applied. There is also significant variation in Ir for individual years, with the highest Ir recorded in 2012/13 and the lowest in 2010/11. The average $Ir_{(2007\text{-}2015)}$ for the nine-year period from 2007 to 2015 is approximately 30% higher than the long-term average.

Using annual Ir data for TQVS 3 – Local sportsgrounds in Figure 8.4, the difference in IWR is represented graphically.

Figure 8.4 Irrigation requirement comparison



The average irrigation requirement for the period 2007 to 2015 has been chosen as the base irrigation requirement (BIr) for use in the Code. The monthly base irrigation water requirement (BIr) for all TQVS categories using BoM data from the Adelaide Airport weather station for warm-season turf grass is detailed in Table 8.12.

Table 8.12 Base irrigation requirement 2007 – 2015 ($BIr_{2007\text{-}2015}$)
Warm-season turf (Couch / Kikuyu) – Adelaide Metropolitan Area

TQVS Cat.	TQVS 1	TQVS 2	TQVS 3	TQVS 4
Month	**$BIr_{2007\text{-}2015}$ (kL/ha)**	**$BIr_{2007\text{-}2015}$ (kL/ha)**	**$BIr_{2007\text{-}2015}$ (kL/ha)**	**$BIr_{2007\text{-}2015}$ (kL/ha)**
September	828	416	313	209
October	1,304	743	603	463
November	1,560	887	718	550
December	1,765	1,008	819	630
January	1,953	1,133	928	723
February	1,575	901	733	564
March	1,290	709	564	419
April	702	317	221	125
Total (kL/ha)	**10,978**	**6,114**	**4,898**	**3,682**

In regional areas, site-specific climatic data can be sourced from the BoM website; other factors remain the same.

The water budget or BIr data provides benchmarks for irrigation requirement using average climatic data for a given period. The climate, evaporation and rainfall can be extremely variable. Changes in weather into the future need to be monitored to determine the actual impact of climate change; the irrigation manager should use the adaptive irrigation management approach to determine the benchmarks used to set budgets and monitor performance.

Benchmarks and BIr data for landscape plantings has not been detailed due to the diversity and mixture of landscape plant species and site conditions. The WUCOLS methodology is used to develop a landscape BIr using the same climatic data references as for the turf examples. A Landscape Irrigation Requirement Model is included in the appendices.

References and Further Information:
Section Number 8 – Plant Water Use / Water Budget

- Allen RG, Pereira LS, Raes D and Smith M (1998) *Crop Evapotranspiration. Guidelines for computing crop water requirements*. FAO Technical Paper No. 56. Rome, Italy. http://www.fao.org/docrep/X0490E/X0490E00.htm

- Connellan, G. 2013. *Water Use Efficiency for Irrigated Turf and Landscape,* CSIRO Publishing Victoria, Australia. http://www.publish.csiro.au/pid/5263.htm

- Bureau of Meteorology (2015) *Reference Evapotranspiration for Australia.* http://www.bom.gov.au/watl/eto/

- CIT (Center for Irrigation Technology) (2011) *Turf Crop Factors.* Wateright. CIT. California State University, Fresno, California. http://www.wateright.org/KcTurf2.asp

- Costello LR and Jones KS (2000) The *Water Use Classification of Landscape Species – A Guide to the Water Needs of Landscape Plantings in California – The Landscape Co-efficienct Method and WUCOLS III.* Department of Water Resources. Sacramento, California, USA

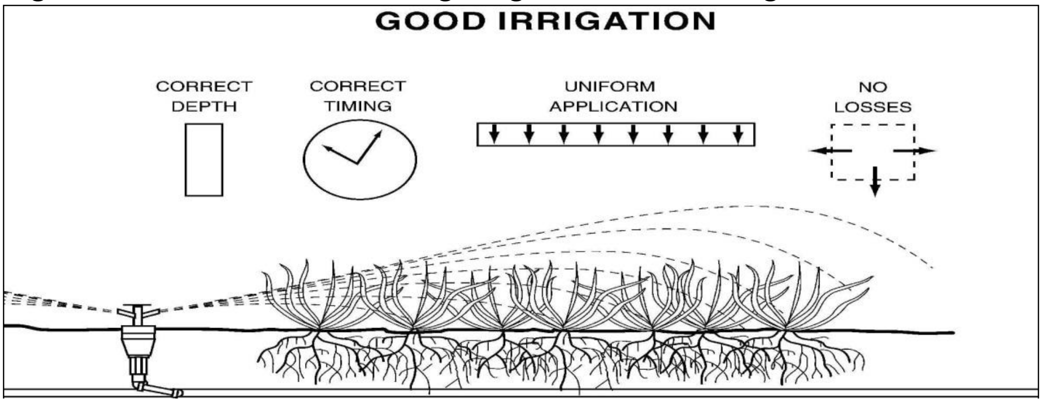
- Handreck, K. A. and Black, N. D. (2005) *Growing Media for Ornamental Plants and Turf,* 3rd Edition, NSW University Press, Kensington, NSW, Australia

- Harivandi, A. M. 2009. *Managing Turfgrass During Drought.* Oakland: University of California Agriculture and Natural Resources Publication 8395, http://anrcatalog.ucdavis.edu/pdf/8395.pdf

9.0 Irrigation Scheduling

9.1 What is involved?
Irrigation scheduling is a critical aspect of effective irrigation management. Irrigation controllers are often programmed at the start of the season with a pre-set program and often not adjusted to respond to changing weather conditions and plant water requirement.

Figure 9.1 Factors influencing irrigation scheduling



(Source: G&M Connellan Consultants)

In order to ensure that only as much water is applied to the turf as is required without wastage through over-watering, the irrigation schedule must be matched to the irrigation requirement of the site. To do this the following information is required:

- How much water does the plant need?
- How much water is stored in soil?
- How much water is available to the plant?
- How much water needs to be applied?
- When should irrigation be applied?
- How long the irrigation system should be operated?

In answering the above questions, an irrigation schedule will be developed for the following site:

- Site: Local soccer ground
- Area: 1.2 hectares
- Location: Adelaide metropolitan area
- Turf species: Kikuyu
- Turf quality standard: TQVS Cat 3
- Soil type: Sandy loam
- Irrigation season: September – April inclusive
- Climate data period: Long-term average
- Irrigation time limits: 9.00pm - 8.00am
- Irrigation day limits: No irrigation Friday/Saturday.

9.2 How much irrigation water does the plant need?
IWR is the amount of water that needs to be delivered into the root zone. The daily IWR is used in developing an irrigation schedule by monitoring the plant water use and changes in the amount of water stored and available in the root zone.

The calculation of the irrigation requirement (IWR) is detailed in Section 8.3 of this document.

Table 9.1 details the irrigation water requirement (IWR) for TQVS Category 3 (local sportsground)

Table 9.1 Daily irrigation water requirement (IWR) – TQVS category 3

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Irrigation water requirement (IWR) (mm)	31	60	73	82	93	71	55	23
Days per month	30	31	30	31	31	28	31	30
Daily in (mm)	1.0	1.9	2.4	2.6	3.0	2.5	1.8	0.8

9.3 How much water is stored in the soil?

Total available water (TAW)
The amount of water stored in the soil and that is available to the plant is referred to as the total available water (TAW). When the soil reservoir is full it is said to be at 'field capacity'. Any further water applied to the soil will either run off or be lost below the root zone by drainage. Plants will extract water from the soil as required until the remaining water in the soil is no longer able to be taken in by the plant. This is called 'wilting point'. If water is not applied, either through natural rainfall or irrigation, the plant may become stressed to the point where it will die.

The total available water in the root zone is the difference between the water content at field capacity and wilting point.

The TAW is determined by the soil type and its water holding capacity (WHC) and the root zone depth (Zr) of the plant.

The calculation is: TAW = WHC x Zr.

Where:
- TAW - total available water (mm)
- WHC - water holding capacity of the soil (mm/cm)
- Zr - root zone depth (mm).

Soil water holding capacity (WHC)
Water is stored in the soil between the pore spaces of the soil particles. Different soils have varying sized pore spaces and there is a significant variation in the water holding capacity of different soils. By taking a soil sample and determining the soil texture, the water holding capacity (WHC) of the soil can be determined from the following table.

Table 9.2 Typical water holding capacity and infiltration rate of soils

Soil type	Soil water holding capacity (WHC) mm/cm	Soil water holding capacity (WHC) mm/cm (Ave)	Soil infiltration rate (mm / hr)
Sand	0.6 - 0.8	0.7	>30
Fine sand	0.8 - 1.0	0.9	20 – 30
Sandy loam	1.0 - 1.4	1.2	15 – 20
Loam	1.8 - 2.2	2.0	10 – 15
Silt loam	1.6 - 1.8	1.7	8 – 12
Clay loam	1.2 - 1.8	1.5	5 – 10
Clay	1.2 - 1.6	1.4	< 5

Note: These values are a guide only and site-specific information is required for detailed irrigation analysis.

Plant root zone depth (Zr)
The extent to which the plant roots grow into the soil determines the depth and volume of water in the soil that the plant can access. Generally, in open soils such as sand, plants tend to develop root systems to a greater depth than heavier clay soils. The depth of roots in turf can be determined by taking a soil sample and measuring the depth of roots of the profile.

Having determined the WHC and the Zr, the TAW can be calculated as follows:

Where Kikuyu is grown in sandy loam with a root zone depth of 150mm:

TAW = WHC x Zr
= 0.12 x 150 = 18 mm

9.4 How much water is available to the plant?

Readily available water (RAW)
The percentage of the TAW that a plant can extract from the root zone without suffering significant stress is the readily available water (RAW). It is the proportion of the total amount of water that can be stored in the root zone and is available for uptake by the plant. It is sometimes called the working storage.

RAW = TAW x MAD

Where:
- RAW - readily available water (mm)
- TAW - total available water (mm)
- MAD - maximum allowable depletion (%).

As the soil water level is reduced, the ability of the plant to take up water is also reduced, due to the increased tension that needs to be exerted to extract water. In most situations it is desirable to maintain the soil water level at a level where the plant is able to extract water with no significant stress. Growth is not restricted. The soil water level must be kept between field capacity and wilting point. This is called the maximum allowable depletion (MAD). When the soil water level reduces to the MAD, irrigation must be applied to bring the soil moisture level back to field capacity.

Determining the MAD is a management decision for each site and it may vary depending upon a number of factors including season, usage of the turf and growth phase of the turf. As a general rule, the MAD for turf is set at 50% of TAW.

Where Kikuyu is grown in sandy loam with a root zone depth of 150mm:

RAW = TAW x MAD
= 18 x 0.5
= 9 mm

9.5 How much water needs to be applied?
When the plant has extracted the RAW from the root zone, irrigation needs to be applied to refill the soil reservoir to field capacity. This is referred to as the refill point. The amount of water that needs to be applied is that extracted from the soil (RAW) plus an additional amount to compensate for irrigation system application inefficiencies (Ea). This is referred to as the irrigation depth or the optimum irrigation event (OIE):

OIE = RAW / Ea

Where:
- OIE - optimum irrigation event (mm)
- RAW - readily available water (mm)
- Ea - application efficiency (mm).

