DWLBC REPORT

Review of South Australian State Agency Water Monitoring Activities in the Torrens Catchment

2006/12

Government of South Australia
Department of Water, Land and Biodiversity Conservation

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Rehanna Kawalec and Sally Roberts

Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

December 2005

Report DWLBC 2006/12

Government of South Australia
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Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
25 Grenfell Street, Adelaide
GPO Box 2834, Adelaide SA 5001

Telephone	National	(08) 8463 6946
	International	+61 8 8463 6946
Fax	National	(08) 8463 6999
	International	+61 8 8463 6999
Website	www.dwlbc.sa.gov.au	

ISBN 978-1-921218-12-5

Preferred way to cite this publication

Kawalec, R & Roberts, S 2006. *Review of South Australian state agency water monitoring activities in the Torrens Catchment,* DWLBC Report 2006/12, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

ACKNOWLEDGEMENTS

The authors wish to thank personnel in the Department of Water, Land and Biodiversity Conservation, Environment Protection Authority and Bureau of Meteorology for their assistance and comments in preparing this report.

Department of Water, Land and Biodiversity Conservation

Neil Power	Manager, Strategy and Planning
Edward Pikusa	Program Manager, Surface Water Group
Dominic James	GIS Analyst, Surface Water Group
Graham Blair	Senior Hydrological Information Officer, Surface Water Group
Robin Leaney	Supervising Hydrographer, Surface Water Group
Bruce Murdoch	Senior Hydrological Information Officer, Surface Water Group
Ashley Greenwood	Program Manager, Surface Water Group
Peter Stace	Principal Hydrological Information Officer, Surface Water Group
Theresa Heneker	Engineering Hydrologist, Surface Water Group
Steve Barnett	Principal Hydrogeologist, Knowledge and Information Division
Lloyd Sampson	Hydrogeologist, Knowledge and Information Division
Michelle Bald	Project Ecologist, Knowledge and Information Division

Torrens Catchment Water Management Board

Keith Downard	Technical Manager, Torrens Catchment Water Management Board
Pedro Schultz	Scientific Officer, Water for the Environment
Marion Santich	Hydrogeologist

Environment Protection Authority

David Duncan	Principal Advisor, Water Quality
Peter Goonan	Senior Aquatic Biologist, Water Quality
Linda-Marie McDowell	SA Waterwatch Coordinator, Community

South Australian Water Corporation

Damien Venema	Water Quality Advisor, Australian Water Quality Centre

O'Connor NRM

Dr Patrick O'Connor

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PREFACE

This report, written during 2005, provides a useful record of water monitoring activities in the Torrens Catchment at the time of writing.

Implementation of the South Australian *Natural Resources Management Act 2004* and subsequent publication of the South Australian *Natural Resources Management Plan 2006* (NRM Plan) have resulted in fundamental changes in the frameworks for monitoring and evaluation in South Australia. This in turn has meant that the roles, responsibilities and constitution of state and regional agencies and organisations may have changed over time, and these changes may not be fully reflected within this publication.

The findings of this report do not imply any commitment or obligation on any agency.

EXECUTIVE SUMMARY

Water resources in the Torrens Catchment are managed to provide water for domestic, agricultural, horticultural and industrial use, while providing for the environmental requirements of water-dependent ecosystems. This review of water monitoring activities in the catchment is based on a desktop evaluation, and seeks to provide the starting point for discussions on the development of an integrated Natural Resources Management (NRM) monitoring framework and strategy.

The review covers information on the six themes of water resources data: surface water quantity, surface water quality, groundwater quantity, groundwater quality, aquatic ecosystems and catchment characteristics. These are convenient thematic divisions of the total resource for monitoring, and fit the current division of responsibilities between agencies. However, a more unified approach is a key goal of the South Australian Government's Natural Resources Management Plan 2006 (NRM Plan), which is for 'Communities, governments and industries with the capability, commitment and connections to manage natural resources in an integrated way'.

Monitoring, evaluation and reporting of water resources in the Torrens Catchment is currently fragmented both within and between government agencies and community based organisations. There is limited communication or exchange of data between the main monitoring networks.

Monitoring of a variety of aspects of water resources, including surface and groundwater quantity and quality, aquatic ecosystems, and marine and estuarine waters, all occur in the Torrens Catchment, but to varying spatial and temporal scales, and with varying frequencies.

An opportunity exists for state and regional agency agreement to ensure that water monitoring programs:

- fulfill the basic requirements of the National Monitoring and Evaluation Framework and National Water Initiative (NWI)
- meet the needs of the National Land and Water Resource Audit and for Natural Heritage Trust (NHT) funded programs
- comply with the State Monitoring and Evaluation Framework for NRM
- satisfy the requirements for regional resource condition assessment and management
- satisfy the requirements of the state Environment Protection Act 1993.

This report is intended to guide the development of future monitoring programs to a greater level of integration and efficiency. However, no onus is allocated for implementation of the proposed actions, as these will be subject to priorities and budgets of individual stakeholder organisations.

This report was written during 2005 and includes references to bodies such as the SA State Water Monitoring Coordination Committee (SWMCC) which has now been superseded by new NRM Monitoring, Evaluation and Reporting groups that are required for the implementation of the SA NRM Plan. Of greatest relevance to this report is the Monitoring, Evaluation and Reporting Policy Group that has been formed to coordinate South Australian Government agencies at the policy level, and to promote consistency and cooperation between stakeholders at national, state and regional scales of interest.

SUMMARY OF PROPOSED FUTURE MONITORING

To fill monitoring gaps for the Torrens Catchment

These suggestions provide a guide to agencies developing monitoring programs in the future (further details are provided in the body of this report and appendices). Response to these suggestions will depend on priorities and funding within stakeholder agencies. The suggestions may assist agencies to prioritise monitoring-related actions and to seek funding where gaps have been identified.

Surface Water Quantity Monitoring

Monitoring category	Gaps	Suggestions for monitoring	Refer	Stakeholder(s)
System inflow–outflow	Inflows to reservoirs, controlled releases, spills, evaporation losses at some locations.	Expand flow and evaporation monitoring within water supply distribution system.	Table 6	SA Water
System inflow–outflow	River Murray transfers.	Monitor flows and water quality at first, second and third 'drop in' points for River Murray water.	Table 6 and Sect 5.6.2.3	SA Water
System inflow–outflow	Gumeracha and Gorge Weirs.	Monitor flow and water quality upstream of Gumeracha and Gorge Weirs.	Table 6	SA Water
Rainfall	Representative sub-catchments are not being monitored.	Determine those sub-catchments that would give good representation of the area and install stations at these sites.	Sect 5.6.1.8	BoM
Evaporation	Most of the catchment.	Expansion of evaporation measurements for an important component of the hydrological cycle.	Sect 5.6.1.8	DWLBC, SA Water, BoM
Stream flow monitoring	Some sites are in disrepair or unused. Several important, possibly representative sites, are not being monitored.	Determine the need for expansion or upgrade of stream flow monitoring to ensure that it captures all catchment characteristics.	Sect 5.6.1.9	DWLBC, BoM, TCWMB
Irrigation water use	Accurate measurements of irrigation water use.	More accurate measurements of irrigation water use, by investigating land management practices, rather than relying on estimations from land-use surveys.	Sect 5.6.1.5	TCWMB, DWLBC, PIRSA
Farm dams	Rural sections, in particular Kersbrook, Footes and Mount Pleasant sub-catchments.	Carry out surveys to ascertain the sources of water in dams, whether surface water, groundwater or both, or from off-line diversions from another stream or catchment.	Sect 5.6.1.4	PIRSA

Surface Water Quality Monitoring

Monitoring category	Gaps	Suggestions for monitoring	Refer	Stakeholder(s)
System inflow–outflow	River Murray transfers, outflows from weirs and reservoirs, and upstream of reservoirs.	Expand water quality monitoring within water supply distribution system.	Sect 5.6.2.3	SA Water, DWLBC
Composite monitoring	Composite monitoring in conjunction with all flow monitoring.	Consideration be given to establishing composite water quality monitoring sites at all stream flow monitoring stations.	Sect 5.6.2.1	
Ambient monitoring	McCormick Creek, Hannaford Creek, Footes Creek and Kangaroo Creek Reservoir.	Expansion of ambient and macro-invertebrate monitoring.	Sect 5.6.2.2	TCWMB, EPA

Groundwater Monitoring

Monitoring category	Gaps	Suggestions for monitoring	Refer	Stakeholder(s)
Groundwater quantity and quality	Most of the catchment.	Expansion of groundwater levels and quality monitoring.	Sect 6.5	DWLBC, TCWMB

Aquatic Ecosystems

Monitoring category	Gaps	Suggestions for monitoring	Refer	Stakeholder(s)
Integrated monitoring program	WMLR region.	Develop calibrated catchment model.	Sect 7.4.1	DWLBC, DEH, EPA, CWMB
Stygofauna	No data.	Basic research.	Sect 7.3.4	DWLBC, EPA
Significant aquatic ecosystems	Not identified.	Identification of priority aquatic ecosystems for ambient monitoring is needed.	Sect 7.4.1.3	DWLBC, EPA, CWMB
Riparian vegetation	Riparian vegetation is degraded.	Monitor restoration of riparian vegetation.	Sect 7.4.1.4	DWLBC, CWMB
Groundwater-dependent ecosystems	Data on distribution and abundance, and impact of altered flow regime.	Survey the distribution and abundance of groundwater-dependent ecosystems. Research the impact of altered flow regime.	Sect 7.3.2	DWLBC, CWMB
Ephemeral streams	Understanding of impact of altered flow regime.	Research the impacts of altered flow regime on ephemeral streams.	Sect 7.3.3	DWLBC, CWMB

Catchment Characteristics

Monitoring category	Gaps	Suggestions for monitoring	Refer	Stakeholder(s)
Changes in land use	Up-to-date data and information.	Collect up-to-date data and information about changes in land use for all catchments.	Section 8	CWMB, PIRSA
Land-use dataset	Land-use dataset specifically designed for water resources assessment.	Develop a land-use dataset specifically designed to be used by agencies involved in water resource monitoring and management.	Section 8	CWMB, PIRSA, DWLBC, EPA
Projected urban growth	Linking information about projected urban growth to current and future land use and practices.	Research predicted urban growth and link to land-use practices with regard to future demands for water.	Section 8	RMCWMB, DWLBC

Data and Information Management

Monitoring category	Gaps	Suggestions for monitoring	Refer	Stakeholder(s)
All monitoring	Data quality, storage and accessibility.	Review monitoring data across all monitoring themes for all agencies.	Section 9	All stakeholders

Roles and Responsibilities

Monitoring category	Gaps	Suggestions for monitoring	Refer	Stakeholder(s)
Integration between agencies	Coordination between state agencies and CWMBs to clarify state-scale and catchment-scale responsibilities.	Agencies and CWMBs coordinate with regard to reviewing, rationalising or expanding monitoring programs, to avoid duplications or gaps, e.g. macro-invertebrate and groundwater.	General	All stakeholders

1. INTRODUCTION

1.1 BACKGROUND

As part of achieving the object of the *Water Resources Act 1997* (now superseded by the *Natural Resources Management Act 2004)*, the State Water Monitoring Coordinating Committee (SWMCC) was established to conduct the State Water Monitoring Review and oversee the coordination of water monitoring in South Australia.

The State Water Monitoring Review involves investigation into current water resource monitoring activities for each catchment in South Australia and development of recommendations for future water monitoring that will meet the state's core business needs and legislative responsibilities. Recommendations are seen as those that would fit into an ideal monitoring strategy to which stakeholders can refer in planning their water monitoring activities within their budgets.

As part of the State Water Monitoring Review, this project has dealt with surface and groundwater resource monitoring for the WMLR, covering the following six major themes:

- surface water quantity
- surface water quality
- groundwater quantity
- groundwater quality
- aquatic ecosystems
- catchment characteristics.

Marine and estuarine waters have not been considered as part of this review. It is advisable that monitoring these systems be reviewed in a separate document.

1.2 AIM

The aim of this project is to provide key stakeholders with suggestions they can use in the development of water monitoring strategies. These have been made on an idealistic basis and not set within current budgetary constraints. This report serves as a reference for the development of subsequent water monitoring strategies into the future.

1.3 OBJECTIVES

The project is intended to meet the following specific objectives:

- establish the monitoring requirements of key stakeholders
- develop an understanding of current water resource data collection, analysis programs and capabilities
- identify data and information gaps limiting critical water management decisions
- analyse the information on current monitoring programs to highlight commonalities

- identify barriers to coordination of monitoring programs
- propose ways of coordinating monitoring requirements to avoid duplication and improve cost-effectiveness
- provide stakeholders with an integrated water monitoring strategy proposal.

1.4 METHODOLOGY

This project has been conducted as a desktop review, using the following steps:

- research regional water resource issues
- discern relevant roles and responsibilities of major stakeholders
- review current water monitoring information and metadata
- identify and map current water monitoring sites
- organise and facilitate workshops for key stakeholders, to identify the purpose of, and agency responsible for, current monitoring sites and to discuss future monitoring needs
- identify gaps and duplications in current monitoring
- make general suggestions for a future water monitoring strategy.

In identifying monitoring gaps, comparisons have been made between existing on-going monitoring and ideal models for monitoring, which can be found in the appendices. Surface water monitoring has been dealt with on a site-by-site basis. Due to their large numbers, groundwater monitoring sites have been dealt with by reference to networks.

1.5 CONSULTATION

Under the auspices of SWMCC, a range of agencies have had opportunities to provide input to the monitoring review process. People within state agencies have been broadly consulted, and the key officers involved are listed in the Acknowledgements Section.

1.6 STUDY AREA

Potable water to metropolitan Adelaide is sourced from the River Murray and from run-off in the Mount Lofty Ranges. Water quality and availability of this water supply must be maintained at suitable levels for drinking and other domestic uses. The quality and volume of surface and groundwater resources for primary production also need to be maintained at levels that can sustain this important part of the economy. In addition, it is imperative that surface and groundwater levels and quality, in both rural and urban areas, are able to sustain aquatic ecosystems.

Rural and urban land management practices, including native vegetation clearance, irrigation activities, agricultural chemicals, groundwater extraction, surface water storages, domestic wastewater disposal, urban stormwater flows and industrial activities have significantly impacted upon the quantity and quality of surface and groundwater resources in the WMLR region. These land management practices present a risk to the sustainable use of water resources in the future.

Pressures from SA Water infrastructure, including the operation of large, major water supply dams and weirs, as well as the use of aqueducts to transfer water, have had a significant impact on flow regimes of natural watercourses. These impacts occur downstream of such infrastructure.

Farm dam development alters the hydrology of a catchment by capturing water that would otherwise flow into streams, reservoirs and recharge aquifers. The current level of farm dam development and potential for further development in some WMLR areas poses a risk to surface water, groundwater and aquatic ecosystem flows. Extensive farm dam development and high demands for groundwater also have the potential to increase levels of surface water and groundwater salinity. High demands for groundwater supplies may also disrupt discharges to streams (particularly during summer), which may have significant impacts on aquatic ecosystems.

Because the hydrological processes of fractured rock aquifers are not well understood, water balance estimates and resulting estimates of sustainable groundwater use should be approached with caution. A better understanding of recharge and flow in these aquifers is needed to ascertain the effects of any increase in extraction rates of groundwater from them.

The main contaminants identified as major risks to surface water and groundwater quality are sediments from stream erosion; overgrazing and intensive horticultural practices; pathogens such as *Escherichia (E.) Coli*, *Cryptosporidium* and *Giardia* from animal waste and septic tank effluent systems; nutrients including phosphorus, nitrogen and carbon from fertilisers; animal waste, sewage and industry effluent; and pesticides from forestry, agriculture and horticulture.

Sediments can adsorb nutrients, pesticides and micro-organisms, and transport them into waterways. Sediment is easily removed from drinking water at water treatment plants but the greater the sediment load the greater is the cost of its removal.

1.7 STAKEHOLDERS

Key stakeholders for monitoring in the Torrens Catchment include (refer to Section 3 for further detail):

- Department of Water, Land and Biodiversity Conservation (DWLBC).
- Environment Protection Authority (EPA).
- Department for Environment and Heritage (DEH).
- South Australian Water Corporation (SA Water).
- Torrens Catchment Water Management Board (TCWMB).

2. CATCHMENT DESCRIPTION

2.1 PHYSICAL FEATURES

The Torrens Catchment consists of the Torrens watershed, the Torrens rural–urban area and the Port Adelaide region. Around half of the Torrens Catchment area is located in the Mount Lofty Ranges Watershed, which supplies ~60% of Metropolitan Adelaide's public water supplies.

Upper Catchment

The River Torrens meanders for ~30 km from its source to Kangaroo Creek Reservoir through undulating terrain, passing the townships of Mount Pleasant, Birdwood and Gumeracha as numerous creeks and tributaries join it along its route. Below Gumeracha Weir, the catchment becomes steeper as the river flows to Kangaroo Creek Reservoir.

Middle Catchment

The middle section of the catchment consists of steep, heavily wooded terrain and comprises First to Sixth Creek sub-catchments. From Kangaroo Creek Reservoir to the western slopes of the Mount Lofty Ranges and the suburban fringe, the main river channel flows for ~20 km through the Torrens Gorge.

Lower Catchment

This section is distinguished by the more gently sloping terrain of the Adelaide Plains. First to Fifth Creeks join the river as it meanders across the plains through the metropolitan area for ~30 km where the river drops from ~100 m to sea level. When it reaches the city, the River Torrens is dammed at the Torrens Weir forming Torrens Lake. At Henley Beach, an outlet to St Vincent's Gulf has been artificially cut through the coastal sand dunes.

2.2 SURFACE WATER RESOURCES

The Torrens Catchment comprises undulating hills, such as Mount Pleasant (which stands at an elevation of 500 m) in the eastern sub-catchments, to steep gullies (such as Gorge Weir which has an elevation of 110 m) in the southwestern sub-catchments (Heneker 2003).

Rainfall in the Torrens Catchment differs significantly over the landscape. Mount Pleasant is the driest area, receiving ~650 mm/y. Rainfall increases down the catchment towards Cudlee Creek, which receives 850 mm/y, before dropping again to 670 mm/y at Gorge Weir. Rainfall increases through each sub-catchment from the main River Torrens channel to higher elevation areas, with the wettest area being Uraidla, which receives ~1000 mm/y (Heneker 2003).

Major impacts on surface water recharge in the Torrens Catchment include the varying land uses such as forestry and livestock grazing as well as farm dam development (see Section 2.5).

2.3 GROUNDWATER RESOURCES

2.3.1 RURAL CATCHMENT

Groundwater is stored in, and moves through, joints and fractures in the rocks underlying these catchments in what are called fractured rock aquifers. Recharge to these aquifers occurs directly from that portion of rainfall which percolates down through the soil profile (most of the rainfall runs off into the streams or is used by plants). Groundwater moves from the higher points in the landscape to the lowest, where discharge occurs to the streams. Consequently, the streams act as drains for the fractured rock aquifer systems. This discharge constitutes the baseflow of the streams which dominates flow for most of the year, particularly over the summer and between rainfall events.

The **Barossa Complex** consists of gneisses, schists and pegmatites which were metamorphosed at high temperature and pressure deep in the Earth’s crust. They occur in the centre of large folds that have been exposed by erosion, and form the basement to the overlying Adelaidean sediments. These rocks occur only in the northwestern part of the catchment between Kangaroo Creek Reservoir and Kersbrook. This unit is generally considered to be a poor aquifer from which irrigation supplies are usually not obtained. This is due to the fine grainsize and rapid decomposition of some of the schistose and granitic rocks to clay, which can considerably reduce permeability.

The **Kanmantoo Group** was formed by rapid subsidence in a broad arc around the eastern side of the present Mount Lofty Ranges. The generally feldspathic sandstone that filled this trough was metamorphosed by heat and pressure into greywacke, schist and gneiss. These metamorphic rocks are found only to the east of Birdwood. Like the Barossa Complex, the Kanmantoo Group aquifers are generally considered to be poor, with higher salinities also evident due to the lower rainfall to the east resulting in reduced flushing of the fractured rock aquifer.

Adelaidean sediments underlie most of the catchment, and are dominated by the Burra Group which consists of siltstone, shale, slate, dolomite, sandstone and quartzite. These are considered good aquifers because of their relatively high yields and low salinity.

Groundwater development in the rural catchment is limited to three specific areas, due to the steep topography and considerable areas of uncleared land to the west, and the location of suitable aquifers to the east. These are the Fourth and Sixth Creeks, and the Birdwood–Gumeracha area.

2.3.2 METROPOLITAN CATCHMENT

Unconsolidated sediments of the St Vincent Basin underlie the Metropolitan Adelaide catchment. They consist of interbedded sands and clays up to 80 m thick, which is turn are underlain by the shelly limestones and sand of Tertiary age, averaging 150 m in thickness. These sediments overlie basement rocks which are exposed in the Hills Face Zone. Because of the urbanised nature of this zone with the predominance of impermeable surfaces (roofs, sealed roads, etc.), and the clayey nature of the soils, direct recharge from rainfall to the shallow watertable aquifer is limited. Recharge to the shallow aquifer does occur from creeks and some reaches of the river through permeable alluvial sediments. The deeper Tertiary aquifers however, are recharged only by groundwater flow from the fractured rock aquifers along the Hills Face Zone.

Groundwater flows through pore spaces in the sand and limestone beds towards the sea, where it eventually discharges. Development of the groundwater resources has occurred mainly from the deep Tertiary aquifer to the west of the city in the Thebarton area.

2.4 AQUATIC ECOSYSTEMS

The WMLR has a diverse range of aquatic ecosystems. The region's ephemeral and permanent streams contain a diversity of habitats such as pools, riffles and the riparian zone and floodplains and gorges. The major freshwater streams of the WMLR are the Gawler, Little Para, Torrens, Sturt and Onkaparinga Rivers and their associated tributaries. The interactions between surface water and groundwater in this area are complex, with many of these habitats dependent either partially or wholly on groundwater. The region would also support subterranean groundwater ecosystems, although little is known about these. These water-dependent ecosystems support a range of flora and fauna including: in-stream, riparian and floodplain vegetation; phyto- and zooplankton communities; macro-invertebrates; fish; birds and mammals.

2.5 LAND USE

2.5.1 IMPACT OF LAND USE ON WATER RESOURCES

It is predicted that there will be a continuing increase in grapevine establishment and an increase in the area dedicated to olives. It also seems that there will be a pressure to increase the number of small allotments for rural living as well as further encroachment of urbanised areas onto rural land (OCWMB 2000).

2.5.2 FUTURE TRENDS IN LAND USE

Changes in land use can have a significant impact on natural resources. It is important to consider current and changing land use in relation to monitoring needs and adapt monitoring activities to encompass the impact of those changes on water resources. An inventory of land-use change is seen as imperative for the creation of an up-to-date water monitoring program. An inventory will also establish an historical perspective on the impacts of land-use change over time by providing historical records of water quantity and quality.

2.5.3 CHANGES IN LAND USE IN RELATION TO WATER MONITORING

Changes in land use can have a significant impact on natural resources. It is therefore important to consider current land-use activities in relation to monitoring needs, as well as an on-going assessment of land use to capture any changes and thus any need for changes in related monitoring activities (refer to Table 1 for major land-use activities). An inventory of land-use change is seen as imperative for the creation of an up-to-date water monitoring program as well as a means of gaining an historical perspective on the impacts of that change in relation to historical records of water quantity and quality data.

