DWLBC REPORT

Water Monitoring Review for the Kangaroo Island Natural Resource Management Region

2006/16

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

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Li Wen

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Department of Water, Land and Biodiversity Conservation

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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

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EXECUTIVE SUMMARY

Water resources in the Kangaroo Island Natural Resource Management (KINRM) Region are managed to provide water for domestic, agricultural and horticultural, and industrial use while maintaining the environmental values of water-dependent ecosystems. This monitoring review represents a first step in the development of a coordinated regional monitoring program for the water resources of Kangaroo Island, and is based on a desktop review of the current situation.

The review covers information on six themes — resource data, surface water quantity, surface water quality, groundwater quantity, groundwater quality, aquatic ecosystems and catchment characteristics. These themes are convenient divisions of the total resource for the purpose of monitoring and fit the current division of responsibilities between agencies. However, these divisions should be used to aid the development of operations that view water resources as an integrated set of interacting components, and not as isolated resources to be managed individually.

Monitoring, evaluation and reporting of water resources in the KINRM Region are currently fragmented both within and between government agencies and community based organisations. There is no coordinated plan for an integrated monitoring strategy, and limited communication or exchange of data exists 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 KINRM Region, but to varying spatial and temporal scales, and with varying frequencies. Subsequently, the following shortcomings are identified:

- The majority of the components of the hydrological cycle are inadequately (spatially and temporally) monitored to allow the development of catchment-based hydrological models, although some baseline data and information were collected for six key catchments through the Rivers of Life Project (ROL). These components include water levels or streamflow, evaporation, soil moisture, water use, and surface water – groundwater interactions.
- Assessment of the impacts of natural resource management actions on water resources is limited by three factors:
  - lack of water balance data for most of the catchments, primarily due to a lack of stream-gauging stations in appropriate locations
  - errors, gaps and breaks in the major current databases
  - deficiency of systemic and/or long-term ambient water quality data.

Clear direction is required to ensure that monitoring programs:

- Fulfil the basic requirements of the National Monitoring and Evaluation Framework and National Water initiative.
- 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 natural resource management.

- Satisfy the requirements for regional resource conditions assessment and management.
- Satisfy the requirements under the State Environment Protection Act.

Several actions are proposed to provide a future path for an integrated monitoring network. These directions are intended to guide the development of future monitoring programs to a greater level of integration and efficiency; however, implementation of the actions will be subject to priorities and budgets of individual stakeholder organisations.

STRATEGIC DIRECTIONS

The following table summarises the strategic directions, and the responsible agencies and organisations are identified. Please be aware that some of the actions are already being initiated by relevant agencies.

Issues	Actions	Agency or organisation
Data and information management		
Errors and breaks in current databases	• Review of standard methods and standard operating procedure.	**DWLBC, EPA, BoM, SA Water, DEH, KINRMB**
Limited or no coordination between monitoring programs	• Develop a water monitoring review process.	**SWMCC**
	• Create and implement a communication plan.	**SWMCC**
	• Define the major state level monitoring networks, including create and manage a logical linkage between monitoring programs.	**SWMCC**, DWLBC, EPA, BoM, SA Water, DEH
	• Establish the linkage between state monitoring networks and KINRMB monitoring and evaluation requirements.	**KINRMB**, DWLBC, EPA, SA Water, BoM, DEH, PIRSA
No real effort has been made to organise data collected by various agencies and make it available in an integrated way	• Develop a data and information clearing house.	**SWMCC**
	• Develop metadata standards.	
	• Prepare a geographically based reference compilation.	
Surface water		
Uncompleted stream-gauging stations spatial coverage	• Establish stream-gauging stations in key catchments.	**DWLBC**, KINRMB
	• Establish water level monitoring in aquatic ecosystems of significant environmental values, e.g. Murray Lagoon, Pelican Wetland System.	**KINRMB**, DWLBC, DEH
Rainfall monitoring biased at catchments with steep topography	• Establish rain gauges at key locations.	**DWLBC**, BoM, KINRMB, EPA, DEH, PIRSA
Deficiency of long-term ambient water quality data	• Incorporate auto-samplers, dissolved oxygen (DO) and pH probes with the current and future gauges.	**DWLBC**, KINRMB
	• Review EPA's Ambient Water Quality Monitoring Program (AWQMP).	**EPA**, DWLBC, KINRMB
	• Conduct special studies.	**KINRMB**, EPA, DEH, DWLBC

Issues	Actions	Agency or organisation
Inadequate parameters	• Analyse historical evaporation data from BoM to picture evaporation pattern across the region.	**KINRMB**, DWLBC, BoM
	• Update farm dam map annually and register farm dams.	**KINRMB**, DWLBC, PIRSA
	• Incorporate soil moisture monitor with existing evaporation monitoring site.	**KINRMB**, DWLBC, BoM, PIRSA
	• Establish urban stormwater and effluent monitoring in major towns, especially in Kingscote.	**KINRMB**, SA Water, DWLBC
	• Establish link between surface and groundwater.	**DWLBC**, KINRMB, SA Water, PIRSA
Groundwater		
Inadequate water level monitoring of the fractured rock aquifer	• Establish new observation wells.	**DWLBC**, KINRMB
No water level monitoring of the Bridgewater Formation aquifers	• Establish new observation wells.	**DWLBC**, KINRMB
Fragmented coverage for water quality monitoring	• Incorporate water quality monitoring with current and future water level observation wells.	**DWLBC**, EPA, KINRMB
Water quality monitoring current limited to salinity	• Include basic water quality variables such as nutrients, pesticides, ions in water quality monitoring.	**EPA**, DWLBC, KINRMB, DEH
No groundwater use information	• Establish database for private wells.	**KINRMB**, DWLBC
Aquatic ecosystem		
Baseline data need to be updated	• Mapping all groundwater and surface water dependent ecosystems.	**KINRMB**, DWLBC, DEH