Irrigation system application efficiency (Ea)
As previously noted, irrigation systems have some inherent inefficiencies, which reduce the uniformity of application of the system. A field irrigation audit, conducted by a qualified irrigation auditor, is required to determine the performance of the irrigation system. The irrigation system application efficiency factor used in the Code is 0.80 or 80% efficiency (Ea = 0.80).

Given the previous information, the OIE or the irrigation depth can be calculated as such:

OIE = RAW x Ea
= 9 / 0.8
= 11.25 mm (11 mm)

The OIE of 11 mm is the amount of water that should be applied by the irrigation system to refill the soil moisture level to field capacity after the depletion of the readily available water (RAW) (9 mm) in the root zone. Any water applied in excess of 11 mm in any one irrigation event will be wasted through deep drainage or runoff.

9.6 When should irrigation be applied?

Irrigation interval (Ti)

The irrigation interval (Ti) is the interval or number of days between the application of the optimum irrigation event (OIE).

Using average climatic data from the BoM to determine the daily net irrigation requirement, the daily soil water depletion can be monitored. When the soil water level reduces to the point where the readily available water (RAW) has been extracted, it is time to apply the optimum irrigation event (OIE).

The irrigation interval (Ti) (number of days between irrigation events) is calculated by dividing the readily available water (RAW) in the soil by the daily net irrigation requirement ($In_{(daily)}$) of the plant.

$Ti = RAW / Ir_{(daily)}$

Where:
- Ti - irrigation interval (days)
- RAW - readily available water (mm)
- $In_{(daily)}$ - daily net irrigation requirement (mm).

Table 9.3 Irrigation interval per month (days)

Item	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Readily available water (RAW) mm	9	9	9	9	9	9	9	9
Daily net irrigation requirement ($In_{(daily)}$) mm	1.0	1.9	2.4	2.6	3.0	2.5	1.8	0.8
Irrigation interval (Ti) days	9	5	4	3	3	4	5	11

9.7 How long should the irrigation system be operated?

To determine how long the irrigation system should operate per station, optimum irrigation event (OIE) is divided by the irrigation system application rate (Iar) to give the irrigation run time (Irt) to ensure application of the required depth of water. The result is multiplied by 60 to convert to minutes.

Irt= (OIE / Iar) x 60

Where:

- Irt = irrigation system run time (minutes)
- OIE = optimum irrigation event (mm) (depth of water applied)
- Iar = irrigation system application rate (mm)
- 60 = multiplier to covert result to minutes.

9.8 Irrigation system application rate (Iar)

The rate at which the irrigation system applies water to the ground is determined during the design process. Factors such as sprinkler type, nozzle, operating pressure, flow rate and sprinkler spacing all impact on the system application rate (Iar). Irrigation systems designed for large areas, such as irrigated public open space, generally have lower application rates than small-irrigated areas such as domestic gardens. Sprinklers or rotors designed for large areas while they have high flow rates, to achieve the required large distance of throw, the application rate is typically in the range of 8 -15 mm per hour. Static, non-rotating sprays, for small areas, tend to have higher application rates in the range 20-40 mm per hour. There are rotating stream sprays now available, which are suited to small areas and have application rates in the range 8-20 mm per hour. It is important to know the specific irrigation equipment being used in order to make decisions about the operation and management of a system.

The application rate of the system can be determined by checking system pressure, flows and sprinkler spacing against the manufacturers sprinkler performance charts or by a field audit of the irrigation system.

The irrigation application rate used in developing a base irrigation schedule in the Code is 13 mm per hour. The irrigation system run time per station is:

Irt (min per station) = (OIE / Iar) x 60
= (11 / 13) x 60
= 0.85 x 60
= 50 mins per station

9.9 Determining the total system run time

Where an irrigation system has 12 stations, the Irt per station is multiplied by the number of stations.

Irt (minutes per site) = Irt (station) x 12
= 50 x 12
= 571 minutes
Irt (hrs per site) = Irt (mins) / 60
= 500 / 60
= 10 hours

An irrigation schedule is then developed in consideration of time restrictions in which irrigation can take place (usually night watering between 9.00 pm and 8.00 am) and usage of the reserve (no irrigation Friday or Saturday pm).

Table 9.4 Irrigation schedule – TQVS category 3

Item	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Number of stations	12	12	12	12	12	12	12	12
Total irrigation run time (mins)	600	600	600	600	600	600	600	600
Total irrigation run time (hrs)	10	10	10	10	10	10	10	10
Irrigation interval (Ti) days	9	5	4	3	3	4	5	11
Program start time	9.00 pm	9.00 pm	9.00 pm	9.00 pm	9.00 pm	9.00 pm	9.00 pm	9.00 pm
Program finish time	7.00 am	7.00 am	7.00 am	7.00 am	7.00 am	7.00 am	7.00 am	7.00 am
Watering days (week one)		M	M, Th	M, Th	S, Th	S, W, Th	M, Th	M
Watering days (week two)	M	M	M, Th	M, Th	S, W, Th	M, Th	M	
Watering days (week three)	M	M	M, Th	M, Th	S, Th	M, Th	M	M
Watering days (week four)	M	M, Th	M, Th	M, Th	S, W, Th	M, Th	M	
Irrigation events per month	3	5	8	8	10	9	5	2

Irrigation schedules should respond to changing plant water requirements and should not be set for standard operation during the entire season. The base irrigation schedule is developed using long-term average climatic data. The plant water requirement is determined by climatic factors and changes with the weather, i.e., evaporation/rainfall. As such, the timing of irrigation events is governed by the irrigation requirement for the current period.

The above irrigation schedule has been developed for a standard sportsground example using a high-quality water source. Many irrigated sites have a variety of slopes, soil types and use water supplies high in salts such as treated effluent. In such cases scheduling parameters such as surface runoff, soil infiltration rates and salt leaching factors need to be considered in the development of the irrigation schedule.

Support tools and resources are available on the SA Water – Irrigated Public Open Space webpage to assist in the development of an irrigation schedule. These include the Basic Irrigation Management Toolkit and the Advanced Irrigation Management Toolkit accessible at https://www.sawater.com.au/business/products-and-services/irrigated-public-open-spaces-ipos/irrigation-management-toolkits

References and Further Information: Section Number 9 – Irrigation Scheduling
• SA Water – Irrigated Public Open Space webpage. *'Irrigation management Toolkits':* https://www.sawater.com.au/business/products-and-services/irrigated-public-open-spaces-ipos/irrigation-management-toolkits • Connellan, G. 2013. *Water Use Efficiency for Irrigated Turf and Landscape,* CSIRO Publishing Victoria, Aust. http://www.publish.csiro.au/pid/5263.htm • Handreck, K. A. and Black, N. D. (2005) *Growing Media for Ornamental Plants and Turf,* 3rd Edition, NSW University Press, Kensington, NSW, Australia.

10.0 Irrigation Management Technology

10.1 Technology categories

The core requirement for the irrigation system is that precise amounts of water need to be applied efficiently at the right time. The first step in a best practice approach is to have a well-designed and maintained irrigation system.

Technologies are available to assist in achieving high efficiency of water use. These technologies range from irrigation application techniques to control of the system.

Broadly, the technologies can be grouped according to:

- improved irrigation application efficiency
- monitoring of environment including weather and soil
- monitoring of system function
- monitoring of water use
- control of system operation.

10.2 Improved application efficiency

10.2.1 Rotating stream sprays

A significant development in irrigation technology has been the availability of a spray that incorporates a moving multi-stream spray as the method for the distribution of water. This technique of delivering water is more effective than fixed nozzle sprays. These rotating stream sprays are suited to small areas.

The distribution of water in a series of moving streams is fundamentally different to water application with fixed sprays. Water applied in a moving stream results in less water applied and a more stable radial distribution of water. Also, the delivery of water in a stream is able to achieve greater distance of coverage for the same flow rate. The water applied is at a higher uniformity and lower precipitation rate than conventional sprays.

10.3 Monitoring of the environment including weather and soil

10.3.1 Weather stations and ETo data

Weather stations can be installed by organisations to provide real time climatic data from which reference evaporation (ETo) can be calculated. Weather stations are particularly useful for regional areas where BoM data is limited or for specific sites where climate data is required.

Weather stations used for monitoring reference evapotranspiration ETo should conform to the requirements specified by the BoM and in the *FAO Technical Paper No. 56*.

Figure 10.1 Automatic weather station

The following measurements are required:

- air temperature
- relative humidity
- wind speed
- solar radiation.

A weather station that is fully compliant with the FAO specifications is likely to cost $20,000 or more. Lower cost weather stations and monitors are available. These do not have the suite of instruments to achieve the precision of the FAO units but they do provide a guide to the weather conditions and overall evaporative demand that is occurring. Using any type of measure as an input into plant water demand and irrigation decision-making is better than relying on human guess work.

10.3.2 Fee for service weather data

Irrigation management fee-for-service companies provide access to climatic data from a network of weather stations. The data are processed by a centralised computer and transmitted to remote irrigation sites initiating and adjusting schedules or regulating irrigation events according to the weather.

10.3.3 Soil moisture sensors (soil moisture based irrigation control systems)

Knowing the actual amount of moisture in the soil provides the irrigation manager with the knowledge to make precise scheduling decisions and to understand the soil water behaviour of the site and soil.

Information gained from soil moisture sensors provides both data on soil water extraction through ETc and feedback, which assists in monitoring and refining climate-based irrigation schedules.

Soil moisture sensors can be directly linked to the irrigation controller and are set at a threshold between field capacity and witling point. The sensor will enable the system to activate a pre-set irrigation event when the sensor records a reduction in soil moisture level to a percentage of field capacity. The irrigation event will apply a quantity of water that replenishes the soil moisture level to field capacity.

Soil moisture sensors can also be used in conjunction with weather-based control systems to monitor soil moisture levels and water movement through the soil profile. They provide a feedback loop from which scheduling parameters can be adjusted to improve irrigation efficiency. Soil moisture sensors can prevent over-watering.

Soil moisture sensors also provides electro-conductivity (EC) measurements, which are useful where treated effluent or water with high salt content is being used. When the sensor readings indicate that salt levels in the soil have reached a critically high point based on the conductivity readings, the turf should be irrigated heavily to leach the salts to below the root zone.

The capacity to monitor other soil parameters including temperature and electro-conductivity (EC) adds value to the sensor as a water management tool.

Soil temperature can also be monitored in conjunction with some soil moisture devices. This assists with the management of grass and fertiliser programs.

With the use of soil moisture sensors, the irrigation manager can potentially be aware of:

- root zone activity and root depth
- drying out of the profile during hot spells
- infiltration levels as the profile builds
- the timing of when to change the irrigation regime to avoid over watering
- the effectiveness of rainfall events in filling up the profile
- the effectiveness of the leaching program of salts below the root zone
- when the actual irrigation events occurred with visual documentation to enable review and improvements.

Key considerations in the use of soil moisture sensors are accuracy in reading site soil, robustness, signal compatibility with the control system and the need to select a representative position at which to take readings.