Land-use data provide information on how specific areas of land are managed. This is important as land management affects the amount of rainfall that will become runoff (Zhang 1999, cited by Heneker 2003).

For the purpose of this report, land use has been defined into 10 categories:

1. *Livestock – broadscale grazing:* includes grazing land for sheep, beef cattle, horses and goats (generally unirrigated).
2. *Livestock – intensive grazing:* includes grazing land for dairy cattle, horses, deer, alpacas, free-range hens, ostriches and emus (generally irrigated).
3. *Forestry – exotic vegetation:* non-native vegetation such as pines, willows, ash and paulownia.
4. *Forestry – native vegetation and protected areas:* native vegetation including forestry, revegetation areas and areas of remnant vegetation.
5. *Protected and recreation areas:* includes conservation and national parks, reserves and parklands, some wetlands, road and water reserves, golf courses and ovals.
6. *Horticulture and floriculture:* includes all orchards such as citrus and stonefruit, row crops such as berries, vegetables and flowers (native, exotic and herbs), but excludes vines as these generally have different water requirements than other crops.
7. *Horticulture – vines:* includes grapes, hop, kiwifruit and passionfruit.
8. *Residential and industrial:* includes residential accommodation, commercial properties, cultural areas such as schools and community buildings, manufacturing and industrial operations, and transport and storage facilities.
9. *Mining:* includes mining and extractive industries such as open cut, alluvial and sand mining, and restored lands.
10. *Water bodies:* includes farm dams, reservoirs, sewage ponds, lakes and some wetlands.

Heneker (2003) defined the main land uses in the Torrens Catchment as broadscale grazing (65% of total area), native vegetation and protected areas (12%), and protected and recreation areas (8%). Other significant land uses include forestry (exotic vegetation; 3.5%), vines (3.1%), horticulture and floriculture (2.8%), and intensive grazing (2.5%). Refer to Table 1 for a breakdown of land use.

Broadscale grazing is the primary land use in all sub-catchments with the exception of Sixth Creek, Kersbrook Creek and Kangaroo Creek, where the majority of the forestry (native vegetation) and protected or recreation areas are located (Heneker 2003).

At a sub-catchment scale, forestry (exotic vegetation), vines, horticulture and floriculture are also significant land uses. The Kersbrook Creek, Gumeracha and Cudlee Creek sub-catchments have the largest areas of both exotic and native vegetation forestry, while intensive grazing is the primary land use in Angus Creek, Hannaford Creek and Birdwood sub-catchments (Heneker 2003).

Table 1. Land Use for the Upper River Torrens Catchment (Heneker 2003)

Land use category	Area (km^2)	Percent of total area (%)
Livestock – broadscale grazing	216.6	65.3
Livestock – intensive grazing	8.4	2.5
Forestry – exotic vegetation	11.7	3.5
Forestry – native vegetation, protected areas	40.8	12.3
Protected and recreation areas	24.8	7.5
Horticulture and floriculture	9.2	2.8
Horticulture – vines	10.2	3.1
Residential and industrial	3.5	1.1
Mining	0.9	0.3
Water bodies	5.7	1.7

2.5.4 IRRIGATION

Irrigation water is generally sourced from either runoff captured in farm dams or from groundwater extracted from bores. In the Upper River Torrens catchment, water usage for irrigation is not monitored and, because of this, estimates have to be made. Areas of land assumed to be irrigated are those containing land uses of intensive grazing, viticulture, horticulture and floriculture (Heneker 2003).

3. ROLES AND RESPONSIBILITIES OF STAKEHOLDERS

3.1 ROLES OF MAJOR STAKEHOLDERS

3.1.1 DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION (DWLBC)

DWLBC is the lead state government agency in the management and administration of the state's water resources, including licensing, allocation, monitoring and policy advice. It has a significant focus on securing the supply of good quality water for South Australia from the Murray–Darling Basin system. Additionally, DWLBC works to ensure the high-quality management of groundwater and other water resources throughout the state (Department for Water Resources 2000; DWLBC 2004).

Knowledge and Information Division, DWLBC

The key focus for the division is to provide knowledge and information about the state, condition, use and management of natural resources. This is achieved through partnerships across government; with natural resources managers, industry and the community, and through excellence in science, professional advice and information management services.

The functions of the division are to:

- establish knowledge and management, including the development of information management systems to support integrated Natural Resource Management (NRM)
- ensure that scientific information is available for decision making within government, industry and the community
- monitor, assess and advise on the status and condition of natural resources and levels of sustainable resource allocation
- support research and development organisations' innovations in NRM technologies, practices and methodologies.

3.1.2 ENVIRONMENT PROTECTION AUTHORITY (EPA)

The EPA is South Australia's primary environmental regulator. It has responsibility for the protection of air and water quality, and the control of pollution, waste and noise, to ensure the protection and enhancement of the environment (EPA 2003).

The EPA is required to meet legislative monitoring and reporting requirements under the *Environment Protection Act 1993* and the *Water Resources Act 1997* (now repealed by the *NRM Act 2004*). The Environment Protection Agency assists the Authority in undertaking these tasks.

The Environment Protection Act requires the Authority to institute or supervise environmental monitoring and evaluation programs relevant to the protection, restoration or enhancement of the environment. Additionally, the Authority is required to prepare and publish the State of the Environment Report (SoE), which must:

- include an assessment of the condition of the major environmental resources of South Australia
- identify significant trends in environmental quality based on an analysis of indicators of environmental quality
- identify significant issues and make recommendations that should be drawn to the attention of the Minister.

In addition to SoE reporting requirements, the Environment Protection Act requires the Authority to provide for monitoring and reporting on environmental quality on a regular basis to ensure compliance with statutory requirements and the maintenance of a record of trends in environmental quality.

The Authority also has reporting responsibilities to provide input into State Water Plan amendments under the Water Resources Act (now repealed by the *NRM Act 2004*).

To satisfy legislative requirements, the EPA's monitoring program needs to:

- be representative of the major environmental resources
- have adequate coverage to identify geographical trends and/or variation
- use indicators that are able to reflect significant trends that are likely to be a response to pressures and/or management strategies
- use indicators that are suitable for multiple reporting requirements (SoE and State Water Plan)
- use monitoring frequency that is optimal for the identification of trends in a cost-effective manner.

3.1.3 DEPARTMENT FOR ENVIRONMENT AND HERITAGE (DEH)

DEH is involved in research, planning and delivery of biodiversity conservation programs and the provision of scientific support and monitoring for biodiversity management, including wetlands (DEH 2004).

DEH manages its business through the following programs:

- Attaining Sustainability — by promoting sustainable and eco-efficient human endeavour with minimal impact on essential life systems.
- Nature Conservation — whereby management, science and education contribute to conserving the state's biodiversity.
- Public Land Management — through the conservation, maintenance and stewardship of the state's public lands.
- Coast and Marine Conservation — by conserving, managing and protecting the state's coast and marine environments.
- Heritage Conservation — through understanding, conserving and protecting the state's rich heritage.

- Environmental Information — through the provision of information to support the state's environmental needs.

3.1.4 SOUTH AUSTRALIAN WATER CORPORATION (SA WATER)

SA Water is responsible for ensuring that potable water supplied to customers is safe to drink. There are agreed levels of service between SA Water and the Department of Human Services (DHS), and regular (monthly) reporting on compliance with these levels, and with the requirements of the Australian Drinking Water Guidelines, is required. This arrangement involves a preventative, multiple-barrier approach to water quality management and requires management of the water system from source to tap.

SA Water's mission is to provide innovative water and wastewater solutions that:

- safeguard public health
- sustain water resources and the environment for the future
- deliver increasing value for its customers, the government and the community (SA Water 2003).

Its primary functions are to provide services:

- for the supply of water by means of reticulated systems
- for the storage, treatment and supply of bulk water
- for the removal and treatment of wastewater by means of sewerage systems (SA Water 2003).

SA Water has the following further function in relation to water monitoring:

- to carry out research and works to improve water quality and wastewater disposal and treatment methods (SA Water 2003).

In satisfying these requirements, SA Water extensively monitors water quality at inlets to water supply reservoirs and water intakes, in the reservoirs, at treatment plants and in the distribution system. Water quality monitoring parameters are chemical, physical, biological (algal) and microbiological. Monitoring is mainly carried out by the collection of 'grab samples'. SA Water carries out load-based monitoring of reservoirs at some sites. All water quality data collected by SA Water are maintained on a central database managed by the Australian Water Quality Centre (AWQC).

SA Water also has an interest in the quantity of water flowing into reservoirs and volumes transferred between storages. An informal arrangement exists with DWLBC to store this information on the HYDSTRA database or as spreadsheets. SA Water is currently developing a system on which to store water transfer data, and is reviewing its water quantity monitoring and data requirements (Kneebone 2000).

3.1.5 TORRENS CATCHMENT WATER MANAGEMENT BOARD (TCWMB)

Catchment Water Management Boards are state government statutory authorities responsible to the Minister for Environment and Conservation. The TCWMB (2002) aims to meet seven main goals:

Goal 1 Improve and maintain water quality in the catchment to a standard suitable for community use (including public water supply), for sustaining natural ecosystems and to reduce impacts on receiving waters.

Goal 2 Ensure that sufficient water is maintained in creeks, rivers and aquifers to be available for equitable and economic community use (both private and public) and to maintain ecosystems.

Goal 3 Protect and enhance water-dependent ecosystems through integrated natural resource management.

Goal 4 Coordinate floodplain management at the catchment scale.

Goal 5 Foster an informed, committed and involved community which takes responsibility for, and actively supports its role in, catchment water management.

Goal 6 Establish monitoring and evaluation systems that enable the board to assess the effectiveness of its programs and the health of the catchment.

Goal 7 Deliver the board's programs in an integrated manner in partnership with all other stakeholders, taking into account environmental, economic and social considerations.

3.1.6 BUREAU OF METEOROLOGY (BOM)

BoM is a major water resource data collection agency for South Australia. It is responsible (since 1988) for providing a flood warning service for non-flash flooding (i.e. rivers that take more than six hours to flood).

Flash flooding (i.e. floods that develop in less than six hours) is probably more critical for Adelaide and surrounding areas. BoM provides hydrological advice and critical support to local councils for flash floods as well as assistance in setting up monitoring equipment for rainfall and water levels, but is not responsible for forecasting or issuing flood warnings for this type of flooding.

Local councils have contributed towards the cost of setting up a network of rainfall and water-level monitoring stations, as well as flood ALERT computer base stations for monitoring flash flooding. These systems are primarily monitoring systems and are not able to provide generalised warnings to the public. BoM maintains the monitoring equipment and computers, and recovers associated costs from councils. All data collected by the ALERT monitoring stations are quality controlled and stored in the DWLBC HYDSTRA database.

BoM also has a significant role in providing rainfall and general climate data for water resource purposes, and maintains sites that collect daily rainfall data, automatic weather stations that collect rainfall data both daily and in ‘time series’ form, and pluviometer sites that collect the full time series record down to 10-second increments.

Data from the pluviometer sites are edited and archived in the DWLBC HYDSTRA database. Data from the sites that collect daily rainfall and the automatic weather stations is held in the National Climate Centre in Melbourne, and can be accessed from the BoM office in Adelaide.

3.2 RESPONSIBILITIES OF MAJOR STAKEHOLDERS

The current responsibilities for water monitoring of principal agencies are shown in Table 2 (adapted from Wen 2005; App. C). The table also provides reference to other principal agencies carrying out related monitoring which can be used in determining information sharing opportunities.

Table 2. Current responsibilities for water monitoring of principal agencies.

Water monitoring category	Responsible stakeholders[1]	Other agencies involved[2]
Surface water quantity		
Rainfall	BoM	DWLBC, SA Water, CWMB
Rainfall intensity	DWLBC	BoM, CWMB, SA Water
Catchment stream flow	DWLBC	EPA, CWMB, SA Water
Sub-catchment stream flow	CWMB	DWLBC, EPA, SA Water
Stormwater	CWMB	DWLBC, EPA
Farm dams	DWLBC	CWMB, EPA
Water-use efficiency	CWMB	DWLBC, SA Water
Surface water quality		
Pesticides, organics, metals, nutrients, DO, pH, turbidity, temperature	EPA	DWLBC, CWMB, SA Water
Macro-invertebrates, indicator bacteria	EPA	DWLBC, CWMB, SA Water
Ambient	EPA	DWLBC, CWMB, SA Water
Groundwater quantity		
Water allocation	DWLBC	EPA, CWMB, SA Water
Environmental flows	DWLBC	EPA, CWMB, SA Water
Groundwater quality		
Salinity	DWLBC	EPA, CWMB, SA Water
Ambient	EPA	DWLBC, CWMB, SA Water
Aquatic ecosystems		
Water quality	DWLBC	EPA, CWMB, DEH
Biological integrity	DWLBC	EPA, CWMB, DEH
Environmental value assessment	DWLBC	EPA, CWMB, DEH

1 Responsible stakeholder — legislative mandate, responsible for: developing monitoring strategy, plan and protocols; data custodian, and supervising data quality assurance; and support monitoring undertaken by other parties.

2 Other agencies involved — need information for business operation, contribute to monitoring through joint funding, advising, etc.

4. CURRENT MONITORING SYSTEMS

4.1 OVERVIEW OF SURFACE AND GROUNDWATER MONITORING IN SA

4.1.1 WATER QUANTITY

Two critical components of water resources monitoring are the monitoring of stream flow and groundwater levels. South Australia is fortunate to have a long history of both. Stream flow in major streams in the state has been monitored for the last 50–150 years. For example, SA Water has been monitoring and recording the River Torrens since 1857, and the Murray–Darling Basin Committee has been measuring the water level along the lower River Murray for over a century. The groundwater levels in some strategic aquifers have been monitored since 1934.

4.1.2 WATER QUALITY

DWLBC collects salinity data for surface water and groundwater, and currently has four stream-gauging stations with the capacity to record electrical conductivity (EC) and temperature. Within the current Obswell network, 232 observation wells are instrumented for EC measurement.

4.1.3 SURFACE WATER

Many Federal, state, and local agencies in South Australia use stream flow data, the many uses of which include:

- water supply assessment
- catchment management
- stream restoration
- bridge design
- flood warning
- sediment and contaminant loading
- recreational activities.

4.1.4 GROUNDWATER

Groundwater level data are used to:

- discern trends (both long and short term)
- provide warnings of unsustainable use
- inform the state's groundwater appropriation permitting process.

Groundwater data are also used during technical investigations (such as quantifying recharge), in environmental water requirement evaluations and in dryland salinity investigations.

4.2 DEFINITIONS OF WATER MONITORING

To 'monitor' is to 'maintain regular surveillance over' (Oxford Dictionary 1995). Brydges (2004) considered it essential that environmental monitoring programs take measurements at regular time intervals over a substantial length of time. There are two fundamental reasons for monitoring natural systems. The first is to establish baselines representing the current resource condition status. The second is to detect changes over time, particularly changes that are outside the natural variation of the baselines (Hicks and Brydges 1994). Alternatively, monitoring may be considered as a process that provides information used in management (Finlayson and Mitchell 1999). In this framework, it is essential that monitoring be able to measure change in reference to a set of objectives (Baldwin et al. 2005).

Monitoring can be categorised on the basis of management-derived objectives (Downes et al. 2002) as:

- **monitoring for SoE reporting** — aims to provide instantaneous reporting of current conditions
- **regulatory and/or compliance monitoring** — evaluates the impact of regulation or development, often as part of compliance with water management plans, statutory reporting, auditing or law
- **project monitoring** — linked to project objectives, which may commonly include the collection of detailed data to support ambient monitoring
- **ambient monitoring** — long-term monitoring to establish and continually assess the resource state and detect any changes in condition; ambient monitoring also includes long-term reference site monitoring.

Monitoring programs undertaken to meet these objectives fall into five broad categories (adapted and modified from Brydges 2004):

- **simple monitoring** — records the values of a single variable (e.g. rainfall)
- **multivariate monitoring** — records multiple variables (e.g. water quality, EC, pH, DO, etc.)
- **survey monitoring** — involves monitoring areas that are affected and unaffected by an observed stress; survey monitoring is used in the absence of historical monitoring data
- **surrogate or proxy monitoring** — uses surrogate measures to infer historical conditions or current impacts in the absence of actual measurements of the desired variable; fossil diatom assemblages are often used to infer historical conditions, and modelled flow volume may be used to infer ecological health
- **integrated monitoring** — uses a range of variables (e.g. hydrological, climatic and biological) sampled over time in order to record changes in the environment and define reasons for those changes.

Monitoring undertaken in the WMLR has been instigated to meet one or more of the management-derived objectives and fits into one or more of the five monitoring types.

Water monitoring is also considered as the process of collecting samples or data. In defining monitoring, however, there are other aspects that should be addressed, including: data acquisition (network design, quality assurance and quality control, laboratory analysis, data handling, data analysis), data utilisation, communication and coordination. Saunders (1985) summarised those aspects of monitoring as below.

- **data editing** — preparation of raw data for entry to databases or for analyses
- **data verification and entry** — ensuring that data looks 'reasonable' based on what is known about the system
- **data storage, security and accessibility** — data should be stored effectively in a secure, maintained database and available to researchers or the public
- **evaluation** — analysis of data to produce information
- **regular review** — adequacy of the water information system (including but not limited to the monitoring network): is the information being provided sufficient to meet foreseeable needs?; are any gaps or redundancies emerging?

As a management tool, water monitoring is identified as a starting point of the management process and as a feedback mechanism to identify how management efforts have affected water conditions. At times, monitoring may serve only a single purpose, either in terms of identifying water conditions or as feedback to a management decision. From the management point of view, the following types of monitoring can be defined (after MacDonald et al. 1991):

- **trend monitoring** — measurements are made at regular, well-spaced time intervals in order to determine the long-term trend in a particular parameter
- **baseline monitoring** — used to characterise existing water quality conditions and to establish a database for planning or future comparisons
- **implementation monitoring** — assesses whether or not activities were carried out as planned
- **effectiveness monitoring** — used to evaluate the effectiveness of specified activities
- **project monitoring** — assesses the impact of a particular activity or project
- **validation monitoring** — deals with the quantitative evaluation of a proposed water quality model to predict a particular water quality parameter
- **compliance monitoring** — used to determine if specified water quality criteria are being met.

4.3 MONITORING METHODS EMPLOYED

4.3.1 SURFACE WATER QUANTITY

DWBLC is the state agency primarily responsible for collecting, analysing and sharing data on surface water quantity (availability and use). In particular, DWLBC is the main collector of stream flow data, which measures the volume of water flowing through a stream using stream gauges. DWLBC collects data through its state stream-gauge network, which continuously measures the level and flow of rivers and streams at 80 stations state wide. These data are available to the public via the Internet: the Surface Water Archive (http://enrims.dwlbc.sa.gov.au/swa/mapindex.htm). The South Australian Government maintains a network of ~200 hydrometric stations across the state. Data collected by other agencies, such as SA Water, are stored in the HYDSTRA data management and reporting system, which is maintained by the Hydrographic Unit of DWLBC.

The stream-gauging stations include a range of in-stream structures designed to channel stream flow, or discharge in a manner that produces a relationship between water level and discharge. The stations are equipped with electronic sensors and data loggers. By electronically recording water level at these structures, a mathematical relationship can be used to continuously measure discharge.

In line with its business requirements, DWLBC has classified the stream-gauging stations into six types (App. B), each type having an assigned priority level, unique purpose and minimum parameter requirement.

4.3.2 SURFACE WATER QUALITY

EPA is responsible for assessing the condition of surface waters on a state-wide basis in accordance with the SA Environment Protection Act. EPA conducts ambient water quality monitoring programs including the rivers and streams program, marine and estuarine program, inland waters (lakes) program and groundwater program. These programs are designed to:

- provide a qualitative and quantitative assessment of South Australia's surface water quality
- determine statistically significant changes or trends in the key characteristics of water quality
- provide data to assess the long-term ecologically sustainable development of surface waters.

The parameters monitored in these programs can be classified as physical, chemical or biological. The choice of water quality parameters is based on those required to support the designated environmental values of the target water body.

Physical parameters measured include turbidity, conductivity (salinity) and temperature. Chemical parameters can be divided into pH and dissolved oxygen (DO), metals (total Cu, Pb, Ni, Hg, Zn and Cd) and nutrients (NOx, NH_3, TKN and total P). Biological parameters include an estimate of algal biomass (chlorophyll *a*), microbiological parameters (*E. coli* and enterococci) and macro-invertebrates. Some of the parameters (i.e. DO, EC, temperature and pH) are measured in the field when samples are taken. The others are analysed in NATA-accredited laboratories, such as the Australian Water Quality Centre. The macro-invertebrate sampling is consistent with AusRivAS (Australian River Assessment System) methodology (see Section 7.2.2).

The current focus of DWLBC surface water quality monitoring is on salinity. However, DWLBC can also establish and operate automatic water quality samplers designed to collect data on nutrients, pesticides and pathogens entering SA Water's urban supply reservoirs. Water salinity is monitored at many hydrometric stream flow gauging stations using an EC probe. Along with temperature, the probe continuously measures EC.

4.3.3 GROUNDWATER

Fluctuations in groundwater levels reflect changes in groundwater storage within aquifers. Two main groups of fluctuation have been identified — long term, such as those caused by seasonal changes in natural replenishment and persistent pumping; and short term, for example, those caused by the effects of brief periods of intermittent pumping and tidal and barometric changes. Because groundwater levels generally respond rather slowly to external changes, continuous records from water-level recorders are often not necessary. Systematic observations at fixed time intervals are adequate for the purposes of most monitoring networks. Where fluctuations are rapid, a continuous record is desirable, at least until the nature of such fluctuations has been determined.

Groundwater monitoring may be divided into three main stages:

- reconnaissance, with the objective of a preliminary appraisal of the available water resources
- general investigations, to obtain information for planning future urban, industrial and agricultural development
- intensive studies of the aquifer(s); this level of investigation requires the greatest effort and is necessary for areas of present or potential intensive development.

During each stage of the groundwater investigation, the information required includes:

- spatial and temporal variations of the piezometric heads, resulting from natural and man-made processes
- hydraulic constants of the aquifer
- geometry of the aquifers and aqueducts
- rates of natural replenishment and outflow
- rates of abstraction and artificial recharge
- water quality.

The data on piezometric heads and water quality are obtained from measurements at observation wells and analysis of groundwater samples. Observation wells are either existing wells, carefully selected from those already drilled in the area, or are drilled and specially constructed for the purposes of the particular study. One of the main costs in groundwater studies is drilling observation wells. Whenever possible, it is advisable to carefully select and incorporate existing wells into the observation network.

In South Australia, monitoring bores have been established to monitor trends in groundwater and/or salinity levels for all areas of the state by a variety of organisations. By law, all wells require the issuing of a permit from DWLBC, and details from the drilling operation must be submitted as a condition of the permit. These data are then recorded on the SAGeodata database. Where the bore is to be used for monitoring purposes, the observation bores are grouped together into ‘networks’ that delineate a region in the state, a particular organisation doing the monitoring, or a specific aquifer. In theory, any group that maintains and reads monitoring bores provides the information to DWLBC for entry onto the state database.

The timeframes for forwarding the information to DWLBC head office for entry onto the database vary. Some groups may forward the information immediately after wells are read; other groups may collate results and forward them periodically, say, on an annual basis.