Issues	Actions	Agency or organisation
Monitoring methodology is yet to be developed (especially for saline wetlands)	• Develop conceptual aquatic ecosystem models for the main types of ecosystem.	**DWLBC**, DEH, EPA, KINRMB
	• Conduct case research to:	**DWLBC**, DEH, KINRMB, EPA
	○ determine what monitoring information is required to inform acceptable impacts of changes	KINRMB, DWLBC, EPA, DEH
	○ study the drivers that cause ecosystem changes, e.g. rainfall, groundwater table declination	
	○ identify key indicators	
	○ understand the responses of the key ecosystem components to ecosystem changes.	
	• Design an integrated aquatic ecosystem monitoring program.	**KINRMB**, DWLBC, EPA, DEH
	• Include WDE in the broad state water resource monitoring program.	**DWLBC**, EPA, KINRMB
Catchment characteristics		
The link between land and water resource conditions is yet to be established	• Conduct catchment-scale study.	**DWLBC**, KINRMB

1. Leading agency or organisation is highlighted in bold.
2. The Responsible agency or organisation is decided based on the systemic model in section 3.4.
3. Natural Resource Management Board (NRMB) and Catchment Water Management Board (CWMB) are NOT distinguished in this table and throughout the report. The roles and responsibilities of NRMB also apply to CWMB.
4. SWMCC will be replaced by the State Natural Resource Monitoring, Evaluation, and Reporting Policy Group.

1. INTRODUCTION

1.1 BACKGROUND

Water resource monitoring is the linchpin for many management activities regarding water allocation, water quality, and aquatic ecosystem health. Water quality data, for example, are crucial for determining whether waters meet the state's standards, and could therefore potentially be the focus of expensive cleanup actions.

Similarly, decision makers need reliable and comprehensive data on the quantity of the nation's water resources to support increasingly important and contentious decisions about how to allocate limited water resources among states and among a variety of competing uses. Figure 1 depicts this relationship, showing that monitoring is essential to identifying water resource issues and determining whether actions taken to address the problems have been successful. The four fundamental functions of monitoring are:

1. Increasing the knowledge and information base about water resources.
2. Describing the status and trends (so called Status and Trend Monitoring).
3. Verifying whether certain standards are met (Compliance Monitoring).
4. Evaluating water resource management (Evaluation monitoring).

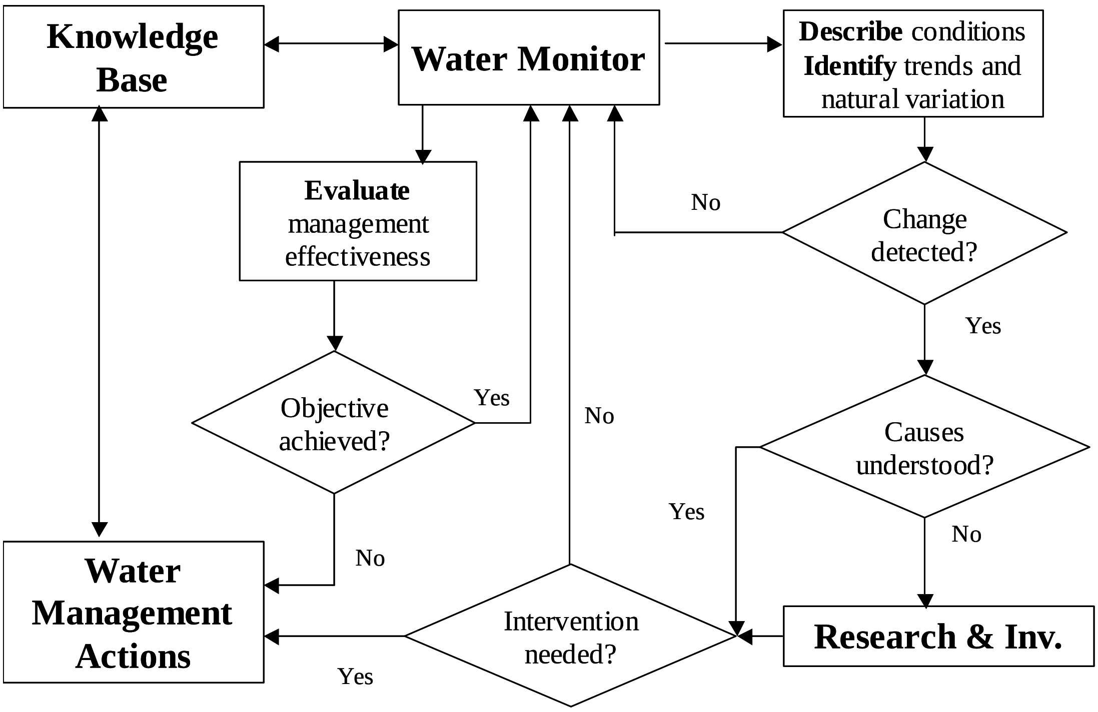

Figure 1. Functions of water monitoring in the framework of water resource management.

The prosperity of Kangaroo Island (KI) is inextricably linked with the wise and sustainable use of the region's water resources. As indicated in the *State Water Plan* (Volume 2, DWR 2000) and *Integrated Natural Resource management Plan for Kangaroo Island* (KINRMB 2004), the maintenance of water quality and quantity are important issues for the region. Chemical, biological and physical contaminations are identified impediments to the achievement of water quality objectives for the region, and sustainability is not necessarily assured under current management regimes. It is therefore crucial that these resources are protected and used in a sustainable manner.