10.3.4 Rainfall sensors and rain gauges

Rainfall sensors are a simple, effective method of interrupting irrigation when an effective rainfall event has been experienced. Rainfall sensors are wired into a controller and can override the irrigation schedule causing the system to shut down in the event of rainfall.

10.4 Monitoring of system function

10.4.1 Flow and pressure sensors

The capacity to monitor and record the system flow rates so that pipeline breaks, missing sprinklers and faulty valves can be detected and shut down minimises water wastage and is very valuable. The consequences of reduced landscape quality and costs can be very significant if a supply or water application event fails.

Flow and pressure sensors, strategically positioned throughout the system, allow the irrigation to be monitored and action taken to alleviate problems.

Monitoring the irrigation of the system hydraulics also provides valuable information (e.g. water volumes) that can be used to evaluate the performance of the irrigation. Monitoring and measuring water use is a key part of good irrigation management.

Monitoring the flow through an irrigation system in real time provides the operator and/or manager with data that greatly increases the capacity to achieve high efficiency.

A flow sensor is an essential part of the management of an irrigation system.

10.4.2 System electrics
Controllers that incorporate the monitoring of the electric-based functions are valuable in indicating if there are any current faults and also in indicating the condition of equipment such as solenoid valves.

10.5 Monitoring of water use

10.5.1 Smart metering
Monitoring the flow through an irrigation system in real time, using a smart meter, provides the operator and manager with data that greatly increases the capacity to achieve high efficiency.

Ready access to an Internet site that hosts data from a smart meter provides additional advantages in terms of water use information management. Analysis and reporting of water use including peak flows, average flows, time of event and accumulated volumes can be readily carried out, with the sharing and remote access of the information adding to the overall quality of the management process.

10.6 Control of system operation

10.6.1 ET controllers (smart controllers)
Irrigation control systems that use climatic data to calculate irrigation run times or to schedule irrigation events have been developed. Such systems are a valuable tool in managing irrigation; they also relieve the irrigation manager of the task of calculating the irrigation requirement and automatically adjust irrigation schedules in response to changing weather conditions.

Some systems are fully automatic and are linked to weather stations from which they retrieve climatic data and automatically calculate reference ETo and effective rainfall. The irrigation requirement is then calculated using pre-set crop co-efficient and system efficiency factors. Semi-automatic systems require manual input of a base irrigation schedule and daily input of reference ETo and effective rainfall from which the system determines the frequency of irrigation events.

10.6.2 Flow management
Irrigation pipe networks are complex and the requirement to complete irrigation in specified time periods can be very demanding. The capability of modelling of the system hydraulics together with the matching to the irrigation demand is a very valuable feature of a controller. In addition to meeting the required time constraints, there are usually significant energy gains through both the efficiency of pumping and the total period of pumping.

10.6.3 Central control
Central control systems have proven to be a significant contributor to the labour efficiency of organisations managing many irrigated remote sites. Through a central host, all of the operating functions can be monitored and also individual and global instructions forwarded to each controlled site.

Case Study Number 3
Hillcrest Primary School
Use of Moisture Sensor Monitoring and Irrigation Control

Hillcrest Primary School, located in the North Eastern suburbs of Adelaide, continues to progressively improve its irrigation management practices demonstrating financial, environmental and social benefits. Through effective irrigation scheduling, the investment in soil moisture monitoring equipment connected to the irrigation control system and effective horticultural maintenance, the school oval is overcoming previous surface cracking issues related to the reactive clay soil.

Figure 1: Before and after images

November 2009

January 2015

This investment in best practice irrigation technology is just one example of a new wave of irrigation system products designed to achieve sustainable outcomes.

For further information refer to the full case study in the appendices or contact Hillcrest Primary School: www.hillcrstps.sa.edu.au

11.0 Turf and Landscape Horticultural Practices

11.1 Achieving healthy plant growth

While the efficient use of water in turf and landscape applications is a primary consideration, it is only one of the inputs necessary to achieve the desired outcome.

Healthy plant growth is achieved when there is adequate water, nutrients and air and when the growing conditions, including light and temperature, are appropriate for the plant species.

Plant growth suffers when:

- there is insufficient sunlight for photosynthesis or too much direct sunlight for the particular plant species and the risk of scorching
- the soil is saturated and there is inadequate air
- nutrient supply rate is too low or too high or out of balance
- the soil is compacted, which inhibits root extension and development
- organic content and viability is inadequate to support healthy plant growth
- pests or disease impact on the plant
- temperatures are outside the preferred range (hotter or colder) for the particular plant species.

While it is important to manage the inputs in correct balance for healthy plant growth, the landscape outcome may need growth to be modified. Practices such as mowing, scarifying, pruning or thinning of plants is often required.

Plant selection, site design conducive to growth, acceptable soil texture and structure and balanced nutrition are critical to achieving the desired landscape outcome. An annual turf and landscape maintenance program should be developed for each site. The aim of the program is to ensure healthy plants by:

- maintaining and/or improving soil texture and structure
- ensuring appropriate nutrient levels
- identifying and treating pests and diseases
- promoting deep root growth
- soil cultivation by aeration, coring
- de-thatching, mowing or pruning as appropriate.

11.2 Turf management practices

Turf is the highest water-using component of a landscape. It is also the most used component subject to intense foot traffic and machinery traffic and must be managed intensively to ensure a safe, fit-for-purpose outcome. Irrigation is essential in Adelaide’s climate where there is little natural rainfall in summer. The turf is mown closely to provide a suitable surface, the soil is subject to high rates of compaction forces particularly on sportsgrounds where training areas are localised and centre corridors are intensely used. Soil nutrition must be balanced with regular applications of fertiliser, particularly on sandy soils, and pests and diseases must be controlled to avoid negative impacts on the turf and surface quality.

11.3 Turf construction

The foundation of a successful sportsground is the soil on which it is constructed. Elite venues and highly managed turf areas such as golf greens and bowling greens are constructed on imported sand profiles aimed at draining water quickly to reduce down time in inclement weather. Premier sports grounds may have some soil amendment and sub-surface drainage installed and local sportsgrounds and passive areas may be built on the original soil or sometimes on imported material of variable quality. The standard of construction and the money invested in the facility must match the intended use and satisfy the expectations of the users and the authority that funds the development and ongoing maintenance.

The cost of turf construction will vary with the quality of the specification and performance standards required. Table 11.1 details the basic specification for each classification of turf, with Table 11.2 detailing the estimated construction costs.

Table 11.1 Turf construction standards

Item	TQVS 1	TQVS 2	TQVS 3	TQVS 4
Area	1.0 ha	1.0 ha	1.0 ha	1.0 ha
Rootzone	Sand profile (250mm)	Existing topsoil w/ slight amendment	Existing topsoil	Existing topsoil
Grade	Domed surface grade	One way fall	One way fall	Existing grade with minimal adjustment
Drainage system	Sub-surface 5m spacings	Sub-surface 5m spacings	Surface drainage only	None
Irrigation	Auto pop-up with pump, shed and storage tank	Auto pop-up with pump, shed and storage tank	Auto pop-up with pump, shed and storage tank	Auto pop-up with pump, shed and storage tank
Turf	Sodded Couch	Sprigged Couch	Sprigged Kikuyu	Sprigged Kikuyu

Table 11.2 Estimated turf construction costs ($/ha)

Construction	TQVS 1	TQVS 2	TQVS 3	TQVS 4
Design/spec./project manage	$18,000	$18,000	$10,000	$10,000
Earthworks	$63,000	$16,000	$16,000	$10,000
Drainage (5 m spacing)	$70,000	$70,000		
Irrigation	$75,000	$75,000	$75,000	$75,000
Topsoil - supply, place and shaping	$200,000	$40,000	$13,000	
Amendments	$6,000	$3,000		
Grassing sodding/12 week grow in	$75,000	$28,000	$28,000	$28,000
Total cost	$507,000	$250,000	$142,000	$123,000

Note: Elite venues could double the cost depending upon construction specifications and techniques.

11.4 Turf maintenance

Mowing heights, fertilizer application rates, compaction relief, rolling, top dressing and such all have an impact on the quality and water requirement of the turf grass. Turf maintenance operations are required to improve soil structure through aeration, de-compaction and promotion of deep root growth ensuring water is utilised to its full potential and turf quality meets its functional objective.

In order to maintain turf to provide an acceptable, fit-for-purpose facility, a sound turf maintenance program should be implemented and aimed at maintaining turf health, soil structure and surface levels. The notes below are generic turf maintenance practices that should be considered as required according to turf condition and desired outcome.

In summer and fortnightly during the colder months when grass growth is slower, height of cut should be between 15 - 25 mm for warm-season turf (Couch / Kikuyu) or between 25 mm – 50 mm for cool-season turf (Ryegrass).

De-compaction – To maintain soil structure, de-compaction works using a mix of deep coring with hollow tynes (verti-drain) and deep slicing (earthquake) in spring and autumn. Varying the de-compaction methods will ensure that a hard-pan layer is not created within the profile.

Rolling – Rolling with a light roller following wear in wet conditions can assist in levelling the surface. Care should be taken to ensure rolling does not result in compaction of the soil. Do not roll saturated soil.

Weed control – Broadleaf weeds should be treated in spring to maintain an even surface and promote a consistent healthy Kikuyu/Couch surface. Other weeds should be treated as required when identified.

Pest / disease control – A pro-active pest and disease program can be developed for elite and premier sportsgrounds. It is generally not necessary to implement a proactive pest and disease control program for local sportsgrounds. Rather, where a pest or disease is identified, specific action will be required.

Sodding – Areas that suffer excessive wear may require sodding in order to maintain acceptable turf and surface quality. Areas such as goal squares and cricket pitch run-ups are particularly susceptible. Maxi-sods, which are 600 mm wide, are preferred. Unless sods are grown on a sandy soil they will require coring with the addition of sand top-dressing to ensure water infiltration through any imported clay loam soil.

Top-dressing – To maintain surface levels, grounds should be top-dressed, concentrating on the centre corridor and goals in early spring following the winter competition season. Top-dressing material should be sandy loam with hydraulic conductivity of > 100 mm/hr and pH of between 6.0 – 7.0. Top-dressing rates are between 100 – 150 tonnes per hectare concentrating on the centre corridor and high-wear areas. Top-dressing should follow sodding and coring to ensure the sand is incorporated into the root zone of the soil profile.

Thatch control – Excessive thatch can be detrimental to turf health and should be minimised. Winter usage schedules will thin turf; thatch can be controlled with close mowing and sound irrigation programming. Thatch levels should be monitored and, if required, scarification should be carried out to remove excessive thatch.

Fertiliser application – Annual soil tests should be carried out to determine the nutrient balance of the soil. It is important that the soil has adequate major nutrients of Nitrogen (N), Phosphorous (P) and Potassium (K) and balanced minor nutrients, trace elements and pH. A fertilizer program should be developed to amend the nutrient balance where required and to provide ongoing maintenance fertiliser. Frequency of application can vary depending upon the required outcome from six-week intervals for high-quality turf to biannual applications in spring and autumn for local sportsgrounds and passive turf.

The tables below detail indicative turf maintenance requirements and estimated costs for each classification of turf.