There are also situations where the information is provided on a purely informal fashion, having been collected for another organisation.

The Obswell searchable interface is linked to SAGeodata and provides access to monitoring bore information. Information on the networks and individual bores associated with each of these networks is available on the Obswell website: http://applications01.pirsa.sa.gov.au:102/new/obsWell/MainMenu/menu.

Water-level and salinity monitoring data are available for users to view and download free of charge. Elevation data, well coordinates and basic construction details are also available.

The major Obswell monitoring networks throughout the WMLR region are listed in the text. Bores are read periodically at intervals specific to the bore or network.

4.3.4 AQUATIC ECOSYSTEMS

Assessing the health of aquatic ecosystems is currently carried out either directly or indirectly. Direct monitoring is carried out by assessing a component of the ecosystem, such as monitoring the distribution and abundance of macro-invertebrates and fish. Indirect monitoring is carried out using a surrogate measure of ecosystem health, such as pool depth as a measure of the health of groundwater-dependent ecosystems.

AusRivAS is a rapid prediction system used to assess the biological health of Australian rivers. It was developed under the National River Health Program (NRHP) by the Federal Government in 1994, in response to growing concern in Australia for maintaining ecological values.

AusRivAS uses bio- and physical assessment methods in its monitoring. These correspond with rapid biological assessment protocols and rapid geomorphic, physical and chemical assessment protocols, respectively.

The bioassessment method uses data obtained by the sampling of macro-invertebrate communities from the basic habitat types (riffles and edge). Representative samples are identified to species level where possible, and physico-chemical characteristics of the site are also measured.

The AusRivAS model works by evaluating the measurements of physical and chemical parameters and, by incorporating the conditions at the site, predicts which families should be present. A ratio of observed:expected animals provides an indication of the ecological condition of the subject site.

4.3.5 COMMUNITY MONITORING

Waterwatch

This program is largely education-based monitoring and community capacity building. The government-resourced, community-based Waterwatch program has sites throughout the state. School or community groups or individuals are encouraged to adopt sites for regular surveys. Participants are encouraged to sample quarterly, although more or less frequent or irregular sampling may occur depending on interest and availability.

Physical and chemical parameters (turbidity, phosphorus and nitrogen concentration, pH, temperature and salinity) are measured to produce a pollution index. Macro-invertebrates are sampled to provide an overall species diversity score.

Frog Census

This program is also community based and is coordinated by the EPA (until 2005–06 when it will be transferred to DEH). The protocol involves the identification of frog species present through identifying their calls. Tape recordings of frog calls are made by volunteers during the second week of September each year and returned for analysis along with site details. Whilst the census is not quantitative, information is gleaned on the distribution and abundance of frogs in South Australia.

5. SURFACE WATER MONITORING

Water monitoring programs considered in this review for identification of monitoring gaps are those that are managed as on-going programs, rather than once-off or occasional. Current on-going water monitoring activities for the Torrens Catchment have been assessed against the Monitoring Station Categories provided in Appendix B, Systemic Model Categories in Appendix C, and TCWMB Issues in Appendix D, that are deemed necessary as major elements of a water monitoring strategy. From this framework, general gaps in monitoring have been identified and suggestions for filling those gaps have been made. Figures 1 and 2 show the location of the current surface water quantity and quality monitoring sites for the upper and lower Torrens, respectively.

5.1 SURFACE WATER QUANTITY MONITORING

5.1.1 RAINFALL

To obtain a realistic assessment of runoff, a good understanding of both the volume and variability of rainfall in a catchment is important. Maintenance of existing, as well as establishment of additional, pluviograph stations at higher elevations within the catchments would provide more information about the spatial variability of rainfall with elevation and improve the rainfall–runoff modelling process (Heneker 2003).

5.1.2 EVAPORATION

The main factors involved in the evaporation process are solar radiation, air temperature, air humidity and wind velocity. Estimates of evaporation are essential for the calculation of water balances in terms of how much rainfall becomes runoff. The availability of long-term, daily pan (evaporation from an open water surface) evaporation data in the Mount Lofty Ranges is very limited. There should be at least one climate station located within major catchment areas that records both pan data and relevant climate variables required to calculate evaporation.

5.1.3 STREAM FLOW

It is important to acquire long-term, good-quality stream flow records in order to calculate levels of runoff over a range of rainfall events. Stream flow data that are inadequate are much more difficult to correct than data for rainfall, as there are many factors that influence runoff.

DWLBC and BoM, along with SA Water and TCWMB, collect daily stream flow data in SA. Table 3 (adapted from Heneker 2003) identifies on-going stream flow gauging station locations in the upper and lower Torrens Catchment to 2002.

Table 3. Ongoing stream flow gauging station locations to 2002

Station number	Location	Custodian	Period of record	% of missing data to 2002
Upper Torrens				
AW504500	River Torrens @ Gumeracha Weir	DWLBC	1974–2002	0.2
AW504501	River Torrens @ Gorge Weir	DWLBC	1974–2002	3.2
AW504512	River Torrens @ Mount Pleasant	DWLBC	1974–2002	–
AW504523	Sixth Creek @ Castambul	DWLBC	1978–2002	6.9
AW504525	Kersbrook Creek @ U/S Millbrook Reservoir	DWLBC	1990–2002	11.4
AW504903	Cudlee Creek @ D/S Road Bridge Lobethal Road	BoM	1996–2002	3.7
AW504911	Millers Creek @ Forreston	BoM	1997–2002	–
AW504912	Angas Creek @ Mullers Road	BoM	1997–2002	6.1
AW504913	River Torrens @ Birdwood	SA Water	1995–2002	29.7*
Lower Torrens				
AW504501	Torrens River at Gorge Weir	SA Water	1937–2002	9.22
AW504509	Hope Valley Reservoir intake channel	SA Water	1992–2002	2.33
AW504513	Torrens River City Weir	Adelaide City Council	–	–
AW504517	First Creek at Waterfall Gully	DEH	1976–2002	5.15
AW504529	Torrens River at Holbrooks Road	P&TCWMB	1978–2002	2.09
AW504547	Hope Valley Reservoir	SA Water	1993–2002	9.54
AW504552	First Creek Catchment at Mount Lofty	DEH	–	–
AW504578	First Creek D/S Botanic Gardens	P&TCWMB	1996–2002	0.00
AW504579	Third Creek at Forsyth Court	P&TCWMB	1996–2002	0.21

*The data from AW504913 is five-minute telemetry data and, if a number of five-minute intervals are missing on a given day, all data for that day are discarded and the day recorded as missing. Hence, this may overestimate the total missing data.

5.1.4 WATER USE

5.1.4.1 SA Water Infrastructure

SA Water carries out water monitoring in relation to its water supply infrastructure (e.g. reservoir water levels). However, continuously recorded data for water supply operations, including reservoir releases and spills from weirs, are not monitored in some cases and need to be included in SA Water's monitoring network. This is important as part of estimating natural runoff for hydrological modelling.

5.1.4.2 Farm Dams

The influence of farm dams on flow data is important with regard to hydrological modelling, as are the sources of water whether surface water, groundwater or both, or diversions from another catchment. Data on water use in relation to farm dams is currently derived from land-use data sets.

5.1.4.3 Irrigation Water Use

Areas irrigated and application rates have not been measured for all agricultural industries. Research was recently carried out to gather information about irrigation activities that are not within prescribed areas for parts of the Adelaide and Mount Lofty Ranges region, the results of which are presented in Binks (2004). Data used to gather information for the project were mainly from on-farm field assessments of irrigation practices for the apple, pear, cherry and viticulture industries, ABS statistics, land status mapping for the Mount Lofty Ranges watershed, and a survey of apple and pear growers.

5.1.5 BASE STATIONS

The role of a base station is to monitor outflow from the major yielding section(s) of a catchment and should be open indefinitely, monitoring rainfall, water level and/or stream flow, and salinity. It is considered to be a high priority form of monitoring.

Two base stations currently operate in the Torrens Catchment. SA Water is monitoring water levels at ‘Torrens River @ Gorge Weir’ (AW504501) as well as water quality at Gorge Weir for algal enumeration, chlorophyll, cryptosporidium, giardia, organochlorine, organophosphorus and triazine, and temperature. It is suggested that at least salinity also be monitored at site AW504501 to meet the requirements for monitoring water quality at a base station.

‘Torrens River D/S Holland Creek’ (A5041003) is a new station recently installed by DWLBC between Holland Creek and Millbrook Creek (inflow); it is intended to run this well into the future.

5.1.6 BASIN OUTFLOW STATION

These stations monitor stream flow leaving the catchment (e.g. flows into the ocean, inland lakes or interstate). This is considered to be a high priority monitoring category to be done as required for statutory reporting purposes. ‘Torrens River @ Holbrooks Road’ (AW504529) is being monitored by TCWMB for water levels and quality (composite monitoring) in relation to pollution of Gulf St Vincent.

5.1.7 SYSTEM INFLOW – OUTFLOW STATIONS

According to the monitoring station categories provided in Appendix B, this high-priority category of monitoring relates to stream flow entering or released from regulated river systems and infrastructure (e.g. upstream and downstream of reservoirs and weirs). The minimum parameters to be measured are water level and/or stream flow for at least 10 years. The systemic model provided in Appendix C also suggests that water quality monitoring be carried out at these locations and in relation to water treatment plants, as well as within reservoirs.

5.1.7.1 Millbrook Reservoir

Water is channelled from Gumeracha Weir to Millbrook Reservoir, which gains very little water from its sub-catchment and is essentially considered an off-stream reservoir. SA Water is monitoring water levels and flow as well as carrying out composite water quality monitoring at ‘Millbrook Reservoir Intake Channel @ U/S Millbrook Reservoir’ (AW504508). ‘Kersbrook Creek @ U/S Millbrook Reservoir’ (AW504525) is a DWLBC site monitoring level and flow, as well as quality through composite monitoring. SA Water is carrying out water level monitoring of the reservoir at ‘Millbrook Reservoir @ Dam Embankment’ (AW504520).

5.1.7.2 Kangaroo Creek Reservoir

Water is released from Millbrook Reservoir down to Kangaroo Creek Reservoir. SA Water is monitoring reservoir water levels and spill at ‘Torrens River @ Kangaroo Creek Reservoir’ (AW504531).

5.1.7.3 Hope Valley Reservoir

Hope Valley Reservoir is an off-stream water body that has water channelled into it from Gorge Weir. SA Water is monitoring reservoir levels, as well as rainfall and evaporation, at ‘Hope Valley Reservoir @ Hope Valley’ (AW504547). SA Water monitors water levels and flow at ‘Hope Valley Reservoir Intake Channel @ Athelstone’ (AW504509).

5.1.7.4 Gumeracha Weir

SA Water carries out water level and spill monitoring at ‘Torrens River @ Gumeracha Weir’ (AW504500).

5.1.7.5 Gorge Weir

The majority of the runoff reaching the weir comes from Sixth Creek sub-catchment and releases from Kangaroo Creek Reservoir. The weir diverts flow to Hope Valley Reservoir. Releases and spills from the Gorge Weir also flow into Torrens Lake (Heneker 2003). SA Water is currently monitoring water levels and spills for Gorge Weir at ‘Torrens River @ Gorge Weir’ (AW504501). The parameters for a new DWLBC site ‘Torrens River @ downstream of Gorge Weir’ (A5041002) are being established.

5.1.8 RIVER MURRAY TRANSFERS

Water from the River Murray is released into the River Torrens at three locations from the Mannum to Adelaide pipeline, two in the Birdwood sub-catchment and one in the Angas Creek sub-catchment. DWLBC is monitoring rainfall and water level at ‘Torrens River @ Mount Pleasant’ (AW504512), that being the first drop-in point for River Murray water.

5.2 CURRENT SURFACE WATER QUALITY MONITORING

5.2.1 PHYSICAL AND CHEMICAL WATER QUALITY MONITORING

The EPA, catchment boards and SA Water carry out full physical and chemical monitoring at selected sites (refer to section on Water Quality Monitoring for the catchment). However, not all sub-catchments are monitored for such water quality parameters. Where it is not practical to carry out continuous composite sampling, all sub-catchments should be monitored for ambient water quality.

It is generally accepted that regular measurements over a period of five years is required before statistically significant conclusions can be made about trends or changes in chemical water quality characteristics. Table 5 illustrates the type of monitoring carried out by each agency.

5.2.2 POINT SOURCE POLLUTION MONITORING

Point source pollution is usually related to urban development (e.g. septic tanks, manufacturing and mining activities). EPA monitors discharges of pollutants by industry and organisations that are required to provide them with such information through a licence agreement. However, pollution by industry, not already monitored by the EPA because as individual industries they fall within the acceptable limits, needs to be addressed in terms of the cumulative affect of these industries on surface water and groundwater.

5.2.3 DIFFUSE SOURCE POLLUTION MONITORING

Diffuse pollution is either a result of widespread land-use practices or numerous small sources, and is usually associated with rural land-use activities. Diffuse pollution monitoring needs to be developed further as sources of diffuse pollution are not well understood.

Methods to estimate diffuse pollution (e.g. application of pesticides and herbicides) risks and loads are currently in a developmental stage. The most promising method uses detailed information on land management, but this information is not always available (a possible partnership could be established between DWLBC and PIRSA for such information collection). Used in combination with trace sampling, whereby pollutant types and loads are monitored at the 'bottom' of sub-catchments and then traced back to the source, it may provide promising results.

5.2.4 PESTICIDES

EPA has carried out targeted studies of pesticides in sediments of rivers, streams, estuaries and lakes. There is a need to expand monitoring programs for pesticide residues in watercourse sediments as they can be bioavailable and have adverse impacts on aquatic ecosystems.

5.2.5 CONTINUOUS RECORDING

There are two sites at which private companies are recording turbidity continuously in the field — AW504584 in Gorge Weir sub-catchment and AW504591 in Hope Valley Reservoir sub-catchment. Turbidity is also measured within the TCWMB composite water quality monitoring program, described below.

5.2.6 COMPOSITE WATER QUALITY MONITORING

Composite monitoring is carried out by extracting a set sample volume from the stream every time a predetermined volume of flow passes the sampling point. Each sample is placed in a single composite container, and at the end of the sampling period (between two and six weeks) the container is stirred and one representative sample is removed for analysis. Loads are calculated by multiplying the average concentration of each parameter by the continuous flow record from that site. Most composite water quality monitoring is carried out by TCWMB, although DWLBC and SA Water also conduct this kind of monitoring.

5.2.7 AMBIENT WATER QUALITY MONITORING

TCWMB also has an ambient water quality monitoring program and carries out ‘grab sampling’ on a quarterly basis. Both the EPA and Onkaparinga Catchment Water Management Board (OCWMB) include macro-invertebrate sampling in their ambient water quality monitoring programs. Water analyses are undertaken monthly, with macro-invertebrates surveyed twice a year.

The board’s ambient (and ambient and macro-invertebrate) monitoring program is carried out over three-year periods, with the aim of renewing contracts for this work for further three-year periods into the future.

5.2.8 EPA AND TCWMB MACRO-INVERTEBRATE SAMPLING

Macro-invertebrates are identified to species level where possible, and macrophytes identified to at least genus level. In addition, a number of parameters are recorded in association with each macro-invertebrate sample site, those being substrate particle size, minimum and maximum flow rates, average depth of stream, slope, distance from source, latitude, longitude, altitude, and percentage shade cover experienced over the sampling day. Other field data include odours, scums, oil slicks, plume, bicarbonate, alkalinity, DO, pH, water temperature and conductivity.

Also collected is information on any significant vertebrates at each sampling site, stream and riparian condition, and stream stability.

All EPA ambient monitoring sites feature macro-invertebrate monitoring biannually (using the methodology developed through the AusRivAS program). TCWMB macro-invertebrate sampling is occurring at selected ambient monitoring sites (see Table 4).

5.2.9 SALINITY MONITORING

Most salinity monitoring is carried out as part of either the TCWMB's ambient water quality grab-sampling monitoring program, its composite water quality monitoring program, or SA Water's monitoring of Adelaide's water supply.

Table 4. Current on-going water quality monitoring, for natural streams, against the agency(ies) responsible. Macro-invertebrate monitoring is carried out quarterly by the catchment board for three-year terms and biannually by the EPA over the long term.

	Site number or location code	Site name	Continuous recording turbidity	Composite sampling	Ambient	Ambient and macro-invertebrate
Upper Torrens						
Mount Pleasant	3465	Griggs Road				TCWMB
	2066	Torrens River @ Mount Pleasant			EPA	
Birdwood	3456	Carnell Boundary Road				TCWMB
Gumeracha	3457	Poplar Grove				TCWMB
Kersbrook Creek	3326	Kersbrook Creek upstream of Millbrook Reservoir				TCWMB
	AW504525	Kersbrook Creek @ U/S Millbrook Reservoir		DWLBC *(to be closed)*		
Sixth Creek	3324	Sixth Creek at Castambul				TCWMB
	AW504523	Sixth Creek @ Castambul		TCWMB		
Gorge Weir	AW504584	Montacute Quarry Creek @ Gorge Road	Private company	Private Company		
Lower Torrens						
First Creek Rural	3318	First Creek U/S Waterfall				TCWMB
	2067	First Creek U/S of Waterfall Gully			EPA	
Hope Valley Reservoir	1851	Silkes Road U/S of the ford				TCWMB
	1896	Fifth Creek			TCWMB	
Lower Portrush	AW504579	Third Creek @ Forsyth Grove		TCWMB		
	1898	Third Creek upstream Torrens River at Forsyth Grove			TCWMB	
	1897	Fourth Creek			TCWMB	
	1852	Windsor Grove				TCWMB
Holbrooks Road	AW504529	Holbrooks Road		TCWMB		
Torrens Lake	AW504593	Torrens River @ D/S Second Creek Junction		TCWMB		
	AW504578	First Creek @ D/S Botanic Gardens		TCWMB		
	1900	First Creek @ D/S Botanic Gardens				TCWMB
	1899	Second Creek upstream Torrens River			TCWMB	
Breakout Creek	1853	South Road				TCWMB
	1854	Tapleys Hill Road				TCWMB

Table 5. Outline of the current parameters being monitored by relevant agencies

Parameters			Agency
Continuously recorded salinity monitoring	Electrical Conductivity Water temperature		TCWMB, DWLBC
Composite monitoring	TDS	Lead	PIRSA
	pH	Zinc	
	Conductivity Sulphate	Iron	
	Cadmium	Nickel	
	Chromium	Aluminium	
	Copper	Manganese	
Ambient monitoring	General data	Bicarbonate	EPA
	pH	Chloride	
	Temperature	Fluoride	
	Organic carbon	Sulphate	
	Dissolved oxygen		
	Total dissolved solids	Nutrients	
	Conductivity	Nitrate	
		Nitrite	
	Physical characteristics	Soluble and total phosphorus	
	Turbidity	Total Kjeldahl nitrogen (TKN)	
	Colour		
		Metals	
	Calcium	Aluminium	
	Magnesium	Copper	
	Potassium	Iron	
	Sodium	Lead	
		Zinc	
		Macro-invertebrates	

Salinity monitoring, as part of the composite water quality monitoring program, occurs at five monitoring stations — Kersbrook Creek (AW504525), Sixth Creek (AW504523), Torrens Lake (AW504578), Lower Portrush (AW504579) and Holbrooks Road (AW504529) sub-catchments, the last four being part of the current TCWMB composite monitoring program.

Kersbrook Creek site AW504525 has been funded by DWLBC, but this funding is to be withdrawn and negotiations for further funding by other agencies is to be carried out. It is proposed that a review of continuous salinity monitoring be carried out for the entire catchment to identify those sub-catchments that are currently or potentially affected by salinity problems and would thus require continuous salinity monitoring.

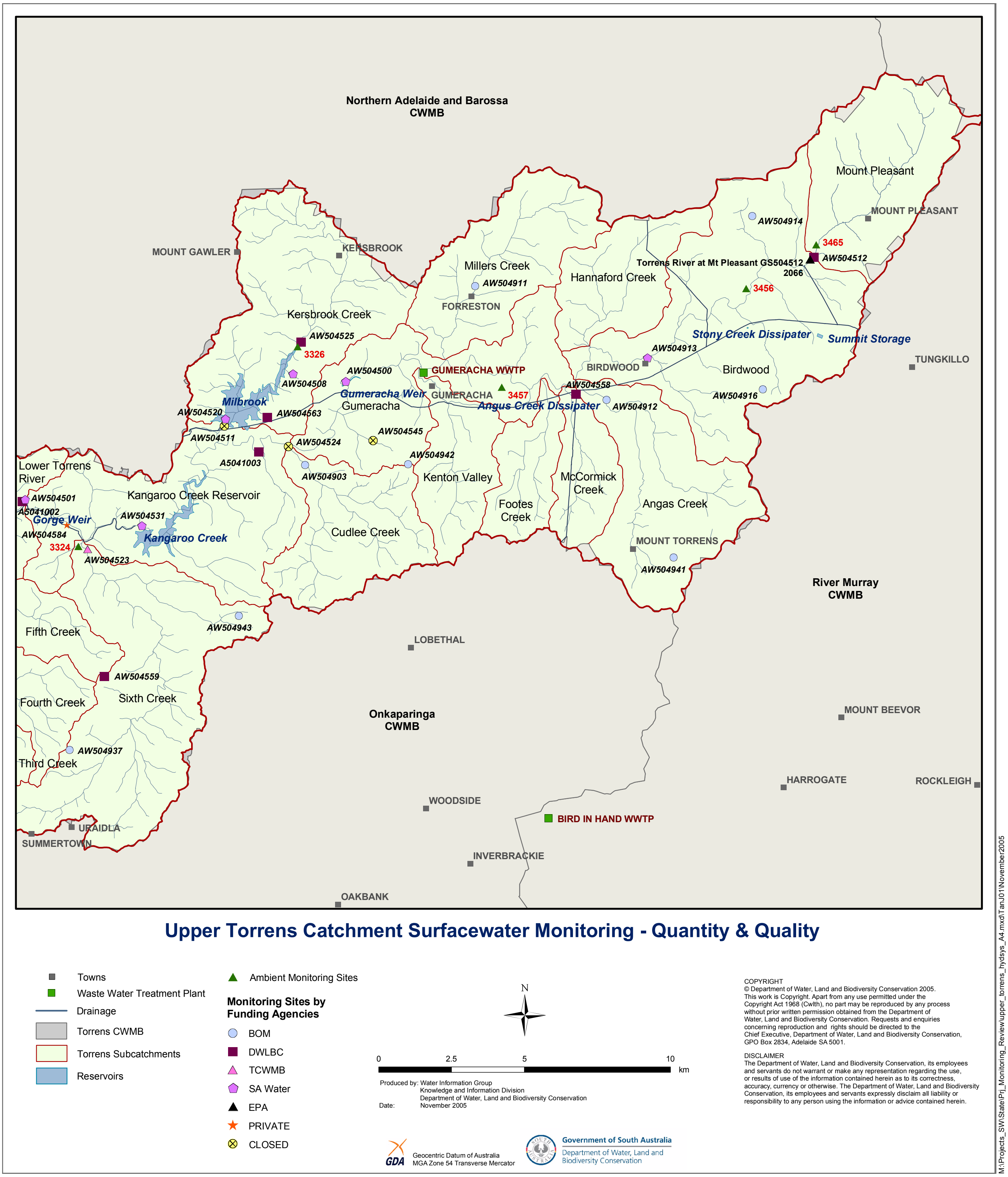
Upper Torrens Catchment Surfacewater Monitoring - Quantity & Quality
Northern Adelaide and Barossa CWMB
River Murray CWMB
Onkaparinga CWMB
Mount Pleasant
MOUNT PLEASANT
AW504914
3465
AW504512
Torrens River at Mt Pleasant GS504512 2066
3456
Hannaford Creek
Millers Creek
AW504911
FORRESTON
KERSBROOK
MOUNT GAWLER
Kersbrook Creek
AW504525
3326
AW504500
GUMERACHA WWTP
AW504508
Gumeracha Weir
GUMERACHA
Gumeracha
3457
Angus Creek Dissipater
AW504558
AW504912
Stony Creek Dissipater
Summit Storage
AW504913
BIRDWOOD
Birdwood
AW504916
TUNGKILLO
Milbrook
AW504520
AW504563
AW504511
AW504545
AW504524
A5041003
AW504903
AW504942
Kenton Valley
Footes Creek
McCormick Creek
Angas Creek
MOUNT TORRENS
AW504941
Lower Torrens River
AW504501
A5041002
Gorge Weir
AW504531
Kangaroo Creek Reservoir
Kangaroo Creek
AW504584
3324
AW504523
Cudlee Creek
AW504943
LOBETHAL
Fifth Creek
AW504559
Sixth Creek
Fourth Creek
AW504937
Third Creek
URAIDLA
SUMMERTOWN
MOUNT BEEVOR
HARROGATE
ROCKLEIGH
WOODSIDE
BIRD IN HAND WWTP
INVERBRACKIE
OAKBANK
Towns
Waste Water Treatment Plant
Drainage
Torrens CWMB
Torrens Subcatchments
Reservoirs
Ambient Monitoring Sites
Monitoring Sites by Funding Agencies
BOM
DWLBC
TCWMB
SA Water
EPA
PRIVATE
CLOSED
N
0 2.5 5 10 km
Produced by: Water Information Group
Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
Date: November 2005
Geocentric Datum of Australia
MGA Zone 54 Transverse Mercator
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Figure 1