However, information on the volume and quality of the island's water resources and their use is incomplete. In some areas, available data is minimal and/or uncertain, and long-term trends are unclear, resulting in planning difficulties. Establishing a network of integrated water monitoring programs covering the full spectrum of water resources was recognised as a cornerstone of natural resource management, and listed as a key action by the KI Natural Resource Management Board (KINRMB).

A number of public and private organisations are currently involved in collecting data to monitor the condition of the region's waters, raising the question as to whether more efficient coordination of the data collection efforts can result in timely, reliable, and completed data for better-informed decision making.

The State Water Monitoring Review was initiated in 2000 to develop an efficient, integrated water monitoring network in each major region and catchment across South Australia, and is being overseen by the State Water Monitoring Coordinating Committee (SWMCC). The Department of Water, Land and Biodiversity Conservation (DWLBC) has undertaken this review on behalf of KINRMB, and is dedicated towards developing an integrated water monitoring strategy for surface water and groundwater resources and water-dependent ecosystems of KI.

1.2 DEFINITIONS AND SCOPE

To identify improvements needed to support more effective decision-making, the review broadly defined monitoring functions. Table 1 lists the consensus definitions for water resources, monitoring functions, and the purposes of water monitoring adopted by the review.

This report addresses the full range of water resources within the KI region, which includes ground and surface waters, and fresh and marine environments. Six water monitoring themes are covered:

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

Table 1. Key definitions of water monitoring adopted in this review.

Water resources	Surface and ground waters, estuaries, and near-coastal waters. Rain water, storm water and treated effluents, saline or sea water. Associated aquatic communities and physical habitats include wetlands.
Water resources data	Physical, which includes quantity (water level, flow, discharge, etc.), timing, duration and frequency. Water quality parameters. Biological and ecological. Associated data, including habitat, land use, demographics, contaminant discharges, and other 'ancillary' information, such as atmospheric deposition.
Monitoring program activities	Identifying and documenting program goals and purposes. Designing and planning monitoring programs. Coordinating and collaborating with other monitoring agencies. Selecting water resource indicators. Locating appropriate monitoring sites. Selecting data collection methods. Collecting field observations and samples. Analysing samples in laboratories. Developing and operating quality assurance programs. Storing, managing and sharing data. Interpreting and assessing data. Reporting and distributing monitoring results. Evaluating the effectiveness of monitoring programs.
Purposes of monitoring	Assessing status and trends. Characterising and ranking existing and emerging problems. Designing and implementing programs and projects. Evaluating program and project effectiveness. Responding to emergencies.

1.3 PROJECT OUTLINE

1.3.1 OBJECTIVES

The overall purpose of this project is to suggest possible approaches to coordinate and improve monitoring on the Kangaroo Island Natural Resource Management (KINRM) Region. The project aims to meet the following specific objectives:

- Establishing detailed monitoring requirements for key stakeholders.
- Developing an understanding of current water resource data collection and analysis programs and capabilities.
- Evaluating the effectiveness of suggestions for standardisation of existing water resource data collection and analysis programs.

- Identifying data and information gaps, which need to be addressed in order to support critical water management decisions.
- Analysing the information gathered to highlight possible commonalities between requirements.
- Identifying key definitions that may be subject to interpretation, and may therefore present possible barriers to harmonisation.
- Proposing ways of harmonising monitoring requirements to avoid duplication, and improve cost-effectiveness.

1.3.2 METHODOLOGY

With the ultimate goal of an integrated and coordinated water monitoring strategy for the KINRM Region, the review was divided into three stages (Fig. 2):

1. background research on stakeholder business requirements and board monitoring needs
2. assessment of existing monitoring networks
3. future directions towards an integrated and coordinated monitoring strategy.

Each stage involved a series of tasks, and is briefly described below.

1.3.2.1 Stage One: Background Research

- Each of the key stakeholders represented on the State Water Monitoring Coordinating Committee identified a series of business needs based on their planning requirements (Kneebone 2000). However, in South Australia, a reform process is currently underway for natural resource management. As a result, the roles and responsibilities of some organisations and state government agencies will change. While some of the detail for the implementation of future natural resource (including water resources) monitoring and evaluation programs will be affected, the fundamental principles are assumed to remain the same.
- Key water resource issues specified in KINRMB (2004) were used to develop water resource condition targets (RCTs). Each of these have a requirement for evaluation, monitoring and reporting as stated in the plan.
- An ideal or systemic conceptual monitoring model, representing all relevant business needs and responsibilities of key stakeholders, was designed. In the model, the following was defined:
    - network coverage and density
    - parameters
    - monitoring frequency
    - the leading organisation
    - data and information sharing mechanisms.