Table 11.3 Turf maintenance standards

Item	TQVS 1	TQVS 2	TQVS 3	TQVS 4
Area	1.0 ha	1.0 ha	1.0 ha	1.0 ha
Mowing	80 x per annum	52 x per annum	52 x per annum	26 x per annum
Fertilising	6 x per annum	3 x per annum	2 x per annum	1 x per annum
Pest/weed control	6 x per annum	3 x per annum	2 x per annum	1 x per annum
Aeration (verti-drain/slicing)	8 x per annum	3 x per annum	2 x per annum	1 x per annum
Rolling	6 x per annum	4 x per annum	2 x per annum	None
Wetting agent	2 x per annum	None	None	None
Top-dressing	200 tonne per annum	100 tonne per annum	50 tonne per annum	None
Sodding/turf replacement	1000 m2 per annum	500 m2 per annum	200 m2 per annum	None
Miscellaneous (irrig mtce)	As required	As required	As required	As required

Table 11.4 Turf maintenance cost estimates ($/ha)

Annual maintenance	TQVS 1	TQVS 2	TQVS 3	TQVS 4
Mowing (weekly/fortnightly)	$6,400	$4,500	$4,500	$2,400
Fertilising	$3,000	$1,500	$1,000	$500
Pest/weed control	$3,000	$1,500	$1,000	$500
Aeration (verti-drain/slicing)	$6,400	$2,400	$1,600	$800
Rolling	$480	$320	$160	$0
Wetting agent	$500	$0	$0	$0
Topdressing	$7,000	$3,500	$1,750	$0
Sodding/turf replacement	$10,000	$5,000	$2,000	$1,000
Miscellaneous	$6,000	$3,000	$1,500	$1,000
Total cost	$42,780	$21,720	$13,510	$6,200

Note: Elite venues could double the cost depending upon maintenance programs and extra services such as thatch removal, logo marking and special requirements.

Further information regarding specific turf maintenance practices is accessible from a variety of books, journals and turf associations.

11.5 Landscape management practices

Urban landscapes should be maintained in a condition that is aesthetically appealing, performs the desired functions to the required standard and ensures that resources are used efficiently.

The plantings should be designed, constructed and maintained so that they are water efficient. Plant selection should be appropriate to the site conditions, local climate and ideally a low water use plant species.

There are a range of factors to consider and practices required to ensure the landscape is effectively maintained and can perform its desired function. These include:

- soils
- mulches
- fertilizing
- pests and disease
- irrigation.

Soils
A healthy soil is required. Nutrients, soil moisture and the physical properties that allow root systems are all essential.

The chemical, physical and biological properties of soils can generally be modified to bring them within acceptable ranges. Acid soils, for example, can be adjusted through the application of lime (calcium carbonate). Alkaline soils can be modified using acidic treatments; however, this may not be economically viable due to the amounts required. The organic properties of soils can be enhanced using composted mulches. Ideally, the soil pH would be in the range of pH 6 to 8. Soil testing should be an integral part of site management.

The physical and chemical requirements of soils suitable for commercial and domestic use are specified in the Australian Standard AS 4419-2003 *Soils for landscaping and garden use*.

Mechanical cultivation techniques, including tynes and aerators, can be used to reduce the effects of compaction.

Mulches
Mulching of the soil is an effective means of preventing weed establishment and reducing water loss from the soil surface. Organic mulches also add to the organic content of the soil as they break down. Organic mulching depths in the range of 50 mm to 80 mm are recommended.

Fertilizing
Fertilizing should be carried out so that applications are appropriate for the plants and the soil chemical properties. Fertilizer formulations should be based on soil test results from the site and the specific requirements of the plants.

Over application of fertilizers should be avoided to minimise risk of chemicals leaching into groundwater and polluting waterways and the broader environment. Nitrates and phosphorous are particular risks to the environment including encouraging the formation of blue-green algae in waterways and water storages.

Pests and disease
Pests and diseases should be ideally be controlled using integrated pest management (IPM) practices. However, chemical applications are often required. It is very important that only registered chemicals for the purpose are used. Applications should be undertaken so that the risks to people, environment and landscape plantings are eliminated.

Irrigation
Irrigation of landscape plantings should be appropriate to the water needs of the plants and the standards required of the landscape. The nature of the plantings and the soil properties will influence the particular irrigation method that will achieve optimum efficiency.

The irrigation water requirements of landscape plants is covered in Section 8.2.4

Tree establishment and maintenance
Successful tree establishment of urban trees is essential. Loss of newly planted/young trees is a waste of resources including water.

The following are best practice for tree establishment:

- Select species appropriate to the site and purpose.

- Use quality nursery stock.
- Use a planting hole of adequate size.
- Transplant with care.
- Prepare the planting hole with sufficient soil moisture.
- Water the tree (root ball) regularly to maintain root growth and development.
- Water for one or two years/seasons at a minimum, longer may be required.
- Water effectively (e.g., create an earthen berm).

Irrigation of established and mature trees
The following are best practice for the watering of mature urban trees:

- Ensure that the tree site can fully utilise rainfall. Ensure runoff is directed to trees and permeability of surfaces in the vicinity of the tree.
- Adopt a pro-active tree watering approach rather than a reactive one. It is better for tree health to water prior to the tree showing visible signs of stress (e.g., leaf loss, change in colour, leaf scorching, leaf curl and wilting).
- Apply water so that it infiltrates the tree soil root volume. Drippers allow effective application. If water is applied using a tanker, an earth berm or containment ring is useful in retaining the applied water so that it has an opportunity to infiltrate rather than run off.
- When using recycled or treated water, check that the water chemical properties (e.g. salts, toxic elements and pollutants) are not going to present a short- or long-term risk to the tree.

Pruning
Pruning is carried out for a number of reasons including:

- encouraging new growth and flowering
- producing specific shape or form
- limiting extended growth
- removing diseased material
- removing deadwood (trees)
- removing potential hazardous limbs (trees) for safety.

Summary
Landscape maintenance practices should aim to:

- maintain the function of the space including the high visual appeal that is often a primary requirement
- provide environmental benefits including species diversity and habitats for fauna
- facilitate rainfall and stormwater use to passively irrigate the plants and improve the quality of water
- allow efficient use of irrigation through species selection and site management
- not impact negatively on the environment as a result of chemical use for plant health or nutrition purposes.

Further information in regard to specific plant maintenance practices is accessible from a variety of horticultural references and books, journals and nursery and garden association publications.

References / Further Information: Section Number 11 – Turf and Landscape Horticultural Practices
• Beard JB (1973) *Turfgrass: Science and Culture* Prentice-Hall USA • McIntyre K. Jakobsen B (1998) *Drainage for Sportsturf and Horticulture* Horticultural Engineering Consultancy. Canberra, Australia • Handreck K, Black N (2005) *Growing media for ornamental plants and turf.* 3rd Edition. University of NSW Press. Sydney NSW • Connellan, G. 2013. *Water Use Efficiency for Irrigated Turf and Landscape,* CSIRO Publishing Victoria, Australia • Sydney Water (2011) *Best practice guidelines for holistic open space turf management in Sydney,* Sydney Water, Sydney, NSW • *Australian Horticulture,* monthly journal, Rural Press Magazines, Melbourne, Australia • *Australian Turfgrass Management,* quarterly journal. Australian Golf Course Superintendents Association, Melbourne, Australia • *Turf Craft International*, quarterly journal. Rural Press Magazines, Melbourne, Australia • *Australian Golf Course Superintendents Association* • *Sports Turf Association, South Australia* • *Nursery and Garden Industry Association*

12.0 Irrigation Monitoring and Performance Reporting

12.1 Irrigation efficiency reporting

It is necessary to monitor both the water consumption and the quality or fit-for-purpose standard of turf to ensure the objectives of efficient and effective turf and irrigation management are being met. The objective of irrigation management is to produce a turf quality outcome that is able to meet its functional objective.

In order to evaluate the past and current irrigation efficiency, it is necessary to compare irrigation applied (I) with the irrigation requirement (BIr or Ir) for a given period.

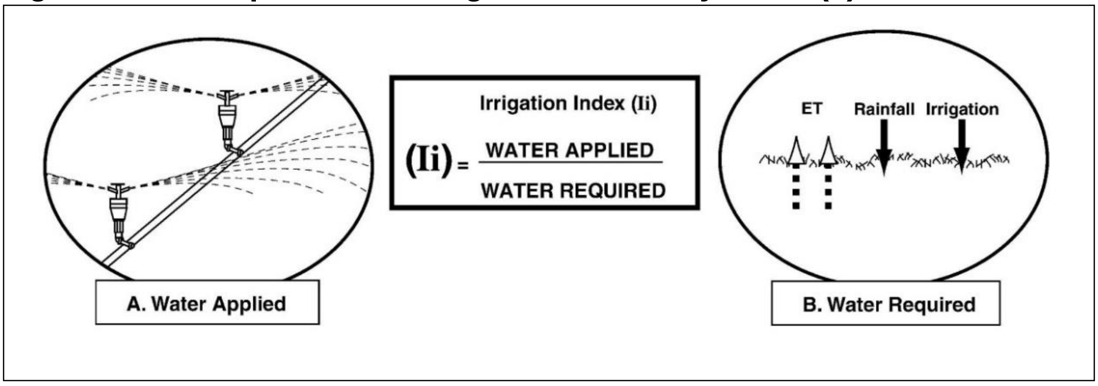
Irrigation efficiency reporting models compare the irrigation applied (I) with base irrigation requirement (BIr) and/or the irrigation requirement (Ir) to calculate an irrigation efficiency index (Ii) for each site. The Ii is used as a measure of water use efficiency.

Ii = I / Ir

Where:

- Ii - irrigation Efficiency Index (decimal)
- I - irrigation applied (I) (mm)
- Ir - irrigation requirement (Ir) (mm).

Figure 12.1 Components of irrigation efficiency index (Ii)



(Source: G&M Connellan Consultants)

The irrigation applied (I) is obtained by reading the water meter or from SA Water consumption records. Dedicated irrigation meters should be fitted to all water supplies to irrigated areas. Where buildings or other uses come off the same water supply, slave meters should be fitted to record consumption for each use. Meters with electronic flow rate output signals that can be monitored remotely are recommended.

Examples of Ii for each TQVS category of turf using $Ir_{(13/14)}$ data are shown in Table 12.1.

Table 12.1 Irrigation index (Ii) - comparison between various categories of turf

Description	TQVS cat.	Area ha	BIr kL/site	$Ir_{(13/14)}$ kL/site	$I_{(13/14)}$ kL/site	Variance (I–Ir) (kL/site)	Irrigation efficiency (Ii)
AFL football ground	1	1.9	20,858	21,120	22,380	1,260	1.06
District cricket ground	2	1.7	10,394	10.424	11,593	1,169	1.11
Local soccer ground	3	1.2	5,878	5,863	5,684	-179	0.97
Local picnic ground	4	0.6	2,209	2,184	3,118	934	1.43

Note: $I_{(13/14)}$ values are for demonstration only.