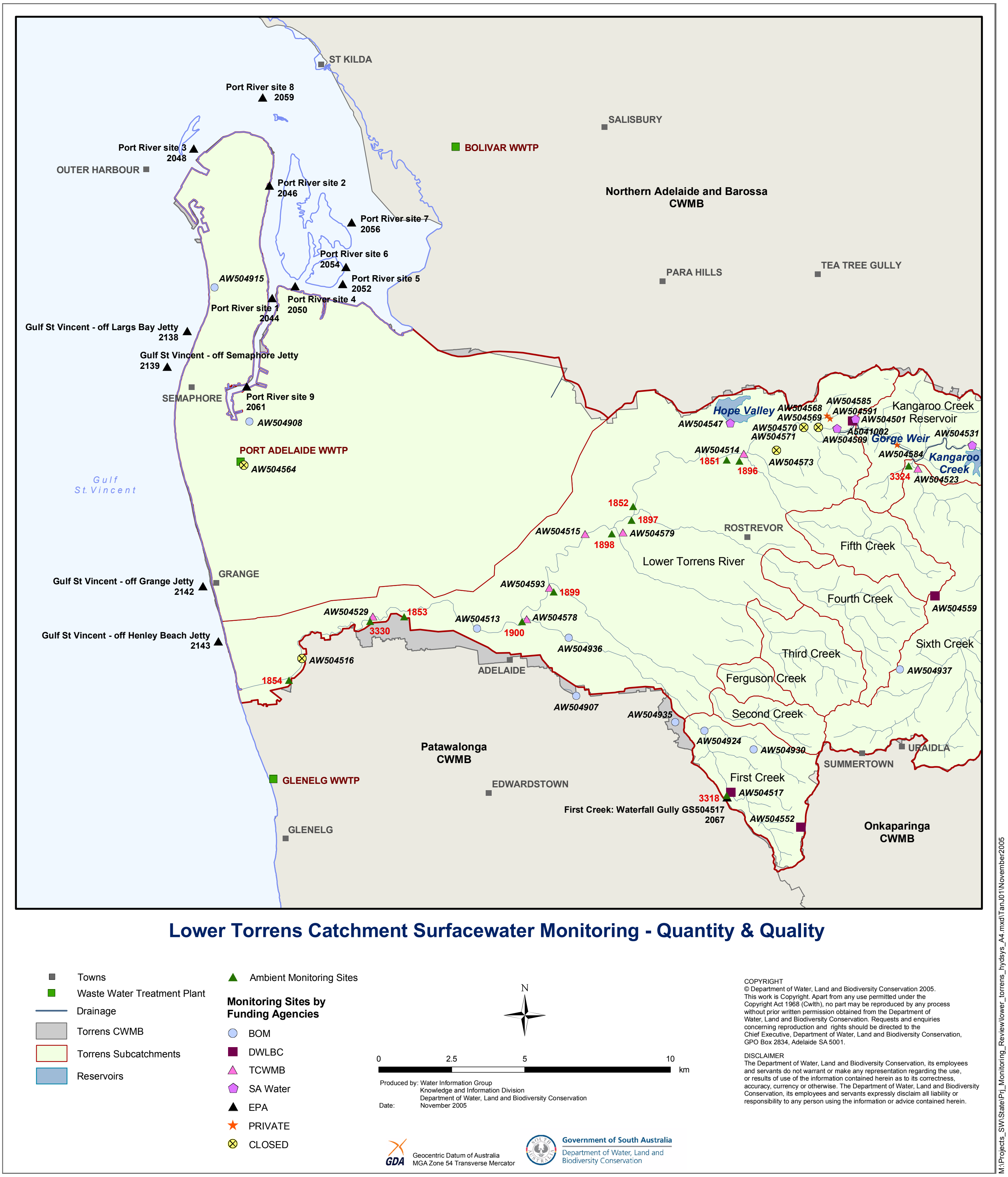
ST KILDA
Port River site 8
2059
SALISBURY
Port River site 3
2048
BOLIVAR WWTP
OUTER HARBOUR
Port River site 2
2046
Northern Adelaide and Barossa
CWMB
Port River site 7
2056
Port River site 6
2054
PARA HILLS
TEA TREE GULLY
AW504915
Port River site 5
2052
Port River site 4
2050
Port River site 1
2044
Gulf St Vincent - off Largs Bay Jetty
2138
Gulf St Vincent - off Semaphore Jetty
2139
SEMAPHORE
Port River site 9
2061
AW504908
Hope Valley
AW504568
AW504569
AW504585
AW504591
Kangaroo Creek
AW504501 Reservoir
AW504547
AW504570
AW504571
A5041002
AW504509
Gorge Weir
AW504531
PORT ADELAIDE WWTP
AW504564
AW504514
1851
1896
AW504573
AW504584
Kangaroo Creek
3324
AW504523
Gulf St. Vincent
1852
1897
AW504515
AW504579
1898
ROSTREVOR
Fifth Creek
Lower Torrens River
GRANGE
Gulf St Vincent - off Grange Jetty
2142
AW504593
1899
Fourth Creek
AW504559
AW504529
1853
AW504513
AW504578
3330
1900
Gulf St Vincent - off Henley Beach Jetty
2143
AW504936
Sixth Creek
AW504516
ADELAIDE
Third Creek
AW504937
1854
Ferguson Creek
AW504907
AW504935
Second Creek
AW504924
AW504930
URAIDLA
Patawalonga
CWMB
SUMMERTOWN
GLENELG WWTP
EDWARDSTOWN
First Creek
AW504517
3318
First Creek: Waterfall Gully GS504517
2067
AW504552
GLENELG
Onkaparinga
CWMB
Lower Torrens Catchment Surfacewater Monitoring - Quantity & Quality
Towns
Waste Water Treatment Plant
Drainage
Torrens CWMB
Torrens Subcatchments
Reservoirs
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Figure 2

5.3 GAPS AND OVERLAPS IN MONITORING

5.3.1 SURFACE WATER QUANTITY

5.3.1.1 Hydrological Modelling

Information about the hydrological cycle and water use is lacking (to varying degrees) for some sub-catchments in the WMLR catchment areas. To calculate a water balance, components of the hydrological cycle need to measured, those being rainfall, evaporation, stream flow (or level) and groundwater interaction, as well as calculations of water use which are dictated by land use. Water balance models should be developed for each sub-catchment to provide meaningful baseline information from which management decisions can be made.

It is important where this is not occurring that sites representative of relevant hydrological, land use and vegetation type characteristics are used to model water balances for those sub-catchments, particularly where it is inappropriate to construct new gauging stations. For sub-catchments where existing data for hydrological modelling are insufficient, including a lack of representative sites, gauging stations should be located in those sub-catchments to aid the modelling process.

The report ‘Surface water assessment of the Upper River Torrens Catchment’ by Heneker (2003) offers a calibrated conceptual surface water model to simulate long-term runoff data for the Torrens Catchment upstream of Gorge Weir.

In terms of the remaining sub-catchments for the Torrens Catchment, and for any other specific purposes for the entire catchment, meteorological and stream flow monitoring gaps are outlined in the following sections.

Table 6 shows where the gaps in monitoring are occurring in regards to system inflow–outflow.

5.3.1.2 Meteorological Monitoring

Rainfall monitoring is occurring in most of the sub-catchments throughout the Torrens Catchment; most sites are managed by BoM and some by DWLBC. SA Water is conducting rainfall and reservoir level monitoring at ‘Hope Valley Reservoir @ Hope Valley’ (AW504547).

The locations of current rainfall stations are provided in Table 7. It is important to note that, whilst the stations are present, they are not necessarily collecting data.

5.3.1.3 Evaporation

Evaporation is currently being monitored at Hope Valley Reservoir (BoM station M023096).

Table 6. Summary of Gaps for System Inflow–Outflow Monitoring.

Location	Gaps in monitoring	Suggested future monitoring
River Murray transfers (into the River Torrens)	Water levels and flow	SA Water to monitor levels and flow at all Mannum–Adelaide drop in points for River Murray transfers.
	Water quality downstream of outfalls	SA Water to monitor water quality in the River Torrens immediately downstream of each of the three locations at which River Murray water is released.
Millbrook Reservoir	Spill from the reservoir	SA Water site 'Millbrook Reservoir @ Dam Embankment' (AW504520) needs a flow rating across all ranges of flow to monitor spills from the reservoir.
	Outflows from the reservoir	SA Water to monitor releases from the reservoir.
		SA Water to establish a gauging station immediately downstream of the reservoir to monitor water flows and quality.
Kangaroo Creek Reservoir	Outflows from the reservoir	SA Water to monitor releases from the reservoir.
		SA Water to establish a gauging station immediately downstream of the reservoir to monitor water flows and quality.
Hope Valley Reservoir	Spill from the reservoir	SA Water site 'Hope Valley Reservoir @ Hope Valley' (AW504547) needs a flow rating across all ranges of flow to monitor spills from the reservoir.
Gumeracha Weir	Upstream of weir	TCWMB and DWLBC to establish a flow and water quality monitoring site.
Gorge Weir	Outflows from weir	SA Water to monitor releases from the weir.
		DWLBC to include both flow and quality monitoring at the new site 'Torrens River @ D/S Gorge Weir' (A5041002).
	Upstream of weir	TCWMB and DWLBC to establish a flow and water quality monitoring site. (Suggest consideration be made of the usefulness of data from the private monitoring station 'Montacute Quarry Creek @ Gorge Road' (AW504584) to supplement upstream data).

Table 7. Location of rainfall stations (adapted from Heneker 2003).

Station number	Location	Period of record	Percentage of missing (accumulated) data
023705	Birdwood Department of Transport	1902–2002	3.8 (0.5)
023719	Gumeracha District Council	1902–2002	1.4 (8.2)
023731	Cudlee Creek (Millbrook)	1914–2002	0.6 (1.4)
023737	Mount Pleasant	1902–2002	2.1 (6.6)
023750	Uraidla	1902–2002	0.7 (7.8)
023803	Ashton Co-op	1933–2002	30.8 (2.8)

5.3.1.4 Stream flow

Stream flow is not recorded directly in the field. Instead, water levels are recorded and then stream flow is calculated from a water level to flow ‘rating curve’. These rating tables are established using in-field measurements. Most sites at which levels are monitored are funded by BoM and TCWMB, and to a lesser degree by DWLBC and privately. Field-based rating curves at these stations have either:

- not been updated for many years (e.g. the latest gauging for site AW504529 — Torrens River at Holbrooks Road in the Lower Torrens — was 1986)
- do not incorporate all flow ratings occurring at the site
- not been established and only theoretical relationships are in use.

In addition, up-to-date information on sites and gaugings are not always available in Hydstra. It is suggested that this information be updated through an audit by site operators and Hydstra updated.

Along the River Torrens there are water extractions in need of more adequate monitoring.

There are no gauging stations in Second, Fourth and Fifth Creeks, and it is suggested that gauging stations be built in these areas.

There are some catchment or creek water losses that need to be monitored. The variability of losses would be different in different seasons of the year. How this phenomenon can be monitored has yet to explored carefully. It is suggested that monitoring of the flow data in a pro-active manner is done, in order to pick up any signal (K. Teoh, Senior Hydrological Information Officer, DWLBC, pers comm., 2006).

Currently, no on-going (Continuous, Composite or Ambient) water quality monitoring of natural streams is occurring in the sub-catchments shown in Table 8.

Table 8. Sub-catchments in which no ongoing water quality monitoring is occurring.

Sub-catchment	Current on-going monitoring	Agency
Upper Torrens		
Angas Creek	Rainfall, water level	BoM
McCormick Creek	Rainfall	DWLBC
Hannaford Creek	None	–
Millers Creek	Rainfall, water level	BoM
Footes Creek	None	–
Kenton Valley	None	–
Kangaroo Creek Reservoir	Water level, reservoir water level	SA Water
Cudlee Creek	Rainfall, water Level	BoM
Lower Torrens		
Second Creek Rural	None	–
Third Creek Rural	None	–
Fourth Creek Rural	Rainfall	BoM
Fifth Creek Rural	Rainfall	BoM
First Creek Urban	Rainfall, water level	BoM

Sub-catchment	Current on-going monitoring	Agency
Second Creek Urban	None	–
Third Creek Urban	Rainfall	BoM
Fourth Creek Urban	None	–
Fifth Creek Urban	None	–

5.3.2 SURFACE WATER QUALITY

Currently, sub-catchments without any water quality monitoring for natural streams are: McCormick Creek, Hannaford Creek, Footes Creek and Kangaroo Creek Reservoir in the Upper Torrens; and Second, Third and Fourth Creeks in the rural region and First, Second, Third, Fourth and Fifth Creeks in the urban region of the Lower Torrens (see Section 5.6.2.1 for proposed future surface water quality monitoring sites).

5.4 FUTURE DIRECTIONS FOR SURFACE WATER MONITORING

5.4.1 STRATEGIC ISSUES FOR DISCUSSION IN RELATION TO SURFACE WATER QUANTITY MONITORING

5.4.1.1 Forestry

Limited information is available on the impacts of forestry development on surface runoff and groundwater recharge, and it is suggested that comprehensive studies be carried out to gain a greater understanding of the impacts of this industry on water resources. Such studies should include comparisons with the impact of re-establishment of native vegetation on surface runoff and groundwater recharge.

5.4.1.2 Recreational Uses of Water

Recreational uses of water include activities such as swimming and fishing in dams and rivers, as well as other water sports. No data are collected for recreational use of water resources in any of the WMLR catchments.

5.4.1.3 Land-Use Changes

Available land-use datasets were current in 1999. Data and information about changes in land use needs to be kept more up-to-date for determining water balances, and should be collected for all sub-catchments. It should also include changes in SA Water infrastructure as any changes in water management practices (e.g. reservoir operation, change to pipeline network) need to be taken into account with regard to hydrological modelling.

5.4.1.4 Farm Dams

More precise investigations into farm dam water use and water sources should be carried out for all sub-catchments on a regular and consistent basis.

5.4.1.5 Irrigation water use

On-farm field assessments of irrigation practices are needed for irrigated pasture, olives, citrus, strawberries, vegetables, potatoes, flowers and nuts to gain more insight into actual irrigation water use. Variations in application rates (e.g. due to crop type or seasonal factors, as well as between individual irrigators growing the same crop, soil type and irrigation system capacity) needs to be addressed. Data should be collected on irrigation water use for all sub-catchments.

5.4.1.6 Reservoirs and Weirs

Water quality monitoring within major reservoirs and weirs should be used in an operational context for drinking water supply protection and improvement as well as in catchment water quality assessments. Monitoring outflows from reservoirs is considered a high priority, in terms of water being released from a regulated section of the river system. Monitoring should be carried out for a medium term of at least 10 years. Monitoring water quantity and quality below reservoirs and some weirs should be carried out in relation to assessment of environmental flow requirements and the impact of water quality on ecosystems. Water flows and quality immediately upstream of reservoirs and some weirs is a high priority form of monitoring for assessing water entering the supply infrastructure. SA Water monitors a selection of water quality parameters in relation to the supply systems.

5.4.1.7 Water balance

It is suggested that consideration be given to monitoring at a sub-catchment scale within the Torrens Catchment in terms of assessing the water balance components of surface water. (Surface water and groundwater interactions would need to be included in water balance calculations and there is a significant gap in understanding of how these processes work.) Consideration should also include water requirements of aquatic ecosystems and other features such as particular hydrological characteristics, vegetation cover and land-use practices, including the impact of farm dams.

Ideally, all sub-catchments with a unique set of these characteristics should have monitoring of water balance components carried out at appropriate sites. Data can then be used in water balance calculations for other sub-catchments with similar characteristics within the catchment. If it is not practical to establish monitoring stations for all representative sub-catchments, then representative sites outside the catchment can be used in water balance calculations.

5.4.1.8 Rainfall and Evaporation

At the Hope Valley Reservoir, both SA Water and BoM are monitoring rainfall and evaporation (AW504547 and M023096, respectively). It is suggested that SA Water monitors reservoir water levels, spill and quality, and that BoM monitors rainfall and evaporation at this location.

It is suggested that representative sub-catchments from other catchments be identified for any future hydrological modelling purposes or that the relevant BoM stations be re-opened. For the remaining sub-catchments, if a need for rainfall data is recognised then it is suggested that representative sub-catchments from within or outside the catchment be used for this purpose. The availability of long-term daily pan evaporation data in the Mount Lofty

Ranges is limited and there are no stations located in the Upper River Torrens Catchment. Evaporation is an important component of catchment hydrology, and the maintenance of stations within the catchment that record both pan evaporation data and the climate variables required to calculate evaporation from empirical equations should be investigated (Heneker 2003). Maintenance of stations at higher elevations within the catchment would provide more information on the spatial variability of rainfall with elevation, and ultimately improve the rainfall–runoff modelling process (Heneker 2003).

5.4.1.9 Stream flow monitoring

It is proposed that monitoring for stream flow be expanded. This does not necessarily mean the establishment of new sites, but better use of existing sites. For example, the ability to accurately record low flow data (which is required at Mount Pleasant, Sixth Creek and Gumeracha Weir) could be, according to Heneker (2003), achieved by modifying the existing control sections. It is suggested that a possible cost-sharing agreement be set up between BoM, DWLBC and possibly CWMBs to reduce costs and produce higher quality, consistent, well-maintained data.

Heneker (2003) also suggested that an improved rating for measuring medium to high flow data is required at Kersbrook Creek. More gaugings are required during high flow events as the current rating only covers low flow.

5.4.2 STRATEGIC ISSUES FOR DISCUSSION IN RELATION TO SURFACE WATER QUALITY MONITORING

5.4.2.1 Composite Water Quality and Flow Monitoring

Composite monitoring is helpful in relation to aquatic ecosystems monitoring and it is suggested that it be carried out at all stations currently monitoring water levels and which have a rating done across all ranges of flow for flow monitoring (a necessary part of the composite sampling process). Refer to Appendix F for surface water level and flow monitoring sites, and Appendix E for the complete list of all on-going monitoring sites for the Torrens Catchment.

It is proposed that water level monitoring (to calculate stream flow) be established at each station monitoring water quality.

5.4.2.2 Proposed New Water Quality Monitoring Stations

The TCWMB is establishing new ambient and macro-invertebrate sites in the following:

- Mount Pleasant
- Angus Creek
- Millers Creek
- Kenton Valley
- Cudlee Creek
- Fifth Creek (Rural).

Once the TCWMB has established monitoring at these sites, then the sub-catchments without any water quality monitoring for natural streams will be: McCormick Creek, Hannaford Creek, Footes Creek and Kangaroo Creek Reservoir in the Upper Torrens; and Second, Third and Fourth Creeks in the rural region, and First, Second, Third, Fourth and Fifth Creeks in the urban region of the Lower Torrens.

5.6.2.3 Water Supply Infrastructure and Transfers

Flows and water quality should be monitored in relation to River Murray transfers to aid in assessing the impacts of these water transfers on the ecological health of the main channel. River Murray water, which is chlorinated and has carried high salinity levels, is discharged into the upper reaches of the River Torrens, and needs to be monitored in relation to its effect on aquatic ecosystems.

6. GROUNDWATER MONITORING

6.1 OVERVIEW OF CURRENT GROUNDWATER MONITORING

Groundwater monitoring networks for levels and salinity need expansion as significant areas are not monitored at all for either parameter. Investigations into leakage between sedimentary aquifers, and the linkages between fractured rock and sedimentary aquifers, should also be carried out to achieve greater accuracy in determining recharge rates.

Fractured rock aquifers are complex, and more understanding of their hydrogeology is required as well as an understanding of recharge rates, surface and groundwater interactions, current yields and irrigation application rates. Possible pollution of aquifer recharge areas needs to be monitored more closely, particularly in the case of unconfined aquifers.

A more comprehensive monitoring of groundwater quality should be initiated, other than just salinity monitoring, because groundwater resources are vulnerable to contamination. For example, contamination can take place through recharge to the fractured rock aquifers which occurs predominantly along preferential flow paths, and provides little opportunity for attenuation of contaminants. Examples of sources of groundwater contamination are urban runoff, diffuse nutrients from fertiliser runoff, animal and industrial waste, pesticides from agricultural activities, as well as corroded bore casings and water transfer pipes. Groundwater residence times in shallow aquifers is often less than 50 years, which means that contaminants can move relatively quickly and in unpredictable directions from their source to points of groundwater discharge.

6.2 CURRENT GROUNDWATER QUANTITY MONITORING

DWLBC undertakes the majority of groundwater level monitoring in the Torrens Catchment. Levels are read quarterly for the metropolitan network (48 wells), and the rural network (35 wells) which is located in areas of significant groundwater extraction, namely the Fourth and Sixth Creeks, and the Birdwood area.