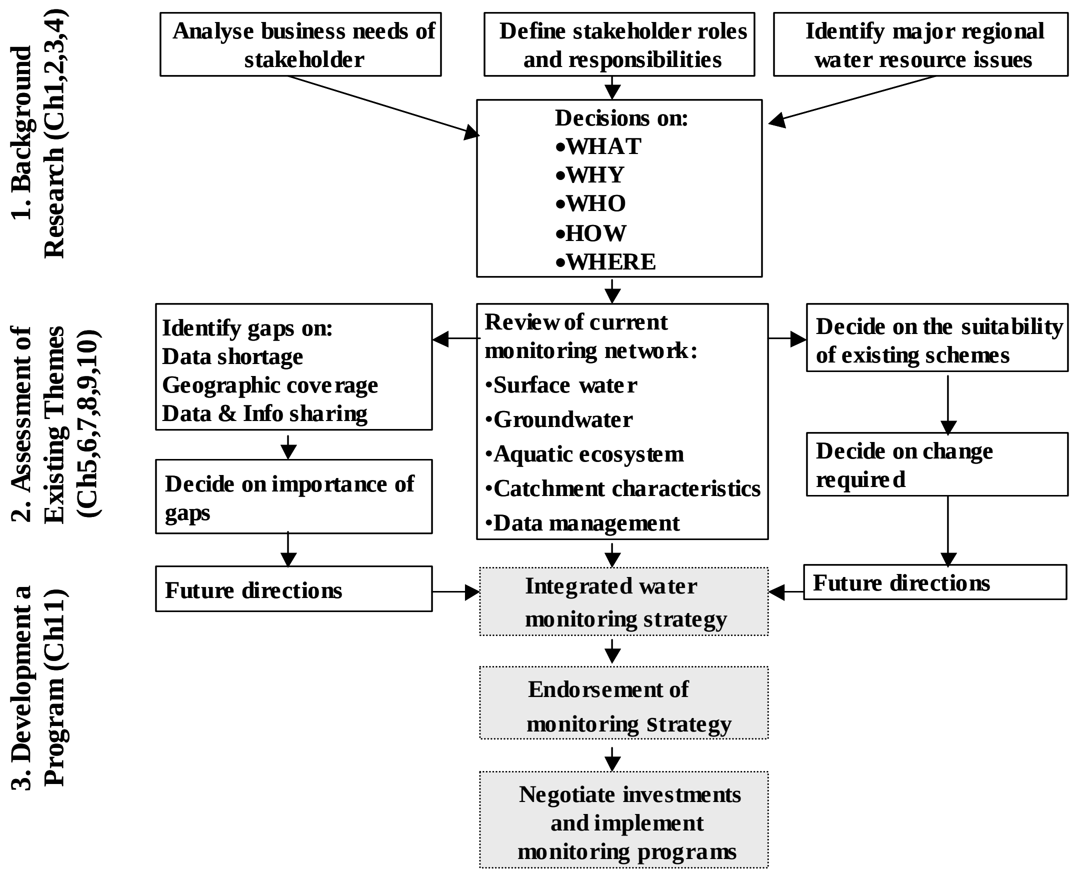

Figure 2. Project plan. The implementation of the last three steps (in shadow) will be dependent on the actions of SWMCC following this report.

1.3.2.2 Stage Two: Assessment of Existing Monitoring Networks

- The current monitoring network includes the existing infrastructure present in the catchment, the database operated and maintained by key stakeholders, and data and information management arrangements (if any).
- Performing an inventory of current monitoring networks; mapping them using geographical information system (GIS) technology.
- By comparing the existing monitoring network with the ideal model, gaps and overlaps are exposed. Gaps to be targeted include:
  - data shortage
  - adequacy of geographic coverage
  - insufficiency of data and information sharing mechanisms.

1.3.2.3 Stage Three: Suggestions for future directions

- Considering regional management priorities, actions are proposed to address each gap.
- Suggestions for an integrated monitoring strategy for KI are proposed.

Depending on feedback received from key stakeholders and the response of SWMCC in deciding on follow-up actions, the next three steps are projected but not covered in the report:

- Based on the actions proposed of the report, an integrated water monitoring strategy for KINRM Region will be developed.
- The SWMCC and regional workshop endorse the strategy, and individual organisation develops monitoring program.
- Communication and negotiation between stakeholders based on the strategy are undertaken to determine the investment priority and cost-sharing arrangement.

1.3.3 PROJECT STEERING GROUP

This project was managed by Caroline Michalski, Manager, Water Monitoring Reviews, DWLBC. The steering group included:

- Patrick O'Connor, Managing Director, O'Connor NRM.
- David Deane, Natural Resource Planner, DWLBC.
- Tom Nelson, Project officer, KINRMB.
- Helen Richard, Executive Officer, KINRMB.

1.3.4 CONSULTATION

Extensive internal and external consultation as part of this review was requested from the following individuals and organisations:

- EPA — David Duncan, Clive Jenkins, Peter Goonan.
- DWLBC — Neil Power, Russell Flavel, Jim Barratt, Scott Evans, Deborah Thomas, Nick Souter, Glen Scholz, Andy Love, Bruce Murdoch, Craig Walker, Karen Parry.
- KINRMB — Colin Willson.
- Bureau of Meteorology (BoM) — Richard Szkup.
- SA Water.
- Department of Environment and Heritage (DEH).
- Department of Human Services (DHS).

2. REGION DESCRIPTION

2.1 GENERAL FEATURES

Kangaroo Island is the third largest island off the coast of Australia, situated 16 km from the tip of South Australia's Fleurieu Peninsula (Fig. 3). Measuring 155 km long and up to 55 km wide, KI has an area of ~4370 km^2, and supports around 4400 people (0.3% of South Australia's population). Kingscote is the principal town, with a population of ~1500 people. Other main towns include Penneshaw, Parndana, and American River.

The KI landscape includes dune limestone and windblown sands on the southern plateau slopes, with hilly uplands on the northern edge of the plateau, which has a significant stream network from which domestic water supplies are collected. The major land use on the western end of the island is the Flinders Chase National Park. Old alluvial floodplains include those of the lower Cygnet River and the Timber and Bugga Bugga Creek Catchments. These are characterised by numerous swamps and lagoons, many of which are now saline.

The island comprises two major geomorphologic regions:

- low-lying eastern plains ~50 m above sea level
- an elevated western plateau with a maximum elevation of ~310 m.