A Ii result of 1.0 indicates that the irrigation application (I) is equal to irrigation requirement (Ir), which is the aim of good irrigation management. Where the result is > 1.0 this indicates more water has been used than required. Conversely, where the result is < 1.0 the indication is that less water has been used than required.

In principle, good irrigation management should aim at achieving an Ii of between 0.90 and 1.10 within 10% of the irrigation requirement.

Support tools and resources are available on the SA Water – Irrigated Public Open Space webpage to assist in the monitoring of water use efficiency. These include the Basic Irrigation Management Toolkit and the Advanced Irrigation Management Toolkit accessible at https://www.sawater.com.au/business/products-and-services/irrigated-public-open-spaces-ipos/irrigation-management-toolkits

12.2 Assessing past irrigation efficiency

When comparing past performance of irrigation application, the BIr is used as the benchmark. The past four- to five-year average of irrigation consumption ($I_{(avge)}$) per site, taken from SA Water records, is divided by the BIr to determine the historical Ii.

The BIr is also used to assess irrigation efficiency against water use targets; however, it is not used to assess irrigation efficiency against the actual irrigation requirement. To achieve this, the irrigation requirement for the current period ($Ir_{(06/07)}$) must be used.

12.3 Assessing current irrigation efficiency

It is important that irrigation efficiency is monitored regularly throughout the irrigation season. The Ir is used to monitor irrigation efficiency for the current period or season. There can be significant variance between the average water requirement (BIr) and the actual water requirement (Ir) due to variations in the weather. Water usage can only be measured retrospectively; therefore, adjustments to consumption can only be made in relation to future irrigation events. Actual irrigation consumption (AIC) should be monitored monthly.

Monitoring of Ii monthly enables the irrigator to adjust irrigation schedules periodically, with minimal impact on the turf quality, to ensure irrigation targets are met throughout the entire season. The cumulative water consumption and Ii can also be monitored during the course of the season.

12.4 Turf quality/fit-for-purpose reporting

Assessing irrigation efficiency is only half the job. With the ultimate objective being the provision of safe, fit-for-purpose turf, the quality of the turf must also be monitored regularly.

Reducing water consumption at the expense of the ability of the turf to perform its intended function is an unacceptable outcome.

The Ii can be linked to turf quality and thereby provide indicators as to the performance of the overall turf and irrigation management.

Table 12.2 provides a correlation between Ii and the turf quality outcome.

Table 12.2 Irrigation efficiency – turf quality analysis matrix

Irrigation efficiency index (Ii)	Efficiency rating	Turf quality indicator
< 0.50	Extremely poor	Ii is greater than 50% less than Ir. Turf under significant stress/dying. Sportsground may be unsafe and not fit for use. Review IMP and scheduling parameters.
0.69 to 0.50	Very poor	Ii is between 31 to 50% less than Ir. Turf wilting does not meet quality standard. Sportsground may be unsafe and not fit for use. Review and alter scheduling parameters.
0.79 to 0.70	Poor	Ii is between 21 to 30% less than Ir. Turf showing signs of stress. Does not meet quality standard. Review and alter scheduling parameters.
0.89 to 0.80	Medium	Ii is between 11 to 20% Ir. Turf quality declining. Increased irrigation required. Check scheduling parameters.
0.99 to0.90	Good	Ii is less than 10% of Ir. Turf meets quality standard. Fine tune scheduling parameters.
1.00	Optimum	Irrigation applied (I) meets irrigation requirement (Ir). Turf meets quality standard.
1.01 to 1.10	Good	Ii is between 1 to 10% greater than Ir. Turf meets quality standard. Fine tune scheduling parameters.
1.11 to 1.20	Medium	Ii is between 11 to 20% greater than Ir. Turf quality high. Reduction in irrigation required. Check scheduling parameters.
1.21 to 1.30	Poor	Ii is between 21 to 30% greater than AIR. Turf lush, exceeding quality standard. Water wastage. Review and alter scheduling parameters.
1.31 to 1.50	Very poor	Ii is between 31 to 50% greater than Ir. Turf lush exceeding quality standard. Wastage of water. Review and alter scheduling parameters.
> 1.50	Extremely poor	Ii is greater than 50% more than Ir. Turf lush. Significant water wastage. Review IMP and scheduling parameters.

Table 12.3 provides turf quality indicators according to varying irrigation efficiency indices. Despite this, the turf must be monitored and inspected to ensure the actual turf quality and fit-for-purpose standards are acceptable.

Turf should be maintained to meet quality and risk management standards appropriate for its intended use. Sporting clubs and ground managers have a duty of care to all persons using facilities. This means that sports facilities, including the turf surface, must not present an unacceptable risk of injury to those using the facilities.

The standards for turf will vary with the TQVS rating and the usage of the ground. It is important to document the required standards using criteria discussed in Section 5.5 of this Code.

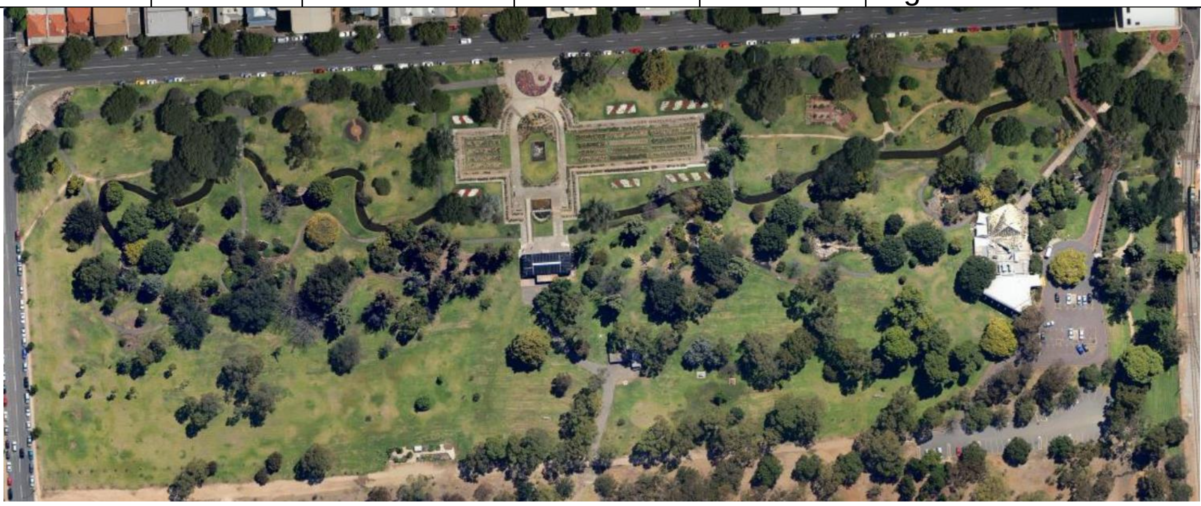
A quality and risk assessment inspection sheet should be prepared to enable sites to be assessed and a record kept of the assessment outcomes. A risk assessment of the turf surface should be undertaken weekly for active sports, with a quality audit undertaken monthly to monitor wear trends and turf quality.

Case Study Number 4
Turf / Landscape Outcomes and Water Use Monitoring
Local Government SA

The allocation of a TQVS classification to a site is directly related to the desired outcome and the subsequent irrigation requirement. Practical examples have been provided for each TQVS classification using 'neamap' images to demonstrate the turf quality outcome of each site. Aerial photographs for February 2012 were chosen as they represent the turf quality achieved for the 2011/12 irrigation season. The water usage was monitored during this period; at each of the sites the amount of water used was within 5% of the required amount.

The example shown demonstrates sound irrigation management in the achievement of the desired outcome for a high-profile, passive parkland of state or regional significance. The ability to use an adaptive management approach is demonstrated in the example of the TQVS 1-2 site, where the most appropriate water stress factor was found to be between the two classifications.

TQVS class / turf crop factors	Irrigated area (ha)	Irrigation requirement (mm)	Irrigation application (mm)	Irrigation efficiency Index	Turf quality outcome
TQVS 1-2 Tsc - 0.7 Tws - 0.8	9.6	811	770	0.95	High-vigour turf and landscape acceptable for a high-profile, passive parkland of state or regional significance.



TQVS 1-2 - Tourism site of state or regional significance (photograph sourced from www.nearmap.com)
For further information refer to the full case study in the appendices.

12.5 Landscape quality reporting

The aesthetic, environmental, health and economic benefits provided by green spaces are directly influenced by the condition and performance of the planting.

The assessment of the quality of a landscape requires a clear understanding of the role of the space or landscape feature, such as a tree.

Each type of space has its own requirements. An annual floral display bed, a shrub planting, perennial border and street tree all have their own specific requirements, which directly influence the quality assessment.

Floral displays require strong visual appeal, uniformity, no weeds and no evidence of pests and diseases.

Shrubs tend to be strongly favoured for the functional services they provide in terms of creating spaces, screening and experience of the natural environment. Flower colour, seasonal display and leaf colour are also all obviously very important.

While the aesthetic qualities of trees are very important, they provide other multiple benefits such as shading, cooling, wind break and habitat.

For irrigated landscapes, the underlying requirements are that the plant is healthy, it is suited to the purpose, compatible with the site conditions and climate and delivers the expected benefits. Maintaining soil moisture is essential for avoiding significant stress and facilitating the growth of plantings.

Lush growth, which has strong appeal, is often associated with high quality. This condition would typically be associated with high levels of readily available soil moisture. It is also strongly dependent on the plant species. Whether or not the site is being appropriately watered or over-watered depends on the plant species and the climate.

Identifying symptoms of plant stress is fundamental to the assessment of the quality of the landscape. For trees, wilting, discolouration, leaf curl, leaf drop and tip burn are examples of stressed plants. In addition to soil moisture, stress conditions may include salinity, toxicity and pests and disease. Evidence of dead branches, thin canopies and reduced branch extension are examples of more serious long-term issues, or even death, of trees.

Defined quality standards for landscape plantings provide a reference point for the monitoring of the water management of landscape sites.

In addition to the need to assess the quality of the trees, with regard to their visual attributes, there is often the need to assess the potential risk of the tree in terms of human and property safety.

Developing a template assessment system is a valuable tool to monitor the condition of a landscape.

13.0 Training and Certification

13.1 Skills and knowledge to implement the Code

The successful implementation of the principles outlined in this Code requires a range of skills and access to detailed information about the site and the factors that affect it. It is recognised that persons using the Code will be from a variety of backgrounds and skill levels including sports club volunteers, school maintenance personnel, turf and irrigation maintenance staff, technical officers, irrigation management and design professionals.

The purpose of the Code is to provide a comprehensive information resource to guide and assist users in implementing the program. The building of skills and knowledge depends on the existing skill level of personnel involved and also their role in the various parts of the program. To assist those not highly skilled in the technical aspects of the Code, support tools have been developed. These tools are available on the SA Water website: https://www.sawater.com.au/business/products-and-services/irrigated-public-open-spaces-ipos/irrigation-management-toolkits

Table 13.1 presents the basic knowledge/skill areas required and support tools available.