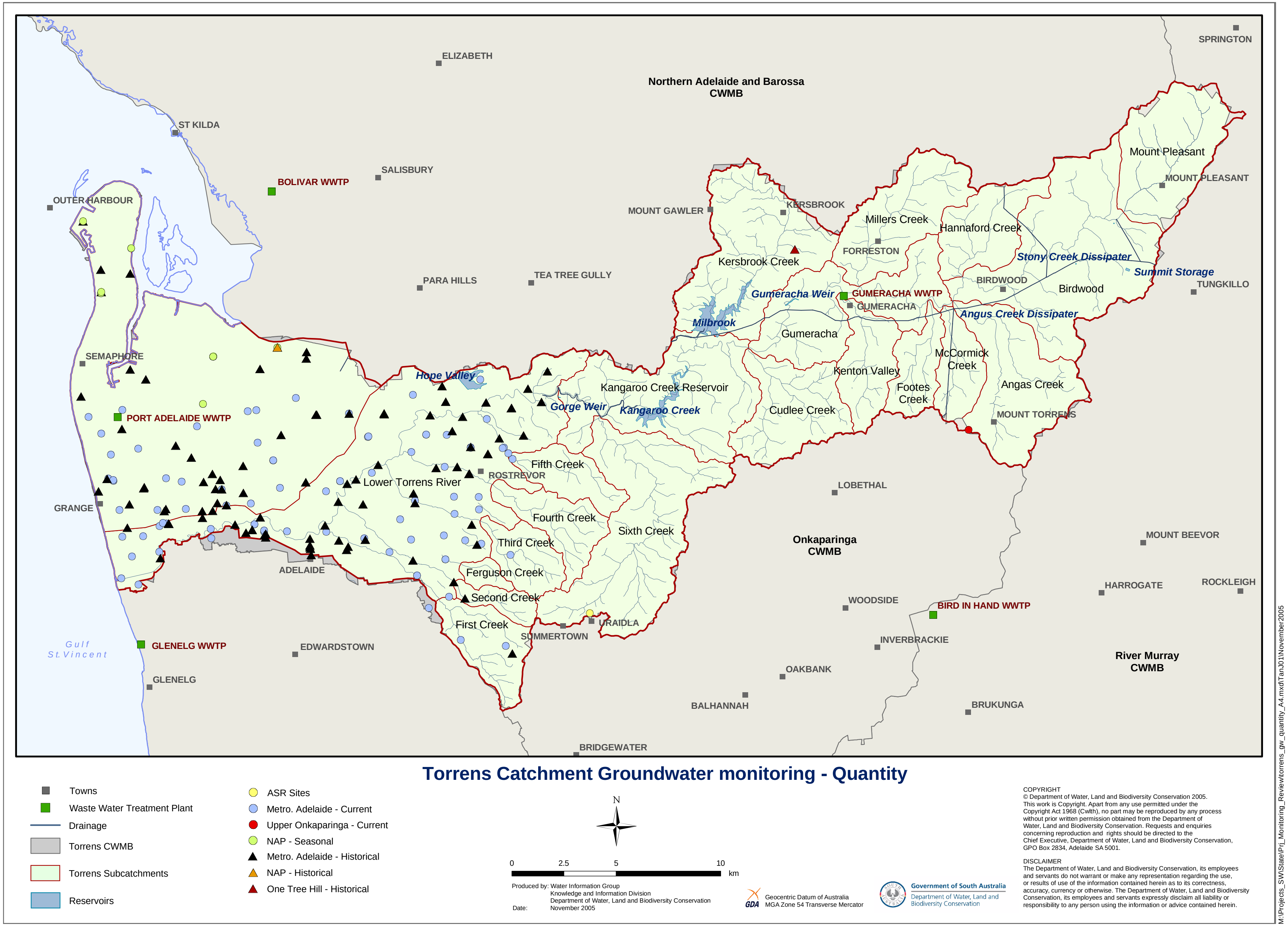
Groundwater recharge is being monitored at “Torrens River @ Holbrooks Road” (AW504529) site by TCWMB.

Figure 3 shows the location of the current groundwater quantity monitoring sites for the upper and lower Torrens.

6.3 CURRENT GROUNDWATER QUALITY MONITORING

DWLBC has mainly focused on groundwater salinity monitoring although it is planning to expand its water quality monitoring parameters.

Figure 4 shows the location of the current groundwater quality monitoring sites for the upper and lower Torrens.


Torrens Catchment Groundwater monitoring - Quantity
Northern Adelaide and Barossa CWMB
Onkaparinga CWMB
River Murray CWMB
Gulf St.Vincent
ELIZABETH
SPRINGTON
ST KILDA
SALISBURY
BOLIVAR WWTP
OUTER HARBOUR
MOUNT GAWLER
KERSBROOK
Millers Creek
Hannaford Creek
Mount Pleasant
MOUNT PLEASANT
FORRESTON
Kersbrook Creek
Stony Creek Dissipater
Summit Storage
TUNGKILLO
PARA HILLS
TEA TREE GULLY
Gumeracha Weir
GUMERACHA WWTP
GUMERACHA
BIRDWOOD
Birdwood
Angus Creek Dissipater
Milbrook
Gumeracha
SEMAPHORE
Hope Valley
Kangaroo Creek Reservoir
Kenton Valley
McCormick Creek
Footes Creek
Angas Creek
Gorge Weir
Kangaroo Creek
Cudlee Creek
MOUNT TORRENS
PORT ADELAIDE WWTP
Fifth Creek
ROSTREVOR
Lower Torrens River
LOBETHAL
GRANGE
Fourth Creek
Sixth Creek
Onkaparinga CWMB
MOUNT BEEVOR
Third Creek
ADELAIDE
Ferguson Creek
HARROGATE
ROCKLEIGH
Second Creek
WOODSIDE
BIRD IN HAND WWTP
First Creek
URAIDLA
SUMMERTOWN
INVERBRACKIE
GLENELG WWTP
EDWARDSTOWN
OAKBANK
GLENELG
BALHANNAH
BRUKUNGA
BRIDGEWATER
Towns
Waste Water Treatment Plant
Drainage
Torrens CWMB
Torrens Subcatchments
Reservoirs
ASR Sites
Metro. Adelaide - Current
Upper Onkaparinga - Current
NAP - Seasonal
Metro. Adelaide - Historical
NAP - Historical
One Tree Hill - Historical
N
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Produced by: Water Information Group
Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
Date: November 2005
GDA Geocentric Datum of Australia
MGA Zone 54 Transverse Mercator
Government of South Australia
Department of Water, Land and Biodiversity Conservation
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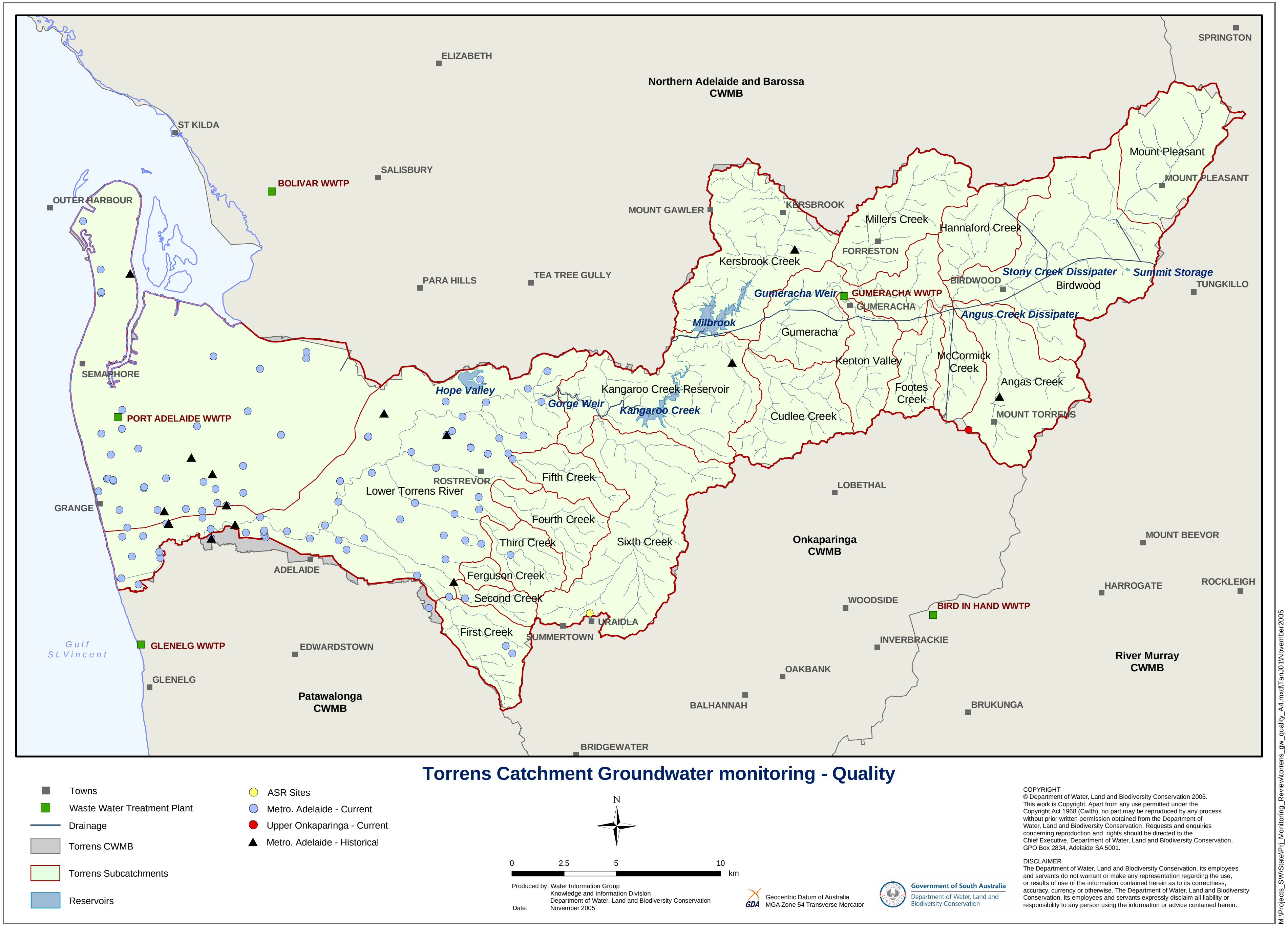
Figure 3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GLENELG WWTP
EDWARDSTOWN
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River Murray CWMB
OAKBANK
GLENELG
Patawalonga CWMB
BALHANNAH
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BRIDGEWATER
Torrens Catchment Groundwater monitoring - Quality
Towns
Waste Water Treatment Plant
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Figure 4

6.3.1 GROUNDWATER SALINITY

Salinity monitoring is carried out infrequently, although DWLBC carries out sampling for chemical analysis in the Metropolitan areas every seven to eight years.

6.4 GAPS AND OVERLAPS IN MONITORING

Groundwater extraction in the rural section in several sub-catchments maybe close to the estimated sustainable limit. Although there is currently a lack of extraction data and information about groundwater use, all licensed extraction wells will eventually be metered under the prescription process for the WMLR.

Across the urban area, groundwater from the shallow aquifer is used extensively for domestic purposes without restriction. There is limited information on the extent of use, although it is expected to be relatively small. Signs of water quality deterioration, in particular increasing salinity, are evident at some high-use sites using the deeper limestone aquifer (e.g. golf courses); the sustainable yield for this deeper aquifer also needs to be quantified.

6.5 FUTURE DIRECTIONS FOR GROUNDWATER MONITORING

There is an obvious need for considerable expansion of groundwater level and quality monitoring in the Torrens Catchment.

For the rural areas, it is important that groundwater quality and levels are monitored where land use or extractions may pose a threat to the resource.

For the urban areas, it is important that major ions, nutrients and metals are monitored in appropriate areas.

7. AQUATIC ECOSYSTEMS

7.1 OVERVIEW OF AQUATIC ECOSYSTEMS

Aquatic ecosystems support a diverse range of native flora and fauna, including numerous threatened species, and comprise complex interactions between plants, animals and the physical, chemical and climatic characteristics of the environment in which they occur. The health of these ecosystems is affected by, and thus provides a measure of, the health of the surrounding catchment. A number of methods can be used to monitor and assess the health of aquatic ecosystems. Biological indicators assess the numbers, health, ecological functions, or life cycles of living organisms. Living organisms are considered to be among the best indicators of ecosystem health as they integrate the many effects caused by changes in the physical and chemical characteristics of the environment (Lopez and Dates 1998).

The following sections discuss commonly assessed indicators in the WMLR.

7.1.1 FISH

Fish have significant recreational, economic and social values, and of all aquatic biota have the highest public profile (MDBC 2004). Fish have a number of advantages as bioassessment tools, including: being relatively long-lived and mobile, fish provide good indicators of long-term and broad spatial impacts; fish communities include a range of trophic levels (herbivores, omnivores and carnivores); and the ecology of Australian fish is relatively well known (Harris 1995).

7.1.2 MACRO-INVERTEBRATES

Macro-invertebrates play a central role in the ecology of Australian aquatic ecosystems. They are ubiquitous and diverse (Williams 1980; Lake 1982; Pearson et al. 1986), and with their variety of feeding habits form many of the key links in aquatic food chains (Chessman 1986). Macro-invertebrates are generally sedentary and may live from a few weeks to a number of years (Marchant 1986), meaning that their communities recover slowly if damaged by disturbance (Chessman 1995). A diverse community of macro-invertebrates is often indicative of a healthy aquatic ecosystem. An ecosystem under stress will be home to a greater number of more stress-tolerant (i.e. pollution) macro-invertebrate species, whereas a healthy ecosystem will have a more even spread of tolerant and less-tolerant species.

7.1.3 DIATOMS

Diatoms are microscopic phytoplankton that occupy a wide variety of habitat niches. They are abundant in almost all aquatic environments and the majority of diatom species are either attached to a substrate, living on rock surfaces, larger plants, mud, silt and sand or, less commonly, planktonic (Reid et al. 1995). Diatoms are used as indicators of water quality as they have distinct ecological requirements and are very sensitive to changes in water chemistry (Reid et al. 1995, and references therein). Changes in diatom communities are rapid in response to environmental changes, and the response time of diatoms provides a useful intermediate between physico-chemical sampling and the response of higher organisms (Reid et al. 1995).

7.2 CURRENT AQUATIC ECOSYSTEMS MONITORING

7.2.1 FISH MONITORING

Numerous fish surveys have been undertaken throughout the WMLR. These surveys have been commissioned by the CWMBs and they are the custodians of this information.

7.2.2 AUSRIVAS

AusRivAS is part of the National River Health Initiative and was carried out by the EPA. This national program monitored river and stream health by studying the type and number of aquatic macro-invertebrates found in a particular river or stream, and compared results with those obtained from a similar type of river or stream that had not been disturbed or affected by human activities. Macro-invertebrate and diatom samples, and a range of physico-chemical parameters, were collected in the autumn and spring of 1994 from across South Australia to determine the condition of the state's rivers and streams. A subset of sites sampled for the AusRivAS program forms the basis of the EPA's ambient and macro-invertebrate monitoring program (see Macro-invertebrate Monitoring section below).

Results of the AusRivAS sampling can be found at http://www.environment.sa.gov.au/reporting/inland/rivers_streams/healthassess.html#eastern_lofty. AusRivAS used multivariate monitoring to provide SoE reporting whilst also providing reference sites.

7.2.3 MACRO-INVERTEBRATE MONITORING

The CWMBs of the WMLR undertake macro-invertebrate monitoring across the WMLR.

7.2.4 AERIAL VIDEOGRAPHY

Aerial videography involves capturing geo-stabilised and geo-referenced video data of a watercourse flown by a helicopter. Aerial videography allows watercourse features to be identified and enables data on stream pool permanency and size to be recorded, along with an assessment of riparian vegetation extent and condition. Aerial videography has been flown for all third-order or larger streams in the WMLR. Aerial videography was flown in the autumn of 2003 as the location and extent of permanent pools is best identified during periods of low flow. Aerial videography was undertaken by the Knowledge and Information Division of DWLBC and the CWMBs of the WMLR.

7.3 GAPS AND OVERLAPS IN MONITORING

No overlaps in aquatic ecosystem monitoring were identified in the compilation of this report. This is largely a result of the limited amount of aquatic ecosystem monitoring that has been undertaken to date. It is not surprising considerable gaps are present because of the little monitoring that has taken place. Baseline data were limited to macro-invertebrates, fish, diatoms and data obtained from aerial videography.

7.3.1 ENVIRONMENTAL WATER REQUIREMENTS (EWR)

EWR have been determined by the CWMB for a subset of rivers within the WMLR, and delivery of environmental water provisions are currently being negotiated for three catchments (Onkaparinga, Torrens and South Para). A draft report by DWLBC (Pikusa and Bald 2005) states DWLBC's position on EWR in the WMLR and sets the foundation for negotiating environmental water provisions. Monitoring programs to assess the effectiveness of these provisions are currently being developed by DWLBC, the CWMBs and SA Water.

7.3.2 GROUNDWATER-DEPENDENT ECOSYSTEMS

Groundwater-dependent ecosystems are known to be important components of the region's aquatic ecosystems. Whilst the location of some are known, there is a lack of data on the distribution and abundance of the region's groundwater-dependent ecosystems. There is also a lack of information on the extent to which these systems rely on groundwater for their survival, and consequently the extent to which they are affected by altered water regimes.

7.3.3 EPHEMERAL STREAMS

Many of the streams in the WMLR catchment are ephemeral, and the current knowledge of these systems is limited. For example, there is a significant lack of understanding of the ecological processes and sensitivities of these ephemeral stream environments to altered flow regimes. This presents a significant knowledge gap.

7.3.4 STYGOFAUNA

Groundwater animals are collectively known as 'stygofauna'. Stygofauna diversity is high in many parts of Australia (Boulton et al. 2003), and many stygofauna species have restricted distributions and exhibit extreme endemicity (Marmonier et al. 1993). Stygofauna are important in aquifers as they help maintain groundwater quality through the maintenance of interstitial voids, modification of redox gradients, and the promotion of biofilm activity (Humphreys 2002; Gilbert and Deharveng 2002).

No data on the stygofauna of the WMLR were found in the preparation of this report. This presents a significant knowledge gap, both to their conservation and the management of the resource.

7.4 AQUATIC ECOSYSTEM MONITORING SUGGESTIONS

Monitoring will be required to determine if resource condition targets in the state and relevant regional NRM plans are being met. It is beyond the scope of this review to suggest specific programs in this area other than to highlight this need. However, such monitoring may fit within the proposed monitoring framework presented below.

7.4.1 A CALIBRATED CATCHMENT

In order to adequately manage the aquatic ecosystems of the WMLR, aquatic ecosystem monitoring should form part of what Brydges (2004) referred to as a 'calibrated watershed' integrated monitoring program. In such a program, monitoring strives to develop a detailed balance of the inputs and outputs of water and chemicals along with intensive biological monitoring of the terrestrial and aquatic components of the catchment. The integrated monitoring should be carried out in conjunction with detailed research projects. The research projects themselves would most likely involve their own integrated monitoring component. Such a 'calibrated catchment (watershed)' program of integrated monitoring and research should be designed to detect change within the catchment and explain why such changes are occurring.

Research is required to define environmental water requirements for aquatic ecosystems if the proposed 'calibrated catchment' model were to be developed. Once these environmental water requirements are defined, the information needed to meet them would also be known. This information, be it physical, chemical or biological, would have to be gathered via monitoring. In some areas this information may be currently available, in others not. Thus, the quantified needs of aquatic ecosystems would determine the extent and type of monitoring required across the region.

7.4.1.1 Significant Aquatic Ecosystems

Identification of priority aquatic ecosystems for ambient monitoring should be carried out across the catchment.

7.4.1.2 Riparian Vegetation

Most of the native riparian vegetation in the WMLR catchment is degraded and often dominated by pasture with no overstorey. If restoration of riparian vegetation is undertaken, then monitoring will be required to assess its progress and success.

8. CATCHMENT CHARACTERISTICS

A number of factors influence the way water and sediment move within a catchment from upland areas into the main channel and then to its terminus. Many of these factors are interrelated and they can be used to make predictions of hydrological behaviour within a catchment as well as for making comparisons between catchments. They are an important component of monitoring, understanding and managing hydrological systems. According to Wen (2005), it is generally accepted that catchment characteristics affect both surface and groundwater quality, but there is no consistent definition and the list of catchment features can vary from study to study. Table 9 offers a number of characteristic definitions, their purpose and their source.

Table 9. Catchment characteristics (adapted from Gordon et al. 2000).

Characteristic	Purpose	Source
Catchment area	Influences water yield and number and size of streams. Includes all upstream land and water surface area that drains to a particular point on a stream.	Topographic map Catchment plan
Stream length	Influences the amount of stream habitat area, travel time of water in a drainage system, and availability of sediment for transport.	Topographic map Catchment plan
Stream patterns	Aids in the description of a catchment.	Topographic map Aerial photography and videography
Stream orders	The order number is indicative of the size of the contributing area, channel dimensions and stream discharge. It provides a means of ranking relative sizes of streams.	Various methods available Most methods rank the smaller tributaries using a low number
Topography/relief ratio	Drainage density and slope of the upland areas are influenced by the basin relief. Prediction of sediment yields is possible from the relief ratio.	Mathematical equation
Average channel slope	One of the factors controlling water velocity.	Mathematical equation
Average catchment slope	Influences surface run-off rates.	Mathematical equation
Longitudinal profile	Describes the way in which stream elevation changes over distance.	Mathematical equation
Aspect	Influences vegetation type, rainfall patterns and wind exposure.	Bearing taken in the downhill direction
Climate	Aids in the description of the catchment and influences components of the hydrological cycle.	BoM
Vegetation cover	Native and introduced vegetation types to aid in identifying location of habitats.	Aerial photography, reports from DEH, DWLBC
Soils	Water movement through soil, soil erosion, vegetation types.	CSIRO, PIRSA
Geomorphology and hydrogeology	For understanding the hydrological processes in groundwater systems.	PIRSA, DWLBC
Land use	Influences water quantity and quality.	DWLBC, PIRSA
Demographics	Influences projected land use.	Planning SA

9. DATA AND INFORMATION MANAGEMENT

9.1 DATA QUALITY

The quality of measurements used for water resource monitoring programs is dependent upon the accuracy of instrumentation, specific site characteristics that may affect readings and thoroughness of the collectors and processors of data. Instrumentation needs to be checked and maintained to obtain good quality data and information on any errors needs to be recorded. Therefore, regular attention to these issues by way of site visits and visual checking of data must occur.

9.2 STORAGE OF SURFACE WATER MONITORING DATA

There is a significant need to centralise surface water monitoring data for all major stakeholders. Maintenance of all on-going quantity and quality monitoring by DWLBC, BoM, SA Water and EPA on one database, or at least provision of a portal that links all databases, would provide ease of access and enhance the usefulness of the information.

Ideally, water quantity and quality monitoring carried out by other agencies (e.g. ambient and macro-invertebrate monitoring by the EPA and catchment boards) should be recorded in an appropriate area on the same database, as well as other forms of water monitoring carried out by major stakeholders.

9.2.1 HYDSTRA DATABASE

This database is managed by DWLBC and has great potential for providing information about surface water monitoring sites. However, there is a significant need to keep records in the database up-to-date, which is currently lacking. This relates to metadata and data entered into HYDSTRA with regard to DWLBC monitoring sites as well as sites that relate to other agencies, including CWMBs, BoM and SA Water. In many cases, stations that are not funded or managed by DWLBC do not have information about gaugings in HYDSTRA.

9.2.2 FREQUENCY OF DATA COLLECTION FOR STREAM FLOW

Monthly averages should be used for studying the seasonal variations in discharge, which are controlled by climate, channel and catchment characteristics. The average daily discharge gives a finer resolution and can be used for determining a relationship between mean daily discharge and ecological features such as fish assemblages. Daily data can also be used to calculate average annual discharge.