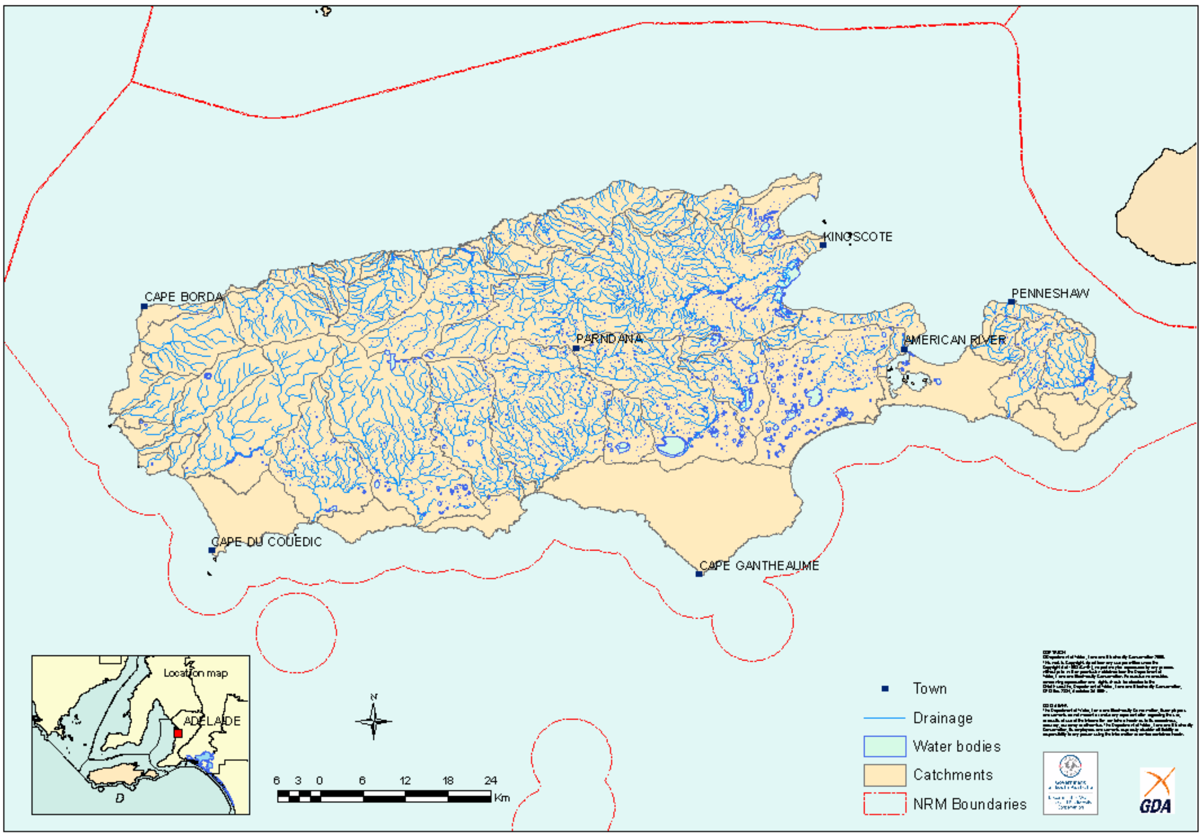

Figure 3. Map of study area — KINRM Region.

Both sections are underlain by Cambrian-aged metasediments of the Kanmantoo Group, which extend into the eastern Mount Lofty Ranges where they are known to form fractured rock aquifers. The contrast in relief between the two regions on KI may be related to the higher metamorphic grade in the west (Preiss 1995), regional deformation and faulting associated with Late Cambrian orogenic activity (Preiss 1995), and glaciation of the eastern section during Permian times (Alley & Bourman 1995).

Soils across the island are the oldest in the Fleurieu Peninsula – Mount Lofty Ranges region, and are usually thin (100–200 mm), overlying a deeply weathered Tertiary-aged relict laterite profile (Northcote & Wright 1983). An indurated, ferruginous pisolitic cap is well developed across the island, particularly on the western plateau which may be an important factor in controlling the shape of the landscape (Hubble & Isbell 1983). Along the south coast, red-brown loamy sands (terra rossa) overlie thick accretions of calcrete similar to those found on Yorke Peninsula (Northcote & Wright 1983).

As a southern offshore island at 33° south, KI experiences a moderate maritime and Mediterranean climate with warm dry summers and cool wet winters. The climate is generally milder than the majority of the adjacent mainland due to the marine influence and low elevations. Highest rainfall is received on the western plateau, which in some areas averages more than 900 mm/y (near Gosse). The 600 mm/y isohyet roughly follows the 120 m topographic contour along the western plateau’s eastern margin. The low-lying eastern sections are drier — the average rainfall is less than 500 mm/y in a rain shadow in the northeast between Shoal Bay and Cygnet River and in the southeast near Pennington Bay.

The island's natural resources underpin a range of industries, dominated by primary production which provides $69 million per year, and tourism which provides $53 million (ABS 2001).

Approximately 50% of the farmland (about 300 farms) is used for dryland agriculture, predominantly sheep for wool and meat, beef, and cropping, but cropping has dramatically increased in recent times. Tourism as an industry has developed to the extent that ~20% of the island's residents are involved in tourism. Emerging industries include freshwater and marine aquaculture ventures, farm and plantation forestry, orchards and horticultural ventures, and seed potatoes.

KI has the highest proportion of native vegetation remaining of any non-arid region in South Australia, with vegetation covering nearly half of the island. More than 30% (~115 000 ha) of the island is protected land, under both Crown and private title. KI is noted for the Flinders Chase National Park and the Seal Bay Conservation Park. An additional 85 000 ha of remnant native bushland exist on privately held land. The region also supports a range of coastal and marine environments.

2.2 CLASSIFICATION OF CATCHMENTS

There are 54 surface water catchments in the KINRM Region. It is necessary to group these catchments to analyse the spatial coverage of monitoring networks, as it is not necessary and practicable to address monitoring catchment by catchment.