Table 13.1 Knowledge and skills matrix

Component of Code	Knowledge/skills	Information source	Support tools available
Policy/planning	Understanding of strategic objectives in relation to sustainable water use.	**CoP Section 3** **Access to organisation plans**	**Irrigation management plan information sheet** **Irrigated public open space principles** **Best practice checklist** **Irrigation efficiency checklist**
Water supply options	Understanding of different water supply options and water-quality issues.	**CoP Section 5** **SA Water** **State government** **Local council**	**N/A**
Best practice irrigation systems	Understanding of irrigation system hydraulics and performance.	**CoP Section 6** **Irrigation design professionals** **Irrigation Australia Ltd** **Irrigation audit professionals**	**Irrigation efficiency checklist** **Irrigation system performance guide** **Code of Practice: operational guide**
Turf and landscape outcomes	**Understanding of function of the site, plant species, and turf quality objectives.**	**CoP Section 7**	**Irrigated public open space principles**
Plant water use/water budget	Understanding of **plant species and climate data**	**CoP Section 8** **IAL industry training**	**SA Water irrigation management toolkits** **Landscape irrigation requirement model** **Code of Practice: operational guide**
Irrigation scheduling	Understanding of: • **plant water requirement** • **soil/water relationships** • **plant species/root depth** • **irrigation system performance/application rates/uniformity** • **site usage constraints.**	**CoP Section 9** **Irrigation audit data** **IAL industry training**	**SA Water irrigation management toolkits** **Code of Practice: operational guide**
Irrigation management technology	**Awareness of irrigation management technology**.	**CoP Section 10** **Irrigation suppliers** **Irrigation professionals**	**N/A**
Turf and landscape horticultural practices	Understanding of: • plant species • soil structure • plant nutrition • horticultural practices.	**CoP Section 11** **Landscape professionals** **Turf professionals**	**Sports turf maintenance guide**
Irrigation monitoring and performance reporting	Understanding of: • **water meter reading** • **plant water requirement** • **turf and landscape quality outcomes**.	**CoP Section 12** **SA Water** **Irrigation professionals**	**SA Water irrigation management toolkits** Code of Practice: operational **guide**

13.2 Personnel and formal qualifications

In order to manage irrigation effectively, specific skill sets or competencies are required at different levels - from the maintenance of grounds and irrigation systems, to scheduling, management and design. Table 13.2 details competencies and formal qualifications required by personnel involved in the management of irrigated public open space.

Table 13.2 Irrigation skills and qualifications matrix

Position/task	Competency level	Minimum qualification/ accreditation
Grounds/ landscape maintenance person	General horticulture skills including: • turf/landscape cultural practices • soils and plant nutrition • turf grass and plant identification • operating irrigation systems	Certificate III Horticulture/Turf Management IAA Certified Irrigation Operator
Irrigation Installer/ maintenance worker	Irrigation installation and maintenance	Certificate III Horticulture/Irrigation IAA Certified Irrigation Installer
Irrigation auditor/ scheduler	Advanced horticulture and irrigation maintenance Monitor performance of irrigation system and turf quality	Certificate IV Horticulture/Turf IAA Certified Landscape Irrigation Auditor
Parks/irrigation manager	Advanced horticulture and irrigation management Manage overall performance of the landscape including human, infrastructure and financial resources	Diploma Horticulture IAA Certified Landscape Irrigation Manager
Irrigation designer	Advanced horticulture and irrigation management Design landscape irrigation systems Provide advice on efficient irrigation practices	Diploma Horticulture/Irrigation IAA Certified Irrigation Designer
Turf/landscape design	Turf/landscape design/plant selection Water sensitive urban design Landscape design	Diploma Turf Management Diploma Landscape Design Bachelor Landscape Architecture

13.0 Conclusion

The Code of Practice – Irrigated Public Open Space provides a process that can be used by managers of IPOS to ensure the planning, management and reporting of water consumption in the urban environment is based on sound principles applied consistently at all levels of management. Providers, practitioners, and regulating authorities can use the Code to set policy, manage resources and regulate water use in the provision of IPOS.

Appendix 1: Reference evapotranspiration and rainfall data 2007 – 2015

Reference Evapotranspiration (ETo) - Adelaide Airport BoM Weather Station

Month	ETo (Long Term Average)	Eto (Actual 06/07	Eto (Actual 07/08	Eto (Actual 08/09	ETo (Actual 09/10)	ETo (Actual 10/11)	ETo (Actual 11/12)	ETo (Actual 12/13)	ETo (Actual 13/14)	ETo (Actual 14/15)	ETo Average 07-15
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Jul	42	54	58	61	61	49	60	53	60	56	57
Aug	59	76	88	69	88	75	75	72	72	71	76
Sep	**85**	**120**	**129**	**126**	**119**	**80**	**126**	**115**	**126**	**119**	**118**
Oct	**127**	**168**	**158**	**170**	**155**	**148**	**139**	**157**	**177**	**171**	**160**
Nov	**157**	**185**	**187**	**183**	**223**	**166**	**187**	**210**	**207**	**184**	**192**
Dec	**186**	**232**	**210**	**191**	**231**	**210**	**219**	**230**	**233**	**190**	**216**
Jan	**201**	**214**	**238**	**258**	**248**	**225**	**244**	**228**	**249**	**206**	**234**
Feb	**171**	**207**	**192**	**221**	**206**	**173**	**171**	**182**	**179**	**202**	**193**
Mar	**147**	**180**	**202**	**159**	**171**	**146**	**156**	**183**	**146**	**151**	**166**
Apr	**99**	**125**	**116**	**112**	**110**	**109**	**108**	**114**	**107**	**89**	**110**
May	61	84	66	62	79	72	66	91	77	68	74
Jun	41	42	58	52	49	58	48	46	51	49	50
Total Sept - Apr	**1173**	**1431**	**1432**	**1420**	**1463**	**1257**	**1350**	**1419**	**1424**	**1312**	**1390**
Total Full Year	1376	1687	1702	1664	1740	1511	1599	1681	1684	1556	1647

Appendix 1: Reference evapotranspiration and rainfall data 2007 – 2015

Rainfall (P) - Adelaide Airport BoM Weather Station

Month	Rainfall (Long Term Average)	Rainfall (Actual 06/07)	Rainfall (Actual 07/08)	Rainfall (Actual 08/09)	Rainfall (Actual 09/10)	Rainfall (Actual 10/11)	Rainfall (Actual 11/12)	Rainfall (Actual 12/13)	Rainfall (Actual 13/14)	Rainfall (Actual 14/15)	Rainfall Average 07-15
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Jul	60	24	47	37	68	47	55	31	97	71	53
Aug	50	9	17	70	33	77	60	53	64	15	44
Sep	**47**	**26**	**28**	**12**	**51**	**58**	**40**	**18**	**37**	**22**	**32**
Oct	**40**	**1**	**21**	**2**	**20**	**34**	**30**	**14**	**15**	**5**	**16**
Nov	**26**	**20**	**32**	**12**	**32**	**19**	**18**	**13**	**5**	**27**	**20**
Dec	**24**	**19**	**36**	**29**	**15**	**38**	**25**	**7**	**10**	**4**	**20**
Jan	**18**	**38**	**12**	**0**	**11**	**16**	**11**	**11**	**13**	**29**	**16**
Feb	**19**	**1**	**3**	**0**	**3**	**38**	**16**	**16**	**81**	**0**	**18**
Mar	**21**	**20**	**12**	**17**	**20**	**75**	**56**	**8**	**23**	**3**	**26**
Apr	**35**	**75**	**29**	**51**	**63**	**18**	**27**	**31**	**31**	**50**	**42**
May	55	35	43	50	60	37	53	60	62	50	50
Jun	57	42	24	38	61	31	115	78	70	20	53
Total Sept - Apr	**230**	**200**	**173**	**123**	**215**	**296**	**223**	**118**	**215**	**140**	**189**
Total Full Year	452	310	304	318	437	488	506	340	508	296	390

Appendix 1: Reference evapotranspiration and rainfall data 2007 – 2015

Base irrrigation requirement (Bir) - TQVS 3 - Kikuyu - Adelaide Airport BoM Weather Station

Month	BIr (Long Term Average)	Ir (Actual 06/07)	Ir (Actual 07/08)	Ir (Actual 08/09)	Ir (Actual 09/10)	Ir (Actual 10/11)	Ir (Actual 11/12)	Ir (Actual 12/13)	Ir (Actual 13/14)	Ir (Actual 14/15)	Bir (Avge 07-15)
	kL / ha	kL / ha	kL / ha	kL / ha	kL / ha	kL / ha	kL / ha	kL / ha	kL / ha	kL / ha	kL / ha
Jul	0	86	0	36	0	0	0	38	0	0	0
Aug	0	276	279	0	179	0	0	0	0	217	57
Sep	**78**	**363**	**389**	**476**	**202**	**0**	**301**	**391**	**320**	**383**	**313**
Oct	**306**	**729**	**560**	**731**	**553**	**435**	**421**	**599**	**681**	**717**	**603**
Nov	**524**	**684**	**618**	**726**	**776**	**608**	**706**	**838**	**874**	**636**	**718**
Dec	**664**	**896**	**694**	**654**	**917**	**681**	**802**	**963**	**957**	**806**	**819**
Jan	**767**	**699**	**966**	**1129**	**1016**	**884**	**999**	**929**	**1008**	**720**	**928**
Feb	**629**	**899**	**821**	**967**	**883**	**519**	**648**	**696**	**277**	**884**	**733**
Mar	**512**	**663**	**809**	**589**	**623**	**170**	**333**	**751**	**495**	**642**	**564**
Apr	**214**	**78**	**326**	**171**	**88**	**364**	**304**	**305**	**274**	**77**	**221**
May	0	149	20	0	0	84	0	23	0	0	11
Jun	0	0	104	0	0	60	0	0	0	89	0
Total Sept - Apr	**3694**	**5011**	**5184**	**5444**	**5057**	**3662**	**4513**	**5471**	**4886**	**4865**	**4898**
Total Full Year	3694	5522	5586	5479	5236	3806	4513	5532	4886	5171	4965

APPENDIX 1: Reference evapotranspiration and rainfall data 2007 – 2015

Summary - Climatic Data / Irrig Req. (Sept - April) - Kikuyu - Adelaide Airport BoM Weather Station

Month	Long Term Avge	Actual 06/07	Actual 07/08	Actual 08/09	Actual 09/10	Actual 10/11	Actual 11/12	Actual 12/13	Actual 13/14	Actual 14/15	Average 07-15
ETo (mm)	1,173	1,431	1,432	1,420	1,463	1,257	1,350	1,419	1,424	1,312	1,390
Rainfall (mm)	230	200	173	123	215	296	223	118	215	140	189
TQVS 1 (kL/ha)	8,826	11,271	11,449	11,656	11,458	9,149	10,419	11,679	11,116	10,605	10,978
TQVS 2 (kL/ha)	4,721	6,263	6,437	6,686	6,337	4,749	5,694	6,712	6,132	6,013	6,114
TQVS 3 (kL/ha)	3,694	5,011	5,184	5,444	5,057	3,662	4,513	5,471	4,886	4,865	4,898
TQVS 4 (kL/ha)	2,668	3,759	3,931	4,201	3,777	2,632	3,331	4,229	3,640	3,717	3,682

Appendix 2: Irrigation management plan guidelines

Why have irrigation management plans?