9.3 HEALTH OF AQUATIC ECOSYSTEMS DATA MANAGEMENT

Data on the health of aquatic ecosystems collected by various agencies including DEH, DWLBC, EPA, CWMBs and community groups needs to be accessible to all stakeholders, and some level of integration of this data should be considered.

9.4 EPA LICENSING DATA

Access to EPA licensing data is currently available to stakeholders on request, but direct access to data would expedite the process. It is recognised that some data may be commercially confidential and therefore not readily accessible.

9.5 GROUNDWATER DATABASES

Extraction rates of private bores need to be monitored and the data and associated information entered onto the SAGeodata and Obswell databases managed by DWLBC. In addition, water-use information generally should be entered onto Obswell. This database would also provide an indication of which aquifer is being monitored by relevant bores.

Making EPA's groundwater quality monitoring data available to other stakeholders, and possible integration with DWLBC's groundwater monitoring database, is desirable.

9.6 LAND-USE DATASET

It is suggested that a standard land-use dataset, suitable for water resource assessment, be developed by major stakeholders (PIRSA, CWMBs, EPA, DWLBC) and made available centrally.

9.7 INFORMATION ACCESS NEEDS OF STAKEHOLDERS

Agencies that require access to information about monitoring or resource assessment, part or all of which they do not carry out themselves, are listed in Table 10.

Table 10. Information access needs of stakeholders.

What	Who	Why
Surface water quantity		
Surface water quantity data	EPA	Relates to water quality monitoring and water for the environment
	Planning SA	Development planning
	Transport SA	Design of Infrastructure
	Forestry SA	To assist in analysing water quality monitoring data
	SA Water	Potential impacts on potable water supplies
Water use	SA Water	Potential impacts on potable water supplies
Surface water quality		
Water quality data collection and assessment	Forestry SA	To monitor impacts of their industry
	Transport SA	Run-off from road surfaces
	Planning SA	Development planning
	Local government	Wastewater and stormwater
	DWLBC	Impacts on ecosystems, water allocation planning, and use and sustainable water management generally
Ambient water quality	DHS	To fulfil their role in protection of human health in relation to potable and recreational water use
	DWLBC	To identify and report on risks of degradation of water resources
Point source pollution	CWMBs	To indicate risks to water resources
	SA Water	To indicate risks to water resources
	DHS	To indicate risks to water resources
	DWLBC	For reporting on risks to water resources, water allocation planning and use, and sustainable water management generally
Diffuse pollution assessments	SA Water	Impacts on reservoir water quality
	DWLBC	Impacts on water quality and ecosystems, water allocation planning and use, and sustainable water management generally
Groundwater quantity		
Groundwater quantity assessments	SA Water	Particularly allocation systems that may impact on the availability of water supplies for potable use
	EPA	Relates to groundwater and surface water quality
	Forestry SA	With regard to development of groundwater resources
Groundwater quality		
Ambient	DHS	Drinking water supplies
Aquatic ecosystems		
Indicators of ecological health of riparian zones	Planning SA	Development planning
	Forestry SA	Impacts of forestry practices
	DHS	Impact on water quality of potable water supplies and water for recreational use

What	Who	Why
	DWLBC	For reporting purposes
Water quantity and quality for the environment	SA Water	To protect aquatic ecosystems and as a major water user to protect potential water supply
	DWLBC	To protect aquatic ecosystems
Estuarine monitoring information	DWLBC	In relation to pollutants and flow regime of the catchments
	CWMBs	In relation to pollutants and flow regime of the catchments
Marine environments		
Water quality	DWLBC	For reporting purposes
	CWMBs	Impacts of surface water and groundwater quality
	DEH	Coasts and marine responsibilities
	SA Water	Impacts of discharges
Community monitoring		
State-wide community monitoring including Waterwatch, Frog Census	DWLBC	For reporting purposes
Catchment characteristics		
Impacts of changes in land use	DWLBC	Policy development and reporting on water use and impacts upon ecological health
	EPA	Potential impacts on water quality and ecological health
Topography, aspect, stream characteristics, climate, vegetation cover, soils, hydrogeology, geomorphology, land use, demographics	All stakeholders	To assist in the interpretation of water monitoring data and making management decisions
Climate change, as reported by BoM and CSIRO	All stakeholders	Impacts of water quantity, quality and ecosystems

APPENDICES

A. RELEVANT LEGISLATION

ENVIRONMENT PROTECTION ACT 1993 (RELEVANT SECTIONS)

Objects of the Act include:

“(b) to ensure that all reasonable and practicable measures are taken to protect, restore and enhance the quality of the environment having regard to the principles of ecologically sustainable development” and

“(vii) to provide for monitoring and reporting on environmental quality on a regular basis to ensure compliance with statutory requirements and the maintenance of a record of trends in environmental quality.”

STATE WATER PLAN 2000

The State Water Plan 2000 is the over-arching policy statement for achieving the object of the Water Resources Act 1997.

“The State Water Plan must (s90(3)):

- Assess the state and condition of the water resources of the State: and
- Include an assessment of the monitoring of changes in the state and condition of the water resources of the State and include proposals for monitoring those changes in the future.”

Relevant Core Indicators for Monitoring Performance of Policy Outcomes: (Also refer to *Report on the Implementation of the State Water Plan,* SA Govt. (for reporting against these indicators).

Sustainable water resource allocation	Water resources (surface and groundwater) allocated within sustainable limits
Environmental water provisions implemented	Proportion of waterbodies where environmental water provisions have been implemented versus determined
Catchment health index	Measure of the state of a waterbody when macro-invertebrate assemblages, water quality, water quantity and riparian condition index trends assessed
The amount of water developed each year by industry sector	Trend over time of volume of water abstracted or developed, by industry sector,. This could include traditional and non-traditional water resources
Plan implementation	The degree to which strategies identified within approved plans have been implemented. This indicator can be expressed by type of plan (e.g. WAP, Catchment Plan, LWCMP etc) and presented as an index
Index of management effort	An index of a composite of management activities including policy implementation, monitoring schemes, government and community incentives, catchment management participation and RD&I. A trend over time for the index would reflect activity within each of the five categories

Consistency between planning and policy	Tallies of management plans or policies that are in conflict with one another across jurisdictions
Trend in community participating in monitoring programs	The number of people participating in monitoring programs over time, related to water resource management
Trend in licensing for activities	A tally over time of the number of granted applications by activity to provide information on future potential pressures
Catchments with appropriate data to assess resource sustainability	Trend over time of catchments with appropriate data (defined as sufficient quality data) to report the catchment health index
Roles and responsibilities for water quality monitoring	Progress of implementation of the agreed roles and responsibilities for water monitoring in South Australia

NATURAL RESOURCE MANAGEMENT ACT 2004

Extracts from the *Natural Resource Management Act 2004* (the Act)

An Act to promote sustainable and integrated management of the State's natural resources; to make provision for the protection of the State's natural resources; to make amendments to the *Crown Lands Act 1929*, the *Dog and Cat Management Act 1995*, the *Dog Fence Act 1946*, the *Environment Protection Act 1993*, the *Groundwater (Qualco-Sunlands) Control Act 2000*, the *Local Government Act 1934*, the *Mining Act 1971*, the *National Parks and Wildlife Act 1972*, the *Native Vegetation Act 1991*, the *Parliamentary Committees Act 1991*, the *Pastoral Land Management and Conservation Act 1989*, the *Petroleum Act 2000*, the *River Murray Act 2003*, the *South Eastern Water Conservation and Drainage Act 1992* and the *Subordinate Legislation Act 1978*; to repeal the *Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986*, the *Soil Conservation and Land Care Act 1989* and the *Water Resources Act 1997;* and for other purposes.

In summary, the objectives of the Act (*Chapter 2, Part 1*) are to assist in the achievement of ecologically sustainable development in the State by establishing an integrated scheme to promote the use and management of natural resources. It provides for the protection and management of catchments and the sustainable use of land and water resources and, insofar as is reasonable practicable, seeks to enhance and restore or rehabilitate land and water resources that have been degraded.

Key principles for ecologically sustainable development *(Chapter 2, Part 1)* of the Act include:

(3)(7)

> *(a) decision-making processes should effectively integrate both long term and short term economic, environmental, social and equity considerations;*
>
> *(c) decision-making processes should be guided by the need to evaluate carefully the risks of any situation or proposal that may adversely affect the environment and to avoid, wherever practicable, causing any serious or irreversible damage to the environment;*

The functions of the minister under the Act include *(Chapter 3 Part 1)*:

(10)(1)

> *(a) to keep the state and condition of the natural resources of the State under review; and*
>
> *(e) to compile, maintain and update information in relation to the State's natural resources; and*
>
> *(f) to promote public awareness of the importance of the State's natural resources and to encourage the conservation of those resources.*

The structure includes an NRM Council, Eight regional NRM Boards and sub-regional NRM Groups.

The functions of the NRM Council include (*Chapter 3, Division 2, Part 2, Division 3)*:

(17)(1)

(b) " to audit, monitor and evaluate the state and condition of natural resources across the State, and to evaluate and report on —

(i) the performance of the NRM authorities established under this Act; and

(ii) the integration of natural resources management practices on account of this Act."

The NRM Council must prepare and maintain a plan to be called the *State Natural Resources Management Plan*. The State NRM Plan is to set out principles and policies for achieving the objects of this Act throughout the State (*Chapter 4, Part 1*).

(74)(3) In connection with the operation of subsection (2), the State NRM Plan must —

(a) —

(i) assess the state and condition of the natural resources of the State; and

(ii) identify existing and future risks of damage to, or degradation of, the natural resources of the State; and

(iii) provide for monitoring and evaluating the state and condition of the natural resources of the State on an ongoing basis; and

(b) identify goals, set priorities and identify strategies with respect to the management of the natural resources of the State; and

(c) set out or adopt policies with respect to the protection of the environment and the interests of the community through the operation of this Act, including through the control of pest species of animals and plants; and

(d) promote the integrated management of natural resources; and

(e) include or address other matters prescribed by the regulations or specified by the Minister.

(6) The NRM Council must review the State NRM Plan at least once in every 5 years.

A draft of South Australia's Natural Resource Management (NRM) Plan (2005-2010) has been released for consultation.

The Act also requires each NRM board to prepare a water allocation plan for each prescribed water resource in its region (*Chapter 4, Part 2, Division 2,*).

(76)(4) A water allocation plan must —

(a) Include —

(i) an assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and the times at which, or the periods during which, those ecosystems will need that water; and

(ii) an assessment as to whether the taking or the use of water from the resource will have a detrimental effect in the quantity or quality of that is available from any other water resource; and

(b) *provide for the allocation (including the quantity of water that is to be available for allocation) and use of water so that-*

   (i) *an equitable balance is achieved between environmental, social and economic needs for the water; and*

   (ii) *the rate of use of the water is sustainable.*

B. MONITORING STATION CATEGORIES — SURFACE WATER MONITORING

(Modified from Greenwood 2001).

Monitoring type	Description	Station type	Role	Minimum parameters	Duration	Frequency of data collection	Priority
Ambient Monitoring	Long-term monitoring to establish and continually assess the state of river systems and detect any changes in their condition.	Base station.	To monitor and characterise stream flow from the major yielding section/s of the catchment, basin or region.	Water level and stream flow; salinity (EC and temperature). Possibly rainfall or other climatic parameters as required.	On-going (at least 25 years).	Continuous.	High.
Project Monitoring	Any monitoring linked to project objectives, which may commonly include the collection of detailed data to support ambient monitoring.	Represent-ative station.	Stream flow from areas with particular hydrological characteristics arising from distinct features for example, vegetation types or land-use practices.	Water level and stream flow; salinity (EC and temperature).	Medium term (10 years).	Continuous.	As per project priorities, but high to medium in supporting ambient programs.
		Environ-mental station.	Sites considered significant for monitoring the water requirements of aquatic ecosystems.	Usually water level, possibly salinity (EC and temperature); other parameters as required.	Short–medium term (5–10 years).	Project specific.	As per project priorities.
		Project station.	Any station designed to collect information for specific objectives, particularly outside the design scope of the ’conventional‘ hydrological assessment network.	As required.	As required, typically 5–10 years.	Project specific.	As per project priorities.

Monitoring type	Description	Station type	Role	Minimum parameters	Duration	Frequency of data collection	Priority
Regulatory and compliance monitoring	Monitoring to evaluate the impact of regulation or development, often as part of compliance with water management plans, statutory reporting, auditing or law.	System inflow–outflow.	Relates to stream flow entering or released from heavily developed or regulated river systems and infrastructure, e.g. in and out of Prescribed Areas and upstream and downstream of reservoirs.	Water Level and stream flow; salinity (EC and temperature). May be subject to other parameters specified in management plan.	For duration of the development or as per the relevant management requirements (years, decades?).	Continuous.	High, subject to resource management requirements.
		Basin outflow station.	Stream flow leaving the catchment, e.g. flows into the ocean, inland lakes or interstate. Could arguably be classified as project type information to augment a conventional network.	Water Level and stream flow; salinity (EC and temperature).	As required for auditing and statutory reporting (5–10 years).	Continuous	High, subject to resource management requirements.

C. SYSTEMIC MODEL FOR WATER MONITORING

Classification	Parameter	Purposes	Lead agency[1]	Collaborative agency[2]	Interested agency[3]
Water availability	Rainfall.	Analyse rainfall patterns. Climate change management. Forecast flood and drought. Calibrate computer models.	BoM	DWLBC, NRMB, SA Water	EPA, PIRSA, DEH
	Rainfall intensity.	Catchment hydrological model. Surface–groundwater relationship. Climate change management.	DWLBC	BoM, NRMB, SA Water	EPA, PIRSA, DEH
	Catchment stream flow.	Water allocation. Flood frequency analysis. Environment flow. Aquatic ecosystem health assessment. Water quality assessment.	DWLBC	EPA, NRMB, SA Water	BoM, PIRSA, DEH
	Sub-catchment stream flow.	Environment flow. Aquatic ecosystem health assessment. Water quality assessment.	NRMB	DWLBC, EPA, SA Water	BoM, PIRSA, DEH
	Reservoir weir in–out flow.	Reservoir operation.	SA Water	NRMB, DWLBC	EPA, BoM
	Reservoir–weir capacity.	Reservoir operation.	SA Water	NRMB, DWLBC	EPA, BoM
	Evapo-transpiration.	Catchment hydrological model.	BoM	DWLBC, NRMB, SA Water	EPA, DEH
	Storm water.	Additional water supplies. Aquatic ecosystem health assessment. Water quality assessment.	NRMB	DWLBC, local councils, SA Water, EPA	DEH, BoM
	Effluent.	Additional water supplies.	SA Water	EPA, NRMB, Local Councils, DWLBC	DEH

Classification	Parameter	Purposes	Lead agency[1]	Collaborative agency[2]	Interested agency[3]
		Receiving waterbody ecosystem health assessment.			
		Water quality assessment.			
	Soil moisture.	Catchment hydrological model.	PIRSA	DWLBC, NRMB	EPA, DEH
	Groundwater level.	Water allocation.	DWLBC	EPA, NRMB, PIRSA, SA Water	DEH
		Environment flow.			
		Groundwater-dependent ecosystem health assessment.			
		Water quality assessment.			
		Dryland salinity management.			
		Surface–groundwater relationships.			
	Climate change.	All aspects of natural resource management.	BoM	PIRSA, DWLBC, DEH, EPA, NRMB, SA Water	
Water withdrawal	Extraction.	Water allocation.	DWLBC	SA Water, NRMB	EPA, DEH
		Environmental flow.			
		Catchment water budget.			
	Water use.	Water allocation.	NRMB	DWLBC, SA Water	EPA, DEH
		Environmental flow.			
		Efficient use of water resources.			
		Catchment water budget.			
	Farm dam.	Catchment hydrological model.	DWLBC	NRMB, PIRSA, EPA	SA Water, DEH
		Environmental flow.			
Return flow	Irrigation drainage.	Catchment hydrological model.	PIRSA	DWLBC, NRMB, SA water, EPA	DEH
		Environmental flow.			
		Salinity management.			
	Deep drainage.	Dryland salinity management.	PIRSA	DWLBC, NRMB	EPA
		Groundwater quality assessment.			

Classification	Parameter	Purposes	Lead agency[1]	Collaborative agency[2]	Interested agency[3]
Water quality	Pesticides, organics, metals, nutrients, DO, pH, turbidity, temperature, structure of aquatic communities, habitat, macro-invertebrates, indictor bacteria, others.	Classify water quality. Trend analysis. Pollution incident report. Assessment of water quality standards. Identify emerging problems.	EPA	DWLBC, NRMB, SA Water	DEH, PIRSA
	Salinity (surface and groundwater).	Water quality assessment. Evaluation of salt interception schemes. Dryland salinity management.	DWLBC	EPA, NRMB, PIRSA, SA Water	DEH
Aquatic ecosystems (inland)	Water regime. Water quality. Biological integrity.	Environmental value assessment. Ecosystem health assessment. Environmental flow. Surface–groundwater interaction.	DWLBC	EPA, NRMB, DEH	PIRSA
Aquatic ecosystems (marine)	Water quality. Biological integrity.	Ecosystem health assessment. Environmental value assessment. Aquaculture based monitoring.	DEH, PIRSA	DWLBC, EPA, NRMB	PIRSA, DWLBC, EPA

1. Lead agency: under legislative mandate, and is responsible for:
   Developing monitoring strategy, plan, and protocols;
   Data custodian, and supervising data quality assurance; and
   Supporting monitoring undertaken by other parties.
2. Collaborative agency: need information for business operation, contribute to monitoring through joint funding, advise and consultation, etc.
3. Interested agency: in the best interests of the business that monitoring is undertaken.

D. EXCERPT FROM TCWMP CATCHMENT MANAGEMENT STRATEGY

(from TCWMP's list of actions as part of its Catchment Management Strategy, seen relevant to this review)

GOAL 1.		**To improve and maintain water quality in the catchment to a standard suitable for community use (including public water supply), for sustainable natural ecosystems and to reduce impacts on receiving waters**		
Strategy 1.1		Assign environmental values for water resources within the catchment and set appropriate improvement targets. Water quality reviews have shown that standards as reflected in the ANZECC guidelines are not being met all the time in the urban and rural catchments. In some cases it would be impossible to meet these criteria. In order to get a clearer direction for management, environmental values need to be adopted and specific water quality levels or loads developed.		
Actions		**Description**	**Outcomes**	**Partners**
Action	1.1.4	Assess water quality (non-salinity) of Adelaide Plains groundwater.	Information to help decide if the Adelaide Plains groundwater should be designated an 'irrigation' environmental value to facilitate ASR opportunities or afforded greater protection for future potable supplies.	TCWMB (lead agency), DWLBC, EPA

GOAL 2.		**To ensure that sufficient water is maintained in creeks, rivers and aquifers to be available for equitable and economic community use (both private and public) and to maintain ecosystems**		
Strategy 2.1		Define water for the environment requirements and review resource use and availability. There is significant use of water from the catchment with farm dams and groundwater competing with the environment and SA Water reservoir diversion supplies. To date there has been little account of environmental needs and current policies need to be reviewed. Water use in the urban area from groundwater and the Torrens is not controlled.		
Actions		**Description**	**Outcomes**	**Partners**
Action	2.1.1	Undertake detailed investigations and surveys for the catchment's Water for the Environment requirements.	Specific survey work in the catchment will include the impact of farm dams, the operation of River Murray transfers and reservoirs.	TCWMB (lead agency), DWLBC, SA Water, DEH, EPA
Action	2.1.4	Establish a monitoring requirement for current large groundwater users of the Adelaide Plains aquifer(s)	At this stage little information is readily available on extraction from Adelaide Plains groundwater aquifers. Monitoring of larger users is needed.	TCWMB, DWLBC (lead agency), Industry

GOAL 3. To protect and enhance water-dependent ecosystems through integrated natural resource management				
Strategy 3.2		Assess and protect aquatic habitat. Although the River Torrens is highly regulated and modified, it is important to assess the aquatic habitat condition and opportunities for production or enhancement. Many local impacts, barriers and inappropriate activities could be degrading aquatic health.		
Actions		**Description**	**Outcomes**	**Partners**
Action	3.2.1	Assess and map important aquatic habitat features and locations including refuge pools for the catchment's Water for the Environment requirements.	Baseline information on aquatic habitat health and local conditions will be provided to assist protection options and landholders. The survey will cover the River Torrens urban reach and all rural watercourses.	TCWMB (lead agency), DEH
Strategy 3.3		Managing urban watercourses. Urban watercourses are typically degraded but there are reaches with important habitat, especially in the River Torrens. Opportunities should be taken to protect and enhance these reaches.		
Actions		**Description**	**Outcomes**	**Partners**
Action	3.3.1	Investigate and trial 'environmental flows' in the River Torrens downstream of the Gorge Weir — summer baseflows.	The upper urban River Torrens is deprived of late spring and summer flows from Sixth Creek by diversions from the Gorge Weir.	TCWMB (lead agency), SA Water, DEH, DWLBC, Councils

GOAL 4. To coordinate floodplain management at the catchment scale				
Strategy 4.1		Coordinate integrated stormwater and flood plain management. The new era of urban stormwater management now integrates water quality and quantity together. Multi-objective aims of enhancing local amenity — improving water quality and reusing stormwater combine with the fundamental flood protection objectives. There still needs to be some leadership taken for floodplain management issues that cross council boundaries and the board will take a coordinating role.		
Actions		**Description**	**Outcomes**	**Partners**
Action	4.1.1	Coordinate flood mapping and mitigation studies required in the catchment.	The level of protection against flooding in many parts of the catchment is well below accepted standard. The board will coordinate cross-council flood mapping and the identification of mitigation options.	TCWMB (lead agency), Councils, DWLBC

GOAL 5.		To foster an informed, committed and involved community that takes responsibility for and actively supports its role in catchment water management		
Strategy 5.2		Support groups and schools in community education and involvement programs. The Our Patch and Waterwatch Programs have been very successful in providing support to community groups and schools to undertake on-ground works and outdoor education activities.		
Actions		**Description**	**Outcomes**	**Partners**
Action	5.2.2	Continue to support continuation and expansion of the Patawalonga and Torrens Waterwatch Programs.	Waterwatch will continue to be supported in the Torrens Catchment. Already involving groups, including many schools, the program has developed very valuable services such as a web site, community water quality reports and a variety of on-ground activities.	TCWMB, EPA, Waterwatch

GOAL 6.		To establish and implement monitoring and evaluation systems which enable the Board to assess the effectiveness of its programs and the health of the catchment		
Strategy 6.1		Link with other existing and proposed data collected in the catchment The range of activities and issues in the catchment make the data collection needs complex. Opportunities need to be taken to coordinate requirements with other agencies and catchment water management boards.		
Actions		**Description**	**Outcomes**	**Partners**
Action	6.1.1	Investigate water-related data collection by SA Water, EPA, councils and other agencies and finalise a catchment monitoring plan in conjunction with the State Water Monitoring Committee.	Further work is needed to establish appropriate linkages with existing data collection systems and identify the gaps. Water use and groundwater monitoring are two areas for consideration.	PCWMB (lead agency), Other agencies
Action	6.2.1	Expand the current water quality–quantity–biological health monitoring program to include the Port Adelaide area and improve the existing Watershed and Torrens Lake composite monitoring.	The Port Adelaide area will have two new stations monitoring in-flows to West Lakes and Barker Inlet Wetlands. New stations upstream of Torrens Lake at Hackney Road and at Gumeracha Weir will also be installed. The biological health monitoring will be carried out every three years.	TCWMB (lead agency), SA Water, EPA, DWLBC