A cluster analysis considering catchment features including average topography (slope), average rainfall, drainage density, farm dam density, and major types of land use (Fig. 4) indicates that the catchments can be loosely categorised into four groups (Fig. 5).

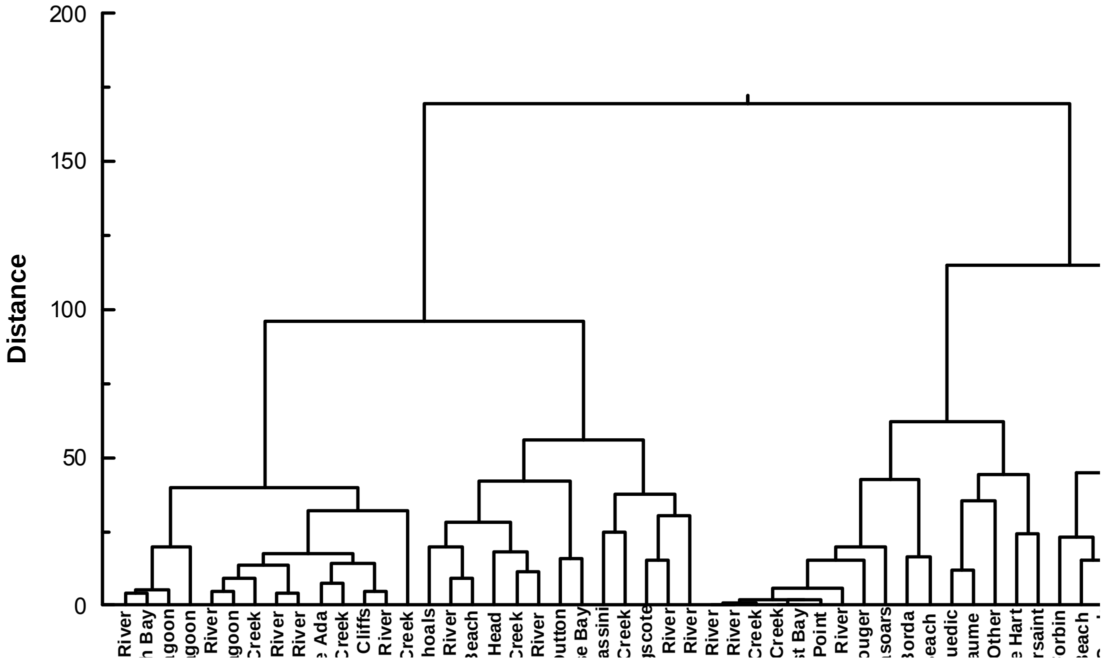

Figure 4. Dendrogram of cluster analysis.

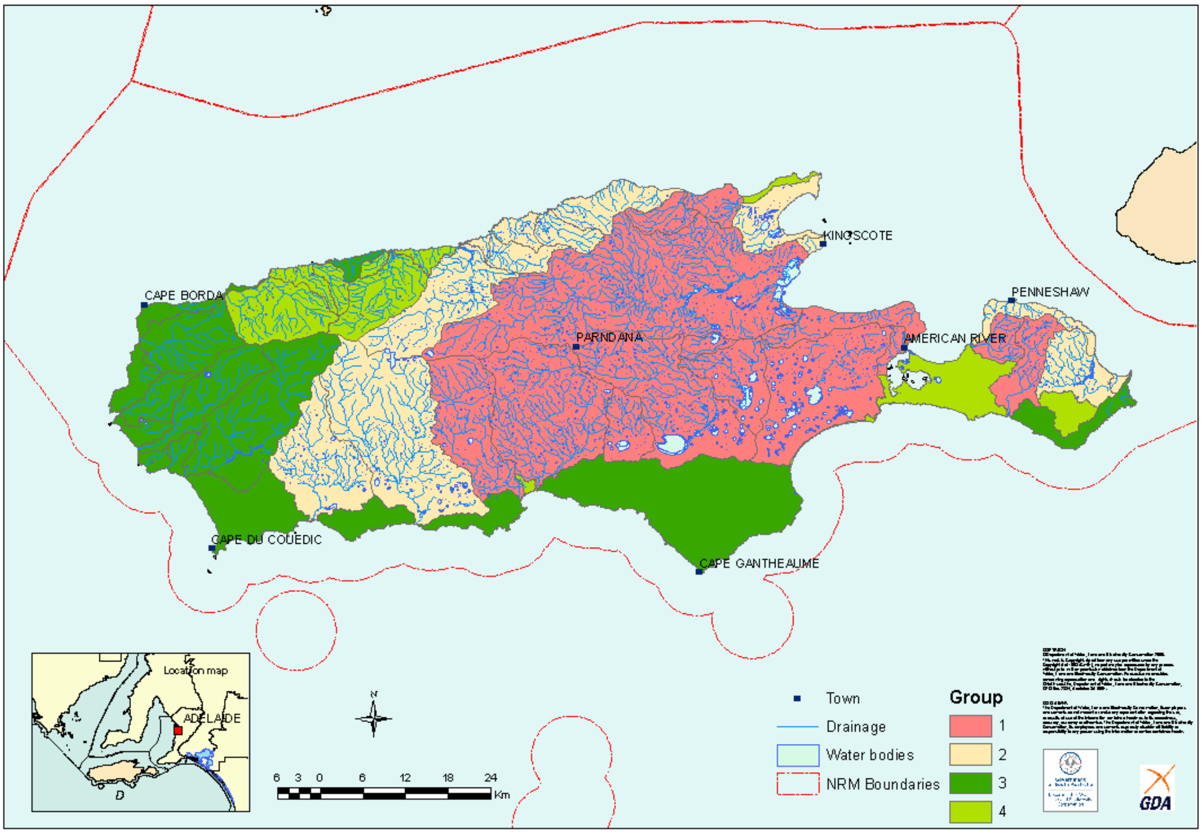

Figure 5. Catchment groups in KI based on cluster analysis.