An irrigation management plan (IMP) is the foundation to achieving high standard functional green spaces and efficient use of water. The IMP expresses the commitment of the organisation to sustainable irrigated turf and landscape areas and outlines the pathway and processes that will be used to achieve those goals.

An IMP identifies the works and practices that will improve all water management including irrigation, drainage and water storage for the site or enterprise.

Structure of the IMP

An IMP has the following four components:

1. Part A. Water policy and objectives:

    - Review national, state, local and organisation policies that may affect the water management of the site.
    - Develop specific water-related objectives for the organisation.
    - Implement best management practices for water management.
    - Set targets for water management performance.
    - Commit to water management objectives.

2. Part B. Information collection:

    - site description including plans, e.g., infrastructure, contour, landscape
    - soil survey
    - vegetation survey
    - local climate
    - water resources
    - irrigation system description and pumps
    - irrigation scheduling and practices
    - drainage infrastructure.

3. Part C. Analysis of water use:

    - Record water consumption.
    - Analyse water consumption relative to water budgets.
    - Evaluate irrigation system uniformity (DU) and efficiency.
    - Report on water use.

4. Part D. Strategies, implementation and review:

    - Establish strategies for sustainable water use.
    - Identify waste, leaks and losses.
    - Establish a drought management plan - outline of strategies that will be implemented to cope with severe water availability and restrictions.
    - Review progress relative to targets.

Appendix 3: SA Water, irrigation management toolkits
Support tools and resources are available on the SA Water – Irrigated Public Open Space webpage to assist in the calculation of the irrigation water requirement, the development of a water budget, irrigation schedules and monitoring water efficiency. These include the Basic Irrigation Management Toolkit and the Advanced Irrigation Management Toolkit accessible at:
https://www.sawater.com.au/business/products-and-services/irrigated-public-open-spaces-ipos/irrigation-management-toolkits

Appendix 4: Landscape irrigation water requirement model
Refer to the Excel spreadsheet. To be included with SA Water irrigation management toolkits.

Appendix 5: Code of Practice, Operational Guide
Refer to the attached brochure. To be included on SA Water IPOS webpage.

Appendix 6: Code of Practice, Irrigated Public Open Space: Best Practice Checklist
Refer to the Excel spreadsheet. To be included on SA Water IPOS webpage.

Appendix 7: Glossary of terms and abbreviations

TERM	ABBREVIATION	DESCRIPTION
Application efficiency	Ea	A measure of the proportion of the water applied by an irrigation system that is delivered into the plant root zone and is available for use by the plant.
Base irrigation requirement	BIr	The amount water to be applied by irrigation to a given irrigated area to produce the desired landscape quality outcome using long-term average climatic data.
Bureau of Meteorology	BoM	Federal government organisation responsible for monitoring and reporting on the weather and climate.
Computerised irrigation management system	CIMS	Centralised irrigation control systems that manage a network of satellite controllers through a central computer.
Crop co-efficient	Kc	A factor that is applied to the reference evapotranspiration (ETo) value to estimate the water demand of a specific crop (ETc).
Crop evapotranspiration	ETc	The evapotranspiration (ETc) rate of a specific crop.
Density factor	Kd	Plant water demand adjustment factor that takes into account the density of planting when calculating the landscape co-efficient.
Distribution uniformity	DU	A statistical measure of the degree on variation of application that occurs with a sprinkler/spray irrigation system. The measure is determined using the average of the lowest 25% of readings from catch cans compared to the average of all test-can readings.
Effective rainfall	Peff	The amount of rainfall that enters the root zone of the soil and is available for use by the plant.
Effective rainfall factor	Pf	An adjustment factor representing the percentage of rainfall that is deemed to be effective.
Evapotranspiration	ET	The combined loss of water by transpiration from plant foliage/leaves and the water that evaporates from the soil.
Field capacity		Water remaining in the soil pore spaces following saturation and drainage of gravitational water. Drainage may take one to two days. Soil water available for extraction by plants.
Irrigation depth	I	The depth of water, in millimetres, applied by the irrigation system.

Irrigation application rate	Iar	The rate at which the irrigation system applies water to the site, expressed as millimetres per hour.
Irrigation efficiency index	Ii	A measure of performance of irrigation system application, which compares the depth of water applied (I) to the estimated depth of water required (Ir) for a given period.
Irrigation interval	Ti	The number of days between irrigation events.
Irrigated public open space	IPOS	Irrigated open space that is managed by or used by the general community. Usually managed by the public sector but also includes private schools' sportsgrounds, parks and golf courses.
Irrigation requirement	Ir	The amount water to be applied by irrigation to a given irrigated area to produce the desired quality outcome, for a given period, using real-time climate data with allowance for irrigation system application efficiency.
Irrigation run time	Irt	The length of time the irrigation system must operate to apply the optimum irrigation event (OIE) depth (mm).
Landscape co-efficient	K_L	Plant water demand co-efficient that takes into account the species, the site microclimate and the density of planting.
Landscape evapotranspiration	ET_L	The evapotranspiration rate of a non-turf landscape plantings.
Maximum allowable depletion	MAD	The amount of soil water that is allowed to be removed from the soil before an irrigation event is initiated to replenish the soil water level to field capacity.
Microclimate factor	Kmc	Plant water demand adjustment factor that takes into account the site microclimate conditions when calculating the landscape co-efficient.
Net irrigation requirement	In	The water requirement of the plant (ETc) less effective rainfall for the period.
Optimum irrigation event	OIE	The amount of water required to refill the root zone of the soil to field capacity. Includes an allowance for application efficiency.
Plant water requirement	PWR	The amount of water required by the plant to produce the desired outcome. Same as ETc.
Rainfall	P	Naturally occurring precipitation.

Readily available water	RAW	The amount of water that is available in the root zone that can be extracted without causing significant stress to the plant.
Reference evapotranspiration	ETo	The ET rate of a reference crop of healthy grass, completely covering the ground to a uniform height of 75 - 125 millimetres and having an adequate supply of water.
Refill point	RP	The value of the soil moisture level (set-point) used to initiate an irrigation event. It can be expressed as a depth of water (mm) or water tension (kPa).
Root zone depth	Zr	The depth that the active plants roots grow into the soil.
Species factor	Ks	Plant water use co-efficient for ornamental plants in calculating the landscape co-efficient (KL).
Total available water	TAW	The amount of water held in the root zone of the soil between field capacity and wilting point.
Turf evapotranspiration	ET_T	The evapotranspiration rate of a specific turf species.
Turf quality visual standard	TQVS	A visual indicator of turf quality based on the functional objective and fit-for-purpose requirement of the turf grass surface.
Turf species co-efficient	Tsc	A factor that is applied to the reference evapotranspiration (ETo) value to estimate the water demand of a specific turf species.
Turf water stress factor	Tws	A factor that is applied to the reference evapotranspiration (ETo) value and the crop co-efficient (Kc) to adjust the crop evapotranspiration (ETc) value in consideration of the plant quality required.
Water holding capacity	WHC	Soil water property that quantifies the amount of water that can be held within the pore spaces of the soil between field capacity and wilting point.
Wilting point		The amount of water remaining in the soil when plant cannot extract any more water from the soil. The plant wilts and does not recover. It defines the absolute lowest storage capacity of the soil root zone.
Water Use Classification of Landscape Species	WUCOLS	A comprehensive guide developed by L. Costello and K. Jones, University of California in 1994 that lists the water use rates of landscape plants.

Appendix 8: Case Study Melbourne Gardens
Royal Botanic Gardens Victoria: Stormwater optimisation and high irrigation efficiency

Site description

Melbourne Gardens is a high-value, botanically important picturesque world-class landscape of more than 38 hectares.

There are more than 50,000 individual plants representing from a diverse 8,000 taxa (including rare and endangered) in the living collection from a variety of habitats and geographical locations around the world. There are more than 1.5 million visitors per year.

Figure: Ornamental Lake and landscape, Melbourne Gardens

Irrigated area

Approximately 15 hectares of lawn and 12 hectares of garden beds are irrigated.

Irrigation system

Completed in 1994, the automated irrigation system has more than 7,000 sprinklers and more than 5,000 solenoid valves. It is controlled using data from an on-site weather station.

Storage and water source for irrigation

Mains potable water and harvested stormwater are used for irrigation. The Ornamental Lake has multiple functions: storage for the harvested stormwater, water treatment and to provide amenity for the Gardens' visitors.

The approximate total storage volume capacity of the lake is 56 megalitres (ML). A storage capacity of approximately 15 ML is available for irrigation, if a drawdown of approximately 300 mm is used.

Soil water banking

An important water management strategy is to deliver water to the deep soil root zones (e.g., 500 to 1000 mm) of the trees during the post winter and spring period.

This provides the trees with adequate soil moisture prior to the high summer water demand period and reduces the need for potable water for irrigation. It also allows harvested stormwater to be beneficially used on the site rather than being discharged to the adjacent Yarra River. During July to September in 2013, 13 ML of water was banked in the deep soil layers.

In the irrigation period of 2013 -14, a total of 47 ML of stormwater was used for irrigation including banking in the soil. This represents 40% of the total irrigation water use.

Water consumption

The typical annual water consumption for irrigation is in the range of 100 to 130 ML.

Soil moisture sensor system

There is an extensive soil moisture monitoring system installed at Melbourne Gardens. It includes six sites with automatic recording, real-time monitoring and uses profile sensors taking multiple readings to 1000 mm. There are also approximately 70 other locations where manual readings are taken of soil moisture at varying depths.

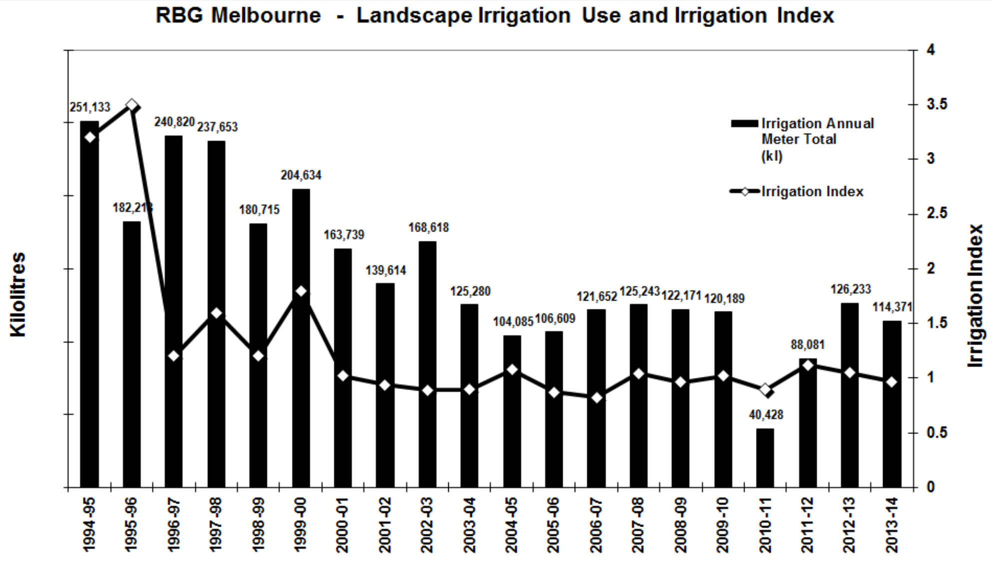
Strategies to improve irrigation efficiency

Soil moisture data is very valuable in informing the water management practices at the site. It is used to determine site-specific landscape co-efficients for each landscape zone. It is also used to determine set-point values for the initiation and termination of irrigation.