GOAL 7.		To deliver the board's programs in an integrated manner in partnership with all other stakeholders, taking into account environmental, economic and social considerations (triple bottom line)		
Strategy 7.1		Support an Integrated Natural Resources Management (INRM) approach across the catchment. The board needs to work closely with a number of organisations and agencies to achieve its goals and fulfil its responsibilities under the Water Resources Act.		
Actions		**Description**	**Outcomes**	**Partners**
Action	7.1.4	Support the coordination of research and development opportunities.	In collaboration with partner organisations, invest in research and development programs that support the board's investigation and data requirements.	PCWMB (lead agency), Partner organisations

E. CURRENT AND HISTORIC ON-GOING SURFACE WATER MONITORING — TORRENS CATCHMENT

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
Upper Torrens							
Mount Pleasant							
3465	Griggs Road	Natural stream	Immediately downstream of Mount Pleasant township, this River Torrens site is upstream of the outfall for River Murray water from the Mannum–Adelaide pipeline. Flow ceases in summer. Riparian users pump the pooled water to off-stream storage in early summer (TCWMB 2000).	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB
AW504512	Torrens River @ Mount Pleasant	Natural stream	SA Water meteorological telemetry.	Recording Rainfall Water level Ad hoc field reading Water level Stream discharge Temperature TDS pH DO Conductivity	DWLBC	Water Data Services	DWLBC
3313	Torrens River @ Mount Pleasant	Natural stream	Same location as AW504512.	Ambient	EPA	EPA	EPA
M023737	Mount Pleasant BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
Upper Main Channel (Birdwood)							
AW504914	Cromer Pluvio @ ALERT Station	Meteorological station	BoM ALERT system.	Recording Rainfall	BoM	BoM	BoM
3456	Carnell Boundary Road	Natural stream	This site is on the downstream	Ambient and macro-	TCWMB,	TCWMB,	TCWMB,

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
			side of the ford which is 0.6 km downstream of the discharge point for the Mannum–Adelaide pipeline. A large pool runs into an extensive riffle (TCWMB 2000).	invertebrates	EPA	EPA	EPA
AW504916	McVitties Hill Pluvio @ McVitties Hill	Meteorological station	BoM ALERT system	Unknown	BoM	BoM	BoM
M023881	Cromer Road BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
M023705	Birdwood Dept of Transport BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
AW504913	Torrens River @ Birdwood	Natural stream	Current infrequent grab samples for water quality. BoM ALERT system. Poor data quality, not adequately rated.	Recording Water level	SA Water	SA Water	SA Water
Angas Creek							
AW504912	Angas Creek @ Muellers Road	Natural stream	BoM ALERT system. Poor data quality.	Recording Rainfall Water level	BoM	BoM	BoM
AW504941	Mount Torrens Pluvio @ Mount Torrens	Meteorological station	BoM ALERT system.	Unknown	BoM	BoM	BoM
M024579	Mount Torrens (Herrmanns Boundary Rd) BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
M023778	Mount Torrens BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
McCormick Creek							
AW504558	Torrens River Catchment Pluvio @ Angas Ck Pump Station	Meteorological station	Flood warning, modelling and field estimation. SA Water meteorological telemetry.	Recording Rainfall	DWLBC	Water Data Services	DWLBC
Hannaford Creek							
–	–	–	–	–	–	–	–

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
Millers Creek							
AW504911	Millers Creek @ Forreston	Natural stream	BoM ALERT system, poor data quality.	Recording Rainfall Water Level	BoM	BoM	BoM
M023880	Ironstone Road (Reserve Road) BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
Footes Creek							
–	–	–	–	–	–	–	–
Kenton Valley							
–	–	–	–	–	–	–	–
Gumeracha							
3457	Poplar Grove	Natural stream	This site is 1 km downstream of the second discharge point from the Mannum–Adelaide pipeline in Angas Creek. A large pool is transversed by bars of bedrock downstream from a braided riffle (TCWMB 2000).	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB
AW504942	O’Deas Road Pluvio @ 3 km S Gumeracha	Meteorological station	BoM ALERT system.	Unknown	BoM	BoM	BoM
AW504500	Torrens River @ Gumeracha Weir	Weir	Related station — AW504508 — Millbrook intake flume. BoM ALERT system.	Recording Water level Ad hoc field reading Water level Stream discharge Temperature TDS pH DO Conductivity	SA Water	SA Water	SA Water
AW504545	Retreat Creek @ Retreat Valley	Urban drainage stormwater	Closed.	Unknown	Closed	Closed	DWLBC
M023719	Gumeracha District Council BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
M023712	Dingo Vale BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
Kangaroo Creek Reservoir							
A5041003	Torrens River D/S Holland Creek	Natural stream	A new station to be run as a base station.	Unknown	DWLBC	Unknown	DWLBC
AW504531	Torrens River @ Kangaroo Creek Reservoir	Dam or water storage	Flood warning. BoM ALERT system.	Recording Water level Reservoir water level	SA Water	Water Data Services	SA Water
Kersbrook Creek							
3326	Kersbrook Creek upstream of Millbrook Reservoir	Natural stream	A tributary site. Immediately downstream of gauging station AW504525.	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB
AW504511	Chain of Ponds Creek @ Millbrook Dissipator	Natural stream	Closed.	Unknown	Closed	Closed	DWLBC
AW504525	Kersbrook Creek @ U/S Millbrook Reservoir	Natural stream	Related station — AW504520 — Millbrook Reservoir @ Dam Embankment.	Recording Water level Ad hoc field reading Water level Water temperature TDS pH DO Conductivity Composite sampling TDS Suspended solids Conductivity Phosphorus Nitrogen	DWLBC	Water Data Services	DWLBC
AW504508	Millbrook Reservoir Intake Channel @ U/S Millbrook Reservoir	Water supply system, pipe	Related station — AW504500 — Torrens River @ Gumeracha Weir. Scheduled to be closed by DWLBC	Recording Water level Ad hoc field reading Water level Stream discharge	SA Water	Water Data Services	SA Water

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
				Water temperature TDS pH DO Conductivity Composite sampling TDS Suspended solids Conductivity Phosphorus Nitrogen			
AW504563	Millbrook Reservoir Automatic Weather Station	Meteorological station		Recording Rainfall Temperature Humidity Wind direction Wind velocity Sunshine duration Solar radiation	DWLBC	Water Data Services	DWLBC
AW504520	Millbrook Reservoir @ Dam Embankment	Dam or water storage	Related station — AW504563 — Millbrook Pluvio @ Millbrook Reservoir.	Recording Reservoir water level Daily read Reservoir water level	SA Water	Water Data Services	SA Water
M023826	Kersbrook Forest Reserve BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023877	Kersbrook Effluent Ponds BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
Cudlee Creek							
M023731	Cudlee Creek (Millbrook) BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
AW504524	Cudlee Creek @ Cudlee Creek	Natural stream	Discharge measurement only. Closed.	Ad hoc field reading Water level Water temperature TDS	Closed	Closed	DWLBC

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
				pH DO Conductivity			
AW504903	Cudlee Creek @ D/S Road Bridge Lobethal	Natural stream	BoM ALERT system. Data are not adequate for calculating flow.	<u>Recording</u> Rainfall Water level	BoM	BoM	BoM
M023879	Berrie Hill O'Deas Road BoM Station	Meteorological station		<u>Daily read</u> Rainfall	BoM	BoM	BoM
Sixth Creek							
3324	Sixth Creek at Castambul		A tributary site. This site is a riffle-pool section just upstream of the Gorge Road Bridge near the confluence with the River Torrens. Flow is fast and the water is clear; trout are always seen as the site is approached (TCWMB 2000).	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB
AW504937	Ashton Pluvio @ Ashton	Meteorological station	BoM ALERT system.	Unknown	BoM	BoM	BoM
AW504523	Sixth Creek @ Castambul	Natural stream	National Water Resources Assessment Program — preliminary study of flooding of River Torrens. BoM ALERT system.	<u>Recording</u> Water Level <u>Ad hoc field reading</u> Water level Stream discharge Water temperature TDS pH DO Conductivity <u>Composite sampling</u> TDS Suspended solids Turbidity Colour Conductivity Phosphorus	TCWMB	Water Data Services	DWLBC

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
				Nitrogen Calcium Magnesium Potassium Sodium Bicarbonate Carbonate Chloride Sulphate Cadmium Chromium Copper Lead Zinc Aluminium			
AW504943	Stringybark Pluvio @ Stringybark	Meteorological station	BoM ALERT system.	Unknown	BoM	BoM	BoM
AW504559	Sixth Creek Catchment Pluvio @ Cherryville	Meteorological station	BoM ALERT system.	Recording Rainfall	DWLBC	Water Data Services	DWLBC
M023865	Stringybark BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
M023892	Torrens Gorge (Montacute) BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
Gorge Weir							
AW504501	Torrens River @ Gorge Weir	Natural stream	Part of River Torrens Basin flood warning scheme. Related station — AW504509 — Hope Valley Intake Flume @ Athelstone. BoM ALERT system.	Recording Water level SA reservoirs yield Catchment yield NLWRA 2000 Catchment yield Ad hoc field reading TDS pH Conductivity	SA Water	Water Data Services	SA Water

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
AW504584	Montacute Quarry Creek @ Gorge Road	Natural stream		Recording: Water Level Turbidity Composite Sampling: Suspended Solids	Private Company	Water Data Services	Water Data Services
Lower Torrens							
First Creek Rural							
3318	First Creek U/S Waterfall	Natural stream	Same location as AW504517.	Ambient	EPA	EPA	EPA
3458	First Creek U/S of Waterfall Gully	Natural stream		Ambient and macro-invertebrates	EPA	EPA	EPA
M023810	Cleland Conservation Park BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
M023868	Mount Lofty ABC Transmitter BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
M023842	Mount Lofty BoM Met Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
AW504930	Cleland National Park Pluvio @ Long Ridge	Meteorological station	BoM ALERT system.	Unknown	BoM	BoM	BoM
AW504924	First Creek @ Waterfall Gully Road	Natural stream	BoM ALERT system.	Unknown	BoM	BoM	BoM
AW504552	First Creek Catchment @ Mt Lofty	Meteorological station	Related Station — AW504517 — First Creek @ Waterfall Gully. SA Water meteorological telemetry.	Recording Rainfall	DWLBC	Water Data Services	DWLBC
AW504517	First Creek @ Waterfall Gully	Natural stream	Other Data — report 'Influence of soils and land use on clay movement and water quality', study by M. Oades and D. Chittleborough of Waite Institute and Adelaide Uni. Other stations monitored in this project are Inverbrackie, Cox and Aldgate Creeks. To be closed by DWLBC.	Recording Water Level Ad hoc field reading Water level Stream discharge Water temperature TDS pH DO Conductivity	DWLBC	Water Data Services	DWLBC

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
Second Creek Rural							
–	–	–	–	–	–	–	–
Third Creek Rural							
–	–	–	–	–	–	–	–
Fourth Creek Rural							
M023767	Norton Summit BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023702	Ashton 1 BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023867	Ashton Marble Hill Orchard BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
M023803	Ashton Co-op BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
Fifth Creek Rural							
M023097	Adelaide (Black Hill Conservation Park) BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
Hope Valley Reservoir							
M023047	Paradise BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023821	Hope Valley (Cocks) BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023096	Adelaide (Hope Valley Reservoir) BoM Station	Meteorological station		Daily read Rainfall Evaporation	BoM	BoM	BoM
M023068	Castambul BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
AW504547	Hope Valley Reservoir @ Hope Valley	Dam or water storage	BoM alert system.	Recording Rainfall Reservoir water level Daily read Rainfall Evaporation	SA Water	Water Data Services	SA Water

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
AW504509	Hope Valley Reservoir Intake Channel @ Athelstone	Water supply system, pipe	Related station — AW504501 — Torrens River @ Gorge Weir. BoM ALERT system.	Recording Water level	SA Water	Water Data Services	SA Water
AW504514	Torrens River @ Clark Crescent	Natural stream	Torrens River Flood Study.	Unknown	TCWMB	Unknown	DWLBC
AW504573	Thorndon Park Reservoir	Meteorological station	Closed.	Unknown	BoM	BoM	BoM
AW504571	Samuel Lake @ Athelstone	Natural lake, swamp	Storm water retention basin for Samuel Creek. Closed.	Recording Water level Ad hoc field reading TDS Conductivity	Closed	Closed	DWLBC
AW504570	Samuel Creek @ Athelstone	Natural stream	Related station — AW504571 — Samuel Lake @ Athelstone. Closed.	Recording Water level Ad hoc field reading TDS Conductivity	Closed	Closed	DWLBC
AW504569	Bradley Lake @ Athelstone	Natural lake	Retention basin for stormwater from Bradley Creek. Closed.	Recording Water level Ad hoc field reading TDS Conductivity	Closed	Closed	DWLBC
AW504568	Bradley Creek @ Athelstone	Natural stream	Inflow to Bradley Lake — SW retention basin. Related station — AW504569 — Bradley Lake @ Athelstone. Closed.	Recording Water level Ad hoc field reading TDS Conductivity	Closed	Closed	DWLBC
AW504591	Whites Quarry @ Whites Quarry	Natural stream		Recording Water level Turbidity	Private company	Water Data Services	Water Data Services
A5041002	Torrens River @ D/S Gorge Weir	Natural stream	New site awaiting details.	Unknown	DWLBC	Unknown	DWLBC
1851	Silkes Road U/S of the Ford		A River Torrens site. A large and deep pool with a cobble base upstream of the pedestrian bridge	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
			and a short riffle extends to the ford (TCWMB 2000).				
1896	Fifth Creek		A tributary site. This site is 50 m upstream of the confluence with the River Torrens at Heather Court, Paradise (TCWMB 2000).	Ambient	TCWMB	TCWMB	TCWMB
First Creek Urban							
M023062	Kensington Park BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023048	Rose Park BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023042	Kensington Upper (Burnside) BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023746	Stonyfell BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023085	First Creek (Seaview) BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
AW504935	Beaumont Pluvio @ Beaumont	Meteorological station	BoM ALERT system.	Recording Rainfall	BoM	BoM	BoM
AW504907	Parklands Creek @ Victoria Park	Natural stream	BoM ALERT system.	Recording Water level	BoM	BoM	BoM
AW504936	Kent Town Pluvio @ Kent Town RO	Meteorological station	BoM ALERT system.	Unknown	BoM	BoM	BoM
Second Creek Urban							
M023040	Adelaide (Trinity) BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023008	Magill Post Office BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
Third Creek Urban							
M023072	Adelaide (Magill Training Centre) BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
Fourth Creek Urban							
M023069	Brookside BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
Fifth Creek Urban							
–	–	–	–	–	–	–	–
Lower Portrush							
M023027	Adelaide (Thorndon Park) BoM Station	Meteorological station		Daily Read Rainfall Evaporation	BoM	BoM	BoM
AW504579	Third Creek @ Forsyth Grove	Urban drain, stormwater		Recording Water level Composite sampling TDS Suspended solids Turbidity Colour Conductivity Phosphorus Nitrogen Calcium Magnesium Potassium Sodium Bicarbonate Chloride Sulphate Cadmium Chromium Copper Lead Zinc	TCWMB	Water Data Services	DWLBC
1898	Third Creek upstream Torrens River at Forsyth Grove		A tributary site. Near AW504579.	Ambient	TCWMB	TCWMB	TCWMB
1897	Fourth Creek		A tributary site. The site is North of Langman Grove, Felixstow, 50 m upstream of the confluence with the River Torrens (TCWMB	Ambient	TCWMB	TCWMB	TCWMB

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
			2000).				
1852	Windsor Grove		A River Torrens site. Upstream of the footbridge at the southern end of Windsor Grove, Windsor Gardens (TCWMB 2000).	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB
Holbrooks Road							
M023088	Adelaide Government House BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023011	North Adelaide BoM Station	Meteorological station		Daily read Rainfall	BoM	BoM	BoM
AW504513	Torrens River @ City Weir	Dam or water storage	This station is primarily used for flood gauging. Current irregular observations.	Ad hoc field reading Water temperature DO	BoM	BoM	BoM
AW504529	Holbrooks Road	Natural stream	A River Torrens site. This is a gauging station at Holbrooks Weir immediately upstream of Holbrooks Road. Data from site will be used for the study of flood runoff, gulf pollution (in association with Bolivar), groundwater recharge and urban runoff.	Recording Water level Suspended solids Ad Hoc Field Reading Water level Stream discharge Water temperature TDS pH DO Conductivity Composite sampling TDS Suspended solids Turbidity Colour Conductivity Phosphorus Nitrogen Calcium Magnesium	TWCMB	Water Data Services	DWLBC

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
				Potassium Sodium Bicarbonate Carbonate Chloride Sulphate Cadmium Chromium Copper Lead Zinc			
Torrens Lake							
M023066	Northfield (Yatala Park) BoM Station	Meteorological Station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023022	St Peters Post Office BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
M023035	Adelaide Botanic Gardens BoM Station	Meteorological station	Closed.	Daily read Rainfall	BoM	BoM	BoM
AW504593	Torrens River @ D/S Second Creek Junction	Natural stream	At billabong D/S of St Peters Weir.	Levels and composite (details unknown)	TCWMB	Water Data Services	DWLBC
AW504578	First Creek @ D/S Botanic Gardens	Urban drain, stormwater	At bottom of First Creek.	Recording Water Level Composite sampling TDS Suspended solids Turbidity Colour Conductivity Phosphorus Nitrogen Calcium Magnesium Potassium Sodium	TCWMB	Water Data Services	DWLBC

Site number	Site name	Type	Purpose, comments	Parameters	Funding agency	Data collection	Data custodian
				Bicarbonate Chloride Sulphate Cadmium Chromium Copper Lead Zinc			
AW504515	Torrens River @ Lower Portrush Road	Natural stream	Torrens River Flood Study.	Unknown	TCWMB	Unknown	DWLBC
1900	First Creek @ D/S Botanic Gardens	Natural stream	A stormwater drain from the car park associated with the Royal Adelaide Hospital contributes more water in summer than the flow in First Creek through the Botanic Gardens (TCWMB 2000). Co-located with AW504578.	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB
1899	Second Creek upstream Torrens River	Natural stream	A tributary site.	Ambient	TCWMB	TCWMB	TCWMB
Breakout Creek							
1853	South Road		A River Torrens site. This site is 200 m downstream of South Road at the first reach where the channel returns from a paved channel to a more natural bed (TCWMB 2000).	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB
1854	Tapleys Hill Road		A River Torrens site. Upstream of the bridge at Lockleys, this part of the Torrens Linear Park is used to agist horses (TCWMB 2000).	Ambient and macro-invertebrates	TCWMB	TCWMB	TCWMB
M023002	Fulham Park BoM Station	Meteorological station	Closed.	<u>Daily read</u> Rainfall	BoM	BoM	BoM
AW504516	Torrens River @ Henley Beach Road	Natural stream	Torrens River Flood Study. Closed.	Unknown (previous infrequent grab samples)	Closed	Closed	DWLBC

F. SURFACE WATER LEVEL AND FLOW MONITORING SITES IN THE TORRENS CATCHMENT

Site number	Site name	Commenced	Ceased	Level continuous recording	Stream flow	Easting	Northing
Mount Pleasant							
AW504512	Torrens River @ Mount Pleasant	2/5/1973	–	Yes	Yes (Latest Gauging 1991)	319631.0	6148870.0
Angas Creek							
AW504912	Angas Creek @ Muellers Road	29/2/1996	–	Yes	Yes	312522.0	6143978.0
Millers Creek							
AW504911	Millers Creek @ Forreston	19/3/1996	–	Yes	Yes	308022.0	6147878.0
Kersbrook Creek							
AW504525	Kersbrook Creek @ U/S Millbrook Reservoir	1/1/1976	–	Yes	Yes (latest gauging 1996)	302052.0	6145960.0
Cudlee Creek							
AW504903	Cudlee Creek @ D/S Road Bridge Lobethal	1/7/1995	–	Yes	Yes	302192.0	6141748.0
Sixth Creek							
AW504523	Sixth Creek @ Castambul	10/11/1977	–	Yes	Yes (latest gauging 2004)	294733.0	6138869.0
Gorge Weir							
AW504584	Montacute Quarry Creek @ Gorge Road	1/6/1999	–	Yes	Yes	294022.0	6139678.0
First Creek Rural							
AW504517	First Creek @ Waterfall Gully	7/10/1976	–	Yes	Yes (latest gauging 2000)	288322.0	6127778.0
Hope Valley Reservoir							
AW504571	Samuel Lake @ Athelstone	2/9/1993	27/7/1994	Yes	No	290822.0	6140278.0
AW504570	Samuel Creek @ Athelstone	4/8/1993	27/7/1994	Yes	Yes (latest gauging 1993)	290822.0	6140278.0
AW504568	Bradley Creek @ Athelstone	4/8/1993	27/7/1994	Yes	Yes (latest gauging 1993)	291322.0	6140278.0
AW504569	Bradley Lake @ Athelstone	18/8/1993	12/1/1995	Yes	No	291322.0	6140278.0

Site number	Site name	Commenced	Ceased	Level continuous recording	Stream flow	Easting	Northing
AW504591	Whites Quarry @ Whites Quarry	11/2/1998	–	Yes	Yes	291722.0	6140578.0
First Creek Urban							
AW504907	Parklands Creek @ Victoria Park	16/3/1995	–	Yes	No	283022.0	6131078.0
Lower Portrush							
AW504579	Third Creek @ Forsyth Grove	16/7/1996	–	Yes	Yes (latest gauging 1998)	284622.0	6136678.0
Holbrooks Road							
AW504529	Torrens River @ Holbrooks Road	7/2/1978	–	Yes	Yes (latest gauging 1986)	276046.0	6133796.0
Torrens Lake							
AW504578	First Creek @ D/S Botanic Gardens	3/5/1996	–	Yes	Yes (latest gauging 1997)	281322.0	6133710.0

G. SALINITY MONITORING SITES FOR SURFACE WATER — TORRENS CATCHMENT

Site number	Site name	Commenced	Ceased	Levels and salinity	Easting	Northing
Kersbrook Creek						
AW504525	Kersbrook Creek @ U/S Millbrook Reservoir	1/1/1976	–	Yes	302052.0	6145960.0
Sixth Creek						
AW504523	Sixth Creek @ Castambul	10/11/1977	–	Yes	294733.0	6138869.0
Torrens Lake						
AW504578	First Creek @ D/S Botanic Gardens	3/5/1996	–	Yes	281322.0	6133710.0
Lower Portrush						
AW504579	Third Creek @ Forsyth Grove	16/7/1996	–	Yes	284622.0	6136678.0
Holbrooks Road						
AW504529	Torrens River @ Holbrooks Road	7/2/1978	–	Yes	276046.0	6133796.0