The analysis of the adequateness of spatial coverage of major current monitoring networks will be based on the classification of catchment assuming the homogeneity of the group.

2.3 WATER RESOURCES

KI's water resources are limited both by quantity and quality. The surface resources are estimated at 16 GL/y, of which less than 1 GL/y is used through SA Water (DWR 2000).

Water resources are required for a variety of enterprises:

- protection of aquatic ecosystems
- dryland and some irrigated agriculture
- aquaculture
- drinking water supplies
- industrial, urban and rural domestic use.

2.3.1 SURFACE WATER RESOURCES

There are over 3000 km of drainage on KI. Most of the rivers form a radial pattern draining the elevated regions of the western plateau to the coast. Streamflows are highly seasonal, with maximum monthly discharges occurring between July and September, usually reaching their greatest volumes in August. In summer, most of the rivers are confined to semi-permanent creeks and waterholes, which become increasingly saline until flushed by break of season rains in April each year. The major rivers include the Cygnet, De Mole, Eleanor, Harriet, Middle, North East, North West, Rocky, Snug Cove, South West, Stunsail Boom, Timber, Wilson, and Western (Fig. 4). The Rocky, Breakneck and North West rivers in the Flinders Chase National Park, and Middle River in the north of the island, are the major freshwater streams. The larger saline waterways include the Cygnet (down stream of Gum Creek), Eleanor and Willson Rivers.

Recorded long-term catchment yields of the western rivers are large compared to other temperate South Australian streams. Mean annual runoff from Rocky River and Middle River are 98 and 152 mm, respectively (NLWRA 2000). The datasets provide an interesting contrast between runoff generated from native vegetation in the Flinders Chase National Park (Rocky River) and a mixed land-use catchment (Middle River). Runoff from Middle River compares closely to Scott Creek, a high runoff catchment in the Onkaparinga River Catchment but covers three times the area. Even greater volumes of runoff would be expected in more heavily developed western catchments of Stunsail Boom, Harriet and Eleanor Rivers.

Little is known of the eastern river catchments. The Cygnet River has the largest catchment area on the island and runs east from its source on the western plateau where its headwaters receive more than 800 mm of rainfall per year. The river leaves the plateau through a well-confined valley ~10 km northeast of Parndana and begins a meandering course across 20 km of plains in a well-defined channel to the sea near Kingscote. Over-bank events are reported to occur 2–3 times each year along the length of the floodplain, forming swamps and billabongs. Timber Creek may be of particular hydrological and environmental significance in the eastern section as KI's only major endoreic stream flowing into the land-locked Murray Lagoon wetland. Issues include its uniqueness, potential ecological significance, the likelihood of more variable (arid) hydrology, groundwater – surface water interactions, and associated concerns regarding increasing dryland salinity.

Domestic water supply is diverse on KI, from rainwater collection to sea water desalination. The primary water source for Kingscote is the Middle River Reservoir, a reservoir of 11 ha of surface area and a capacity of 470 ML. Rainwater collection is used extensively at American River and for farm supplies, while a desalination plant (300 kL/d of fresh water) provides drinking water to Penneshaw.

With the exception of the Rocky River and Breakneck Catchments, all other catchments in the KINRM Region are subject to considerable farm dam development to intercept and store surface water flow for domestic water supply, stock supply, irrigation purposes and aquaculture industries.

2.3.2 SURFACE WATER QUALITY

2.3.2.1 Chemical and physical water quality

Long-term and comprehensive surface water quality is measured at only one site in the region, the Rocky River. The Rocky River Catchment is covered in native vegetation consisting of open forest, woodland, heath and shrub land.

The results of the monitoring program indicate that Rocky River has generally good water quality based on the following:

- salinity and turbidity is low
- nutrients concentrations are low
- concentrations of heavy metals, except soluble aluminum, are low to moderate.

From 2002 to 2004, the Rivers of Life conducted water resource assessment for six selected catchments on the Island. The project collected baseline data and information about physical, chemical, biological, geomorphic and ecological characteristics of the rivers and streams. The analysed and interpreted results from this project will fulfil some information gaps about the state and condition of the island's water resources. Additionally, considerable efforts have been channelled into the Cygnet River Catchment, the largest catchment area on the island, to understand the seagrass loss in the adjacent Nepean Bay since 2002. Notably, in conjunction with the EPA, KINRMB installed a composite sampler in the lower reaches of the Cygnet River to estimate the total catchment nutrient loadings to the bay. The Save Our Seagrass project (KINRMB) sampled 132 sites in the catchment from three different land uses and six stream orders to investigate the movement of nutrients in the catchment for targeting on-ground works and measures (e.g. fencing and revegetation of riparian systems).

2.3.2.2 Biological Water Quality

According to AusRivAS (Australian River Assessment System), which sampled 38 sites (Fig. 11) covering the major rivers and streams in KI, most sites are in good condition and similar to other reference rivers in the state. Catchments on the western end of the island in Flinders Chase National Park, including Rocky River and Breakneck River, are largely in pristine condition as reflected by their biota and water quality. They are among the most undisturbed riverine catchments in South Australia. Other rivers along the southern margin of the island with good bioassessment classification include Stunsail Boom and Eleanor Rivers. One site on the Willson River on Dudley Peninsula has a biota equivalent to other reference sites in the state. Impacted sites occur on the Middle River (poor habitat, reservoir), Timber Creek (salinity, habitat), Springy Water Creek (habitat) and Willson River near the estuary (salinity, habitat).