The key to the success of water management at the site is the application of the adaptive management approach, which uses a broad range of data, including assessment of plant condition, as feedback and education to continually improve the efficiency of water use.

Evaluating irrigation efficiency

Table: Annual water consumption and irrigation index (Ii) – Melbourne Gardens



The irrigation index reported shows the high standard of water management carried out at the site. From an initial high level of more than 3.0, it is now close to the target value of 1.0.

The graph shows how very significant improvements have been made in irrigation efficiency mainly through professional development of staff and technology. The graph illustrates the point that while due to weather variability the volume of water used for irrigation may vary from year to year, the high efficiency level is maintained.

Appendix 9 Case Study: Hillcrest Primary School monitoring soil moisture to achieve best practice irrigation

Overview

Hillcrest Primary School, located in the North Eastern suburbs of Adelaide, continues to progressively improve its irrigation management practices demonstrating financial, environmental and social benefits. Through effective irrigation scheduling, the investment in soil moisture monitoring equipment connected to the irrigation control system and effective horticultural maintenance, the school oval is overcoming previous surface cracking issues related to the reactive clay soil.

Figure 1: Before and after images

November 2009

January 2015

This investment in best practice irrigation technology is just one example of a new wave of irrigation system products designed to achieve sustainable outcomes.

Method

Hillcrest Primary School installed a soil moisture monitoring system linked to the irrigation control system sought from industry providers to manage the moisture level in their soil profile and schedule irrigation accordingly. The system is fitted with a flow sensor that records water use and a rain sensor recording rainfall.

Figure 2 illustrates a screenshot of the system output accessed by computer. The irrigation program is set to operate when soil moisture drops to a pre-set refill point (the red section, Figure 2). The aim is to monitor the soil moisture and achieve a sustainable level that is optimal for healthy plant growth. By monitoring soil moisture some irrigation events are prevented because water may be supplied by rainfall or water isn't lost from the soil because of mild conditions. Combining this scheduling system with an effective turf maintenance program has resulted in high water use efficiency and an improved turf quality outcome.

Results

Figure 2: Irrigation control graph, soil moisture vs. time (days)

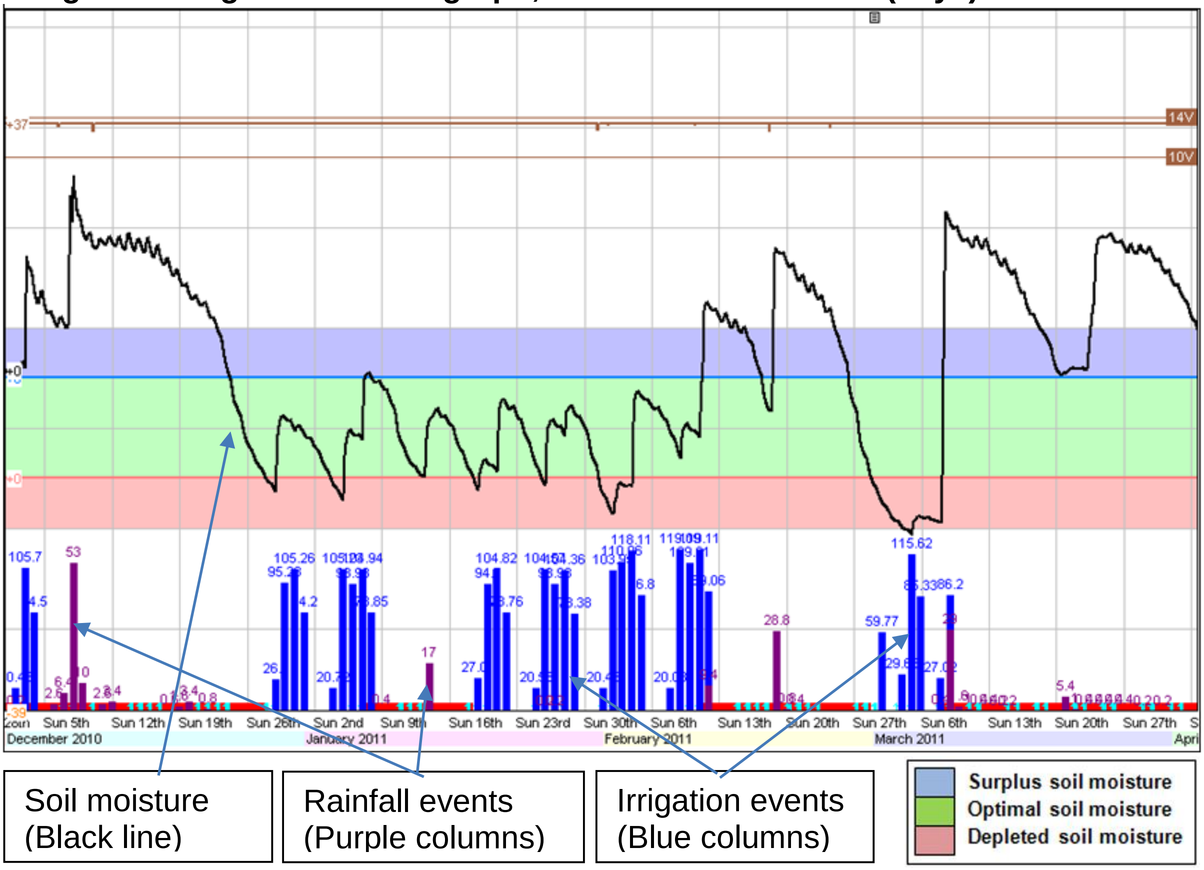


Table 1: Water use efficiency

Location	Irrigation season	Water used (kL)	Irrigation requirement (kL)	Irrigation variance (kL)	Irrigation efficiency index
Hillcrest PS Oval	2010/11	4,755	4,662	93	1.02
Hillcrest PS Oval	2011/12	5.632	5,464	168	1.03
Hillcrest PS Oval	2012/13	7,520	6,808	712	1.10
Hillcrest PS Oval	2013/14	5,902	5,914	-12	1.00
Hillcrest PS Oval	2014/15	6,301	5,616	685	1.12
Hillcrest PS Oval	Average	6,022	5,693	329	1.06

Since installation of the soil moisture monitoring and control system in 2010, water use efficiency has been high with water used being within 10% of the irrigation requirement while maintaining an improved, fit-for-purpose sportsground.

Conclusions

- Industry is providing technology to help monitor and schedule water use to achieve desired outcomes and best practice irrigation management with an optimal volume of water.
- Associated environmental, financial and social benefits have been achieved.

For further information Contact Hillcrest Primary School:
Telephone: (08) 8261 2845
Website: www.hillcrstps.sa.edu.au

Appendix 10 Code of Practice - Irrigated Public Open Space
Case Study – City of Charles Sturt Water Proofing the West

Water Proofing the West - Stage One Project, completed in December 2014, is a unique, integrated WSUD solution to the challenges associated with stormwater management stormwater quality improvement, flood management and water supply management in a fully developed urban environment.

The vision for Water Proofing the West was to create a system that harvests, treats and stores water and distributes the recycled water through sections of western Adelaide. The Project demonstrates multiple benefits of water reuse, water quality improvement, flood mitigation and bio-diversity, supporting many water sensitive cities principles.

This Project was a major initiative by the City of Charles Sturt with a final cost in the order of $71.5 million; it was a collaborative effort funded from nine funding bodies using water reuse and flood mitigation funds, with contributors from local, state and the Commonwealth Governments, a private land developer and the West Lakes Golf Club.

The Project involved developing infrastructure capable of capturing and treating up to 2400 megalitres of water and supplies recycled water to replace current and future potable water demands, as well as demonstrating sustainable groundwater resource use in the City of Charles Sturt area.

Water assets were created across five linked sites and two stormwater catchments, containing approximately 11 hectares of wetlands. Water harvesting is enhanced with the capture of excess River Torrens water, which would otherwise be discharged to sea. The water is harvested, treated and stored in underground rock aquifers and subsequently distributed through approximately 36 kilometres of mains to reserves, schools and as at third pipe water system in new residential developments at St Clair and Woodville West.

The project has five key elements with the following components:

1. **Old Port Road:** Stormwater from the surrounding catchment and flows from the River Torrens are treated in 1Ha of wetlands as well as being diverted to Cooke Reserve and West Lakes Golf Club wetlands prior to aquifer storage and recovery. This project component also includes flood mitigation works and stormwater drainage upgrades for the local stormwater catchment along Old Port Road.

2. **Cooke Reserve and West Lakes Golf Club:** Partially treated water from the Old Port Road wetlands is diverted to 4Ha of wetlands in Cooke Reserve and West

Lakes Golf Club plus bio-filters in Cooke Reserve, prior to storing the harvested water in the aquifer following water treatment.

3. **St Clair wetlands:** Stormwater from the local and surrounding catchment and flows from the River Torrens are to be diverted to 6 Ha wetlands for water treatment prior to aquifer storage.
4. **Linking and distribution mains:** Approximately 36 kilometres of linking and distribution mains connect the St Clair, Old Port Road, Cooke Reserve and West Lakes Golf Club sites and distribute recycled water.
5. **River Torrens diversion system:** At Bonython Park, excess river water is harvested and directed to the Old Port Road, Cooke Reserve, West Lakes Golf Cub and St Clair wetlands.

Water Proofing the West - Stage One Project is a multi-objective project that:

- harvests up to 2400 ML of stormwater and treats, stores and distributes recycled water through parts of the City of Charles Sturt as an alternative water source
- reduces flooding (improve flood mitigation) in the suburbs of Queenstown, Royal Park and Hendon
- harvests excess River Torrens water that would otherwise discharge to the sea
- reduces potable water usage for irrigation and other non-potable consumption
- recharges aquifers, reducing the consumption of a natural resource, which is being impacted and is becoming progressively more saline with usage
- improves public amenity of the area
- reduces the quantity of pollutants discharged into the marine environment.

Benefits of the project include:

- Creating an alternative water supply source for the community and supporting the SA State Government in achieving its targets as identified in the *Water for Good Plan*.
- Reducing flood risk in the Old Port Road area.
- Reducing the use of mains water and decreasing the reliance on River Murray water.
- Harvesting excess River Torrens water that would otherwise discharge to the sea.
- Providing an economic benefit of cheaper water source for irrigation.
- Reducing the discharge of nutrients to marine environment in Gulf St Vincent.
- Ability to continue watering reserves during a drought with water restrictions.
- Undergrounding of power lines and improving streetscape to Old Port Road - a major arterial road in Adelaide.

Government of South Australia

SA Water

Local Government Association of South Australia