H. WATER SUPPLY INFRASTRUCTRE WATER QUALITY MONITORING

Location	Frequency	Site number	Site type	Parameters		
Upper Torrens						
Mannum Summit — Millbrook Tap	Weekly	2078	Major pipeline key operational location	Temperature Chlorine	Coliforms	E Coli
Mannum Summit Storage Tank	Nominated day, week and month	2077	Major pipeline open storage	Odour Turbidity Colour Dissolved organic carbon	Phosphorus Ammonia Nitrate	Nitrite TKN FILT reactive phosphorus
Millbrook Reservoir Intake Channel @ U/S Millbrook Reservoir	Continuous	AW5045 08	Water supply system	TDS Suspended solids	Conductivity Phosphorus	Nitrogen
Millbrook Reservoir Gumeracha Weir	Nominated day, week and month	1630	Indirect storage other location	Algal enumeration Chlorophyll Cryptosporidium	Giardia Organochlorine	Organophosphorus and Triazine Temperature
Millbrook Reservoir Location 1	Nominated day, week and month	1301	Service Reservoir Offtake @ Surface	Algal enumeration Ammonia Chlorophyll Coliforms Colour Conductivity Dissolved organic carbon	DO E Coli FILT reactive phosphorus Iron Manganese Nitrate Nitrite	Phosphorus TDS Temperature TKN Turbidity
Millbrook Reservoir Location 1 @ 10 m Depth	Nominated day, week and month	1302	Service Reservoir Offtake @ Depth	Algal enumeration Colour DO	Iron Manganese	Temperature Turbidity
Millbrook Reservoir Location 1 @ 20 m Depth	Nominated day, week and month	1303	Service Reservoir Offtake @ Depth	Algal enumeration Colour DO	Iron Manganese	Temperature Turbidity
Millbrook Reservoir Location 4	Nominated day, week and month	1304	Service Reservoir Other Location	Algal enumeration		

Location	Frequency	Site number	Site type	Parameters		
Millbrook Reservoir Location 5	Nominated day, week and month	1305	Service Reservoir Other Location	Algal enumeration		
Millbrook Reservoir Location 6	Nominated day, week and month	1306	Service Reservoir Other Location	Algal enumeration		
Millbrook Reservoir Location 7	Nominated day, week and month	1307	Service Reservoir Other Location	Algal enumeration		
Kangaroo Creek Reservoir Location 1	Nominated day, week and month	1321	Indirect storage offtake at surface	Algal enumeration Ammonia Chlorophyll Colour Cryptosporidium Dissolved organic carbon DO	FILT reactive phosphorus Giardia Iron Manganese Nitrate Nitrite Organochlorine	Organophosphorus and Triazine Phosphorus Temperature TKN Turbidity
Kangaroo Creek Reservoir Location 1 @ 10 m Depth	Nominated day, week and month	1322	Indirect storage offtake at depth	Algal enumeration Chlorophyll Colour	DO Iron	Manganese Turbidity
Kangaroo Creek Reservoir Location 1 @ 30 m Depth	Nominated day, week and month	1323	Indirect storage offtake at depth	Algal enumeration Chlorophyll Colour	DO Iron	Manganese Turbidity
Lower Torrens						
Hope Valley Reservoir Gorge Weir	Nominated day, week and month	1615	Inlet to Service Reservoir	Algal enumeration Chlorophyll Cryptosporidium	Giardia Organochlorine	Organophosphorus and Triazine Temperature
Hope Valley Reservoir Location 1	Nominated day, week and month	1361	Service Reservoir Other Location	Algal enumeration		
Hope Valley Reservoir Location 4	Nominated day, week and month	1364	Service Reservoir Other Location	Algal enumeration		
Hope Valley Reservoir Location 5	Nominated day, week and month	1365	Service Reservoir Other Location	Algal enumeration		

Location	Frequency	Site number	Site type	Parameters		
Hope Valley Reservoir Location 6	Nominated day, week and month	1366	Service Reservoir Other Location	Algal enumeration		
Hope Valley Reservoir Location 9	Nominated day, week and month	1369	Service Reservoir Offtake @ Surface	Algal enumeration	DO	Phosphorus
				Ammonia	E coli	TDS
				Chlorophyll	FILT reactive phosphorus	Temperature
				Coliforms	Iron	TKN
				Colour	Manganese	Turbidity
				Conductivity	Nitrate	
				Dissolved organic carbon	Nitrite	
Hope Valley Water Filtering Plant Inlet	Nominated day, week and month	1101	Water treatment plant inlet	Manganese	Alkalinity	Magnesium
				Dissolved organic carbon	Bicarbonate	Mercury
				Lead	Cryptosporidium	Silver
				Chloride	Organophos and Triazine	Aluminium
				TKN	Organochlorine	Tin
				Temperature	pH	Boron
				Sodium	Ion Balance	Conductivity
				Sulphate	Ammonia	Selenium
				Chromium	Colour	E coli
				Carbonate	MIB (cyanobacteria)	TDS
				Phosphorus	Odour	Coliforms
				Cadmium	Giardia	DO
				Carbon dioxide	Fluoride	Nickel
				FILT reactive phosphorus	Copper	Beryllium
				Iron	Antimony	Molybdenum
				Potassium	Turbidity	Iodide
				Arsenic	Nitrate	Cyanide
				Calcium	Nitrite	Barium

I. WATER QUALITY PARAMETERS MEASURED IN THE TORRENS CATCHMENT

Sub-catchment	Site number	Site name	Parameters	Dates ad hoc monitoring occurred
Upper Torrens				
Mount Pleasant	AW504512	Torrens River @ Mount Pleasant	Water Level Stream discharge Temperature TDS pH DO Conductivity	
Gumeracha	AW504500	Torrens River @ Gumeracha Weir	Water level Stream discharge Temperature TDS pH DO Conductivity	
Kersbrook Creek	AW504525	Kersbrook Creek @ U/S Millbrook Reservoir	Water level Water temperature TDS pH DO Conductivity	
	AW504508	Millbrook Reservoir Intake Channel @ U/S Millbrook Reservoir	Water level Stream discharge Water temperature TDS pH DO Conductivity	
Cudlee Creek	AW504524	Cudlee Creek @ Cudlee Creek	Water level Water temperature TDS pH DO Conductivity	
Sixth Creek	AW504523	Sixth Creek @ Castambul	Water level Stream discharge Water temperature TDS pH DO Conductivity	
Gorge Weir	AW504501	Torrens River @ Gorge Weir	TDS pH Conductivity	

Sub-catchment	Site number	Site name	Parameters	Dates ad hoc monitoring occurred
Lower Torrens				
First Creek Rural	AW504517	First Creek @ Waterfall Gully	Water level Stream discharge Water temperature TDS pH DO Conductivity	
Hope Valley Reservoir	AW504571	Samuel Lake @ Athelstone	TDS Conductivity	
	AW504570	Samuel Creek @ Athelstone	TDS Conductivity	
	AW504569	Bradley Lake @ Athelstone	TDS Conductivity	
	AW504568	Bradley Creek @ Athelstone	TDS Conductivity	
Holbrooks Road	AW504513	Torrens River @ City Weir	Water temperature DO	
	AW504529	Holbrooks Road	Water level Stream discharge Water temperature TDS pH DO Conductivity	

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

GLOSSARY

Ambient water monitoring — All forms of monitoring conducted beyond the immediate influence of a discharge pipe or injection well, and may include sampling of sediments and living resources.

ANZECC — Australia New Zealand Environmental Consultative Council.

Aquatic community — An association of interacting populations of aquatic organisms in a given water body or habitat.

Aquatic ecosystem — The stream channel, lake or estuary bed, water, and/or biotic communities, and the habitat features that occur therein.

Aquatic habitat — Environments characterised by the presence of standing or flowing water.

Aquifer — A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

AusRivAS — Australian River Assessment System. A national river and stream health assessment program run by the Australian Government.

AWQC — Australian Water Quality Centre.

Bioassessment — An evaluation of the biological condition of a water body by using biological surveys and other direct measurements of a resident biota in surface water.

Biological integrity — Functionally defined as the condition of the aquatic community that inhabits unimpaired water bodies of a specified habitat as measured by community structure and function.

Biomonitoring — The measurement of biological parameters in repetition to assess the current status and changes in time of the parameters measured.

BoM — Bureau of Metrology, Australia.

Catchment — The land area that drains into a stream, river, lake, estuary, or coastal zone.

Compliance monitoring — A type of monitoring done to ensure the meeting of immediate statutory requirements, the control of long-term water quality, the quality of receiving waters as determined by testing effluents, or the maintenance of standards during and after construction of a project.

Contaminant — A material added by humans or natural activities that may, in sufficient concentrations, render the environment unacceptable for biota. The mere presence of these materials is not necessarily harmful.

Data comparability — The characteristics that allow information from many sources to be of definable or equivalent quality, so that this information can be used to address program objectives not necessarily related to those for which the data were collected. These characteristics need to be defined but would likely include detection limit precision, accuracy, bias, and so forth (ITFM/Data Methods Collection Task Group).

DES — Drillhole Enquiry System. A database of groundwater wells in South Australia, run by DWLBC.

DEH — Department for Environment and Heritage, South Australia.

DHS — Department of Human Services, South Australia.

Diversity — The distribution and abundance of different kinds of plant and animal species and communities in a specified area.

Dryland salinity — The process whereby salts stored below the surface of the ground are brought close to the surface by the rising watertable. The accumulation of salt degrades the upper soil profile, with impacts on agriculture, infrastructure and the environment.

DO — Dissolved Oxygen.

DOC — Dissolved Organic Carbon.

DWLBC — Department of Water, Land and Biodiversity Conservation, South Australia.

EC — Electrical Conductivity.

Ecological indicators — Plant or animal species, communities, or special habitats with a narrow range of ecological tolerance. For example, in forest areas, such indicators may be selected for emphasis and monitored during forest plan implementation because their presence and abundance serve as a barometer of ecological conditions within a management unit.

Ecosystem — A system that is made up of a community of animals, plants, and bacteria, and its interrelated physical and chemical environment.

Effectiveness monitoring — Documents how well the management practices meet intended objectives for the riparian area. Monitoring evaluates the cause and effect relations between management activities and conditions of the riparian-dependent resources. Terrestrial and instream methods constitute monitoring that evaluates and documents the total effectiveness of site-specific actions.

Emerging environmental problems — Problems that may be new and/or are becoming known because of better monitoring and use of indicators.

Environmental water requirement — The water regimes needed to sustain the ecological values of water-dependent ecosystems, including their process and biological diversity.

EPA — Environment Protection Authority, South Australia.

Estuarine habitat — Tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean and in which ocean water is at least occasionally diluted by freshwater run-off from the land.

FC — Faecal Colliform.

FIB — Faecal Indicator Bacteria.

Fixed-station monitoring — The repeated long-term sampling or measurement of parameters at representative points for the purpose of determining environmental quality characteristics and trends.

FS — Faecal streptococci.

GIS — Geographic Information Systems. A computerised system for combining, displaying, and analysing geographic data. GIS produces maps for environmental planning and management by integrating physical and biological information (soils, vegetation, hydrology, living resources, etc.), and cultural information (population, political boundaries, roads, bank and shoreline development, etc.).

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground.

Habitat — (1) A place where the physical and biological elements of ecosystems provide a suitable environment, and the food, cover, and space resources needed for plant and animal existence. (2) The physical–chemical theatre in which the ecological play takes place; it is a template for the biota, their interactions, and their evolution.

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of the aquifers.

Impact — A change in the chemical, physical, or biological quality or condition of a water body caused by external sources.

Impairment — A detrimental effect on the biological integrity of a water body caused by impact that prevents attainment of the designated use.

Implementation monitoring — Documents whether or not management practices were applied as designed. Project and contract administration is a part of implementation monitoring.

Indigenous species — A species that originally inhabited a particular geographic area.

MDBC — Murray–Darling Basin Commission.

Metadata — Information that describes the content, quality, condition, and other characteristics of data (Federal Geographic Data Committee).

Method comparability — The characteristics that allow data produced by multiple methods to meet or exceed the data quality objectives of primary or secondary data users. These characteristics need to be defined but would likely include data quality objectives, bias, precision, information on data comparability, etc.

Monitoring — (1) The repeated measurement of parameters to assess the current status and changes over time of the parameters measured. (2) Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals, and other living things.

NATA — National Association of Testing Authorities.

Native species — Any animal and plant species originally in Australia.

NLWRA — National Land and Water Resource Audit.

Non-point-source pollution — A contributory factor to water pollution that cannot be traced to a specific location. For example, pollution that results from water run-off from urban areas, construction sites, agricultural and silvicultural operations, etc.

OBSWELL — Observation Well Network.

OCWMB — Onkaparinga Catchment Water Management Board.

P —- Phosphorus.

Perennial streams — Permanently inundated surface stream courses. Surface water flows throughout the year except in years of infrequent drought.

PIRSA — Department of Primary Industries and Resources, South Australia.

Point-source pollution — Pollution discharged through a pipe or some other discrete source from municipal water treatment plants, factories, confined animal feedlots, or combined sewers.

Population — (1) For the purposes of natural resource planning, the set of individuals of the same species that occurs within the natural resource of interest. (2) An aggregate of interbreeding individuals of a biological species within a specified location.

Potable — Water that is fit to drink.

Prescribed water resource — A water resource declared by the Governor of South Australia to be prescribed under the Water Resource Act 1997. Includes undergroundwater to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated by a licensing system.

Prescribed well — A well declared to be a prescribed well under the Water Resource Act 1997. See also Prescribed water resource.

PWA — Prescribed Wells Area.

RCT — Resource Condition Targets.

Reticulated water — Water supplied through a piped distribution system.

Riparian — Of, pertaining to, or situated or dwelling on the bank of a river or other water body.

Riparian areas — Geographically delineable areas with distinctive resource values and characteristics that compose the aquatic and riparian ecosystems.

Riparian-dependent resources — Resources that owe their existence to a riparian area.

Riparian ecosystems — A transition between the aquatic ecosystem and the adjacent terrestrial ecosystem; these are identified by soil characteristics or distinctive vegetation communities that require free or unbound water.

Riparian habitat — The transition zone between aquatic and upland habitat. These habitats are related to and influenced by surface or subsurface waters, especially the margins of streams, lakes, ponds, wetlands, seeps, and ditches.

Riverine habitat — All wetlands and deep-water habitats within a channel, with two exceptions — wetlands dominated by trees, shrubs, persistent emergent mosses or lichens, and habitats with water that contains ocean-derived salt in excess of 0.5 parts per thousand.

SA Water — South Australian Water Corporation.

SOP — Standard operating procedure.

Sub-catchment — The area of land determined by topographical features within which rainfall will contribute to run-off at a particular point.

Surface water — Water flowing over land (except in a watercourse), (1) after having fallen as rain or hail or having precipitated in any other manner; or (2) after rising to the surface naturally from underground; or (3) water of the kind that has been collected in a dam or reservoir.

SWMCC — State Water Monitoring Coordination Committee.

TDS — Total Dissolved Solids. A measure of water salinity (in mg/L).

Tertiary aquifer — A term used to describe a water-bearing rock formation deposited in the Tertiary geological period (1–70 million years ago).

Threatened species — Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

TKN — Total Kjeldahl Nitrogen.

TN — Total Nitrogen.

Toxic — Relating to harmful effects to biota caused by a substance or contaminant.

TP — Total phosphorus.

USGS — United States Geological Survey.

Water allocation — In respect of water licensing, is the maximum quantity of water that a licensee is entitled to take and use pursuant to an authorisation under section 11 of the Water Resource Act 1997.

Water Allocation Plan (WAP) — A plan prepared by a Catchment Water Management Board or water resource planning committee and adopted by the Minister in accordance with Division 3, Part 7 of the Water Resource Act 1997.

Water-dependent ecosystems (WDE) — Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground. The in-stream area of rivers, riparian vegetation, springs; wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems.

Water quality criteria — comprised of both numerical criteria and narrative criteria. Numerical criteria are scientifically derived ambient concentrations developed by the EPA (Australian Federal Government) or the states for various pollutants of concern, so that human health and aquatic life can be protected. Narrative criteria are statements that describe the desired water quality goal.

Water quality data — Chemical, biological, and physical measurements or observations of the characteristics of surface and groundwaters, atmospheric deposition, potable water, treated effluents, and waste water, and of the immediate environment in which the water exists.

Water quality information — Derived through analysis, interpretation, and presentation of water quality and ancillary data.

Water quality monitoring — An integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions, and designated water uses.

Water quality standard — A law or regulation that consists of the beneficial designated use or uses of a water body, the numerical and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Water resource monitoring — An integrated activity for evaluating the physical, chemical, and biological character of water resources, including: (1) surface waters, groundwaters, estuaries, and near-coastal waters; and (2) associated aquatic communities and physical habitats, which include wetlands.

Water resource quality — (1) The condition of water or some water-related resource as measured by biological surveys, habitat-quality assessments, chemical-specific analyses of pollutants in water bodies, and toxicity tests. (2) The condition of water or some water-related resource as measured by habitat quality, energy dynamics, chemical quality, hydrological regime, and biotic factors.

Wetlands — Habitat that is transitional between terrestrial and aquatic where the watertable is usually at or near the land surface, or land that is covered by shallow water. Wetlands have one or more of the following characteristics: at least periodically, the land supports predominantly hydrophytic plants; the substrate is predominantly undrained hydric soil; the substrate is nonsoil and is saturated with water or covered by shallow water at sometime during the yearly growing season.

WMLR — Western Mount Lofty Ranges.

REFERENCES

Baldwin, DS, Nielsen, DL, Bowen, PM & Williams, J 2005, *Recommended methods for monitoring floodplains and wetlands,* MDBC Publication 72/04, Murray-Darling Basin Commission, Canberra.

Binks, W 2004, *Mount Lofty Ranges irrigation evaluation.* Final project report, for Rural Solutions SA.

Boulton, AJ, Humphreys, WF & Eberhard, SM 2003, 'Imperilled subsurface waters in Australia: biodiversity, threatening processes and conservation', *Aquatic Ecosystem Health and Management,* 6, pp. 41-54.

Brydges, T 2004, 'Basic concepts and applications of environmental monitoring', in GB Wiersma, (ed.), *Environmental monitoring,* CRC Press, pp. 83-110.

Chessman, BC 1986, 'Dietary studies of aquatic insects from two Victorian rivers', *Australian Journal of Marine and Freshwater Research,* 37, pp. 129-46.

Chessman, BC 1995, 'Rapid assessment of rivers using macro-invertebrates: a procedure based on habitat-specific sampling, family level identification and a biotic index', *Australian Journal of Ecology,* 20, pp. 122-129.

DEH 2004, *Department for Environment and Heritage Annual Report 2003–04,* Department for Environment and Heritage, Adelaide.

DWLBC 2004, *Department of Water, Land and Biodiversity Conservation Annual Report 2003–04,* Department of Water, Land and Biodiversity Conservation, Adelaide.

Department for Water Resources, 2000, *State Water Plan 2000,* Adelaide.

Downes, BJ, Barmuta, LA, Fairweather, PG, Faith, DP, Keough, MJ, Lake, PS, Mapstone, BD & Quinn, GP 2002, *Monitoring ecological impacts: concepts and practice in flowing water,* Cambridge University Press, New York.

EPA 2003, *Environment Protection Authority Annual Report 2002–2003, a review* (unpublished).

EPA 2005, *Environment Protection Authority water quality monitoring programs* (unpublished report).

Finlayson, CM & Mitchell, DS 1999, *'Australian wetlands: the monitoring challenge',* Wetlands Ecology and Management, 7, pp. 105-112.

Gilbert, J & Deharveng, L 2002, *'Subterranean ecosystems: a truncated functional biodiversity',* BioScience, 52, pp. 473-481.

Gordon, N, McMahon, T & Finlayson, B 2000, *Stream hydrology: an introduction for ecologists,* John Wiley and Sons, Chichester.

Greenwood, AG 2001, *Surface water monitoring review, Volume 1: The Mount Lofty Ranges,* Department of Water Resources, South Australia (unpublished report).

Harris, JH 1995, *'The use of fish in ecological assessments',* Australian Journal of Ecology, 20, pp. 65-80.

Heneker, T 2003, *Surface water assessment of the Upper River Torrens,* Report DWLBC 2003/24, Department of Water, Land and Biodiversity Conservation, Adelaide.

Hicks, BB and Brydges, TG 1994, *'A strategy for integrated monitoring',* Environmental Management, 18(1), pp. 1-12.

Humphreys, WF 2002, *'Groundwater ecosystems in Australia: an emerging understanding',* Proceedings of the International Association of Hydrogeologists Conference, Darwin, 2002, pp. 1-14.

Kneebone, J 2000, *State Water Monitoring Review: Monitoring Partnerships Paper,* Environment Protection Agency, Adelaide.

Lake, PS 1982, *'Ecology of macro-invertebrates of Australian upland streams — review of current knowledge',* Bulletin of the Australian Limnological Society, 8, pp. 1-16.

Lopez, C & Dates, G 1998, *'The efforts of community volunteers in assessing watershed ecosystem health',* in D Rapport, R Costanza, PR Epstein, C Gaudet and R Levins (Eds), Ecosystem Health, Blackwell Science, Malden, MA, pp. 103-128.

MacDonald, LH, Smart, AW & Wissmar, RC 1991, *Monitoring guidelines to evaluate effects of forestry activities on stream in the Pacific Northwest and Alaska.* EPA-910/9-001, U.S. Environmental Protection Agency, Seattle, Washington.

Marchant, R 1986, *'Some quantitative aspects of the life history of aquatic insects in temperate Australian rivers',* in P de Decker, WD Williams and D Junk (Eds), Limnology in Australia, Dordrecht, CSIRO, Melbourne, pp. 151-158.

Marmonier, P, Vervier, P, Gilbert, J & Dole-Olivier, M-J 1993, *'Biodiversity in groundwaters',* Trends in Ecology and Evolution, 8, pp. 392-395.

MDBC 2004, *Fish theme pilot audit technical report — sustainable rivers audit,* Murray Darling Basin Commission Publication 06/04, Canberra.

OCWMB 2000, *Onkaparinga Catchment Water Management Plan,* 2000.

OCWMB 2004, *Onkaparinga Catchment Water Management Board Annual Report 2004.*

Pearson, RG, Benson, LJ & Smith, REW 1986, *'Diversity and abundance of the fauna in Yuccabine Creek, a tropical rain-forest stream',* in P de Decker, W Williams and D Junk (eds), Limnology in Australia, Dordrecht, CSIRO, Melbourne, pp. 329-342.

Pikusa, E & Bald, M 2005, *'Environmental water provisions from SA Water reservoirs in the Western Mount Lofty Ranges',* Draft DWLBC Report, Department of Water, Land and Biodiversity Conservation.

Reid, MA, Tibby, JC, Penny, D & Gell, PA 1995, *'The use of diatoms to assess past and present water quality',* Australian Journal of Ecology, 20, pp. 57-64.

Saunders, P 1985, *Hydrometric network plan for South Australia,* EWS library ref 85/9, Engineering and Water Supply Department, Adelaide.

SA Water 2003, *South Australian Water Corporation Annual Report 2003.*

TCWMB 2002, *Torrens Catchment Water Management Plan 2002–07.*

Wen, L 2005, *Review of, and recommendations for, water monitoring in Eyre Peninsula NRM Region,* Report DWLBC 2005/38, Department of Water, Land and Biodiversity Conservation, Adelaide.

Williams, WD 1980, *Australian freshwater life. The Invertebrates of Australian inland waters,* McMillan, Melbourne.