2.3.3 AQUATIC ECOSYSTEM (WETLANDS)

KI's inland wetlands can be broadly classified into either saline or freshwater. The saline wetlands generally occur on the eastern end of the island, and are located in a largely fragmented habitat with cleared land occupying a majority of the landscape. A concentration of saline wetlands occurs ~20 km south of Kingscote, the largest of which are Rush Lagoon, White Lagoon and Waidrowski Lagoon. The freshwater wetlands tend to be located on the western section of KI, with wetlands of high biodiversity values located within the national parks and wildlife reserve areas, or areas under private conservation management. Wetlands such as Grassdale Lagoon, Six Mile lagoon and Murray's Lagoon are excellent examples of inland freshwater wetlands.

Regionally, there is no comprehensive, scientifically based information on the condition or extent of wetlands across KI. Nevertheless, DEH has assessed the environmental status of selected regional wetlands (Seaman 2002). The assessments covered a range of representative wetlands, and provided a once-off snapshot of wetland condition and conservation value. Of the 26 wetlands assessed in the surveys, 16 are considered nationally important by meeting the ANZECC criteria of being a good example of a wetland type occurring within a biogeographic region in Australia. These wetlands include Six-mile Lagoon, Duck Lagoon and D'Estrees Swamp. Three wetlands are recommended for monitoring — Grassdale Lagoon, Six Mile Lagoon and Rush Lagoon.

2.3.4 GROUNDWATER RESOURCES

Despite relatively good rainfall, the groundwater resources on KI are limited, with localised good quality groundwater available only in small supplies. Just over 75% of all wells drilled on the island have a salinity of over 2000 mg/L TDS, with 95% of all wells yielding less than 1 L/sec. As a result, extraction of groundwater for livestock purposes is limited. This is mainly because of the unfavorable geology. The deep clayey weathering zone of the Kanmantoo Group basement rocks has restricted recharge and contributed to high salinities. The consolidated aeolianite dunes contain low salinity groundwater but have the potential to be contaminated by underlying saline water if overpumped (Barnett & Dodds 2000).

Potential exists from the alluvium and underlying Tertiary limestone in the Cygnet River area, and from aeolianite formations along the south coast, where groundwater quality is around 700 mg/L TDS (Dooley et al. 2002).

2.3.5 GROUNDWATER QUALITY

Groundwater quality across KI is subject to many influences. These include the depth of systems, potential for contamination, and geohydrological influences.

The unique shallow groundwater system across the region is highly susceptible to any human-induced contamination. Examples of this relate to poorly maintained septic systems in small communities that can contaminate localised groundwater systems and even impact on the marine environment through discharge points. However, there are limited data and information to assess the groundwater quality.

2.4 KEY REGIONAL ISSUES

The major issues in regard to water resources on KI include both the quality and quality of the available water. Stresses caused by development can adversely affect the water resources in the region. Gaining a greater understanding of the potential influences of the stressors on water resources is one of the fundamental goals of a monitoring program. Stressors and their potential effects on water resources, especially on water dependent ecosystems in the KINRM Region, are discussed in the following sections.

2.4.1 STRESSORS

2.4.1.1 Change in flow regimes

There have been significant changes in land uses on the Island since 1945. Clearance of native vegetation for cropping and grazing has been identified as one of the biggest stressor to water resources. These changes include:

- intensified dairying
- increases in viticulture and forest plantation
- increased numbers of small farm dams.

These changes, together with potential climate change and increased water allocation, have two significant consequences:

- alteration of baseflows
- alteration of flood regime.

In the dry season, baseflow discharges have been steadily decreasing due to upstream (Middle River) reservoir operation, increasing water interception (farm dam construction), and declining groundwater recharge (associated with increasing runoff and decreasing infiltration in urban developments). In tributary drainages, baseflows have been increasing due to irrigation. Decreasing baseflows in the mainstream can reduce groundwater levels and reduce the abundance of pool (wetland) habitats. Increasing baseflows in the tributaries are modifying their hydrology from natural intermittent flows to perennial baseflows, and may facilitate the establishment of exotic species such as willow.

Development projects, such as urbanisation and channelisation, can increase the magnitude of peak flood events, with corresponding negative impacts on riparian habitat and sediment dynamics. Urbanisation and channelisation also alter the flood regime by increasing the velocity and number of flood events, and altering the timing of peak flood events. At the same time, some of the impacts may be offset by the cumulative effects of upstream storages, especially the larger storages such as the Middle River Reservoir. It is unknown how this modified catchment response affects geomorphic processes, the frequency and extent of floodplain inundation, and sediment dynamics. These alterations can potentially reduce the establishment of new cohorts of riparian vegetation, reduce formation of new pool habitat, and change the composition of substrates.

2.4.1.2 Alteration of water chemistry

Point and diffuse discharges contribute suspended and dissolved solids, nutrients, metals, petroleum compounds, pathogens, and other pollutants to surface waters. Some of the contaminants also find their way to shallow groundwater aquifers. The pollutants can alter the productivity, species composition, and habitat quality of aquatic habitats. For example, elevated nutrient levels are of particular concern in that they can cause algal blooms and depressed DO concentrations in water bodies. These effects are particularly important during baseflow periods (normally summer).

2.4.1.3 Alternation of natural sediment deposits

Land uses in the KI catchments have likely altered the sediment transport regime. Sediment is naturally delivered to, and transported in, streams. Anthropogenic activities can alter catchment conditions and affect processes that determine the suspended sediment load in streams. These changes can potentially affect native species that have evolved to cope with the naturally occurring sediment regime.

2.4.1.4 Coast and marine degradation

Contamination from land-based sources impacts on the quality of marine waters and associated natural biodiversity. Human activities such as fishing, aquaculture, effluent disposal, and development have the potential to impact on the biodiversity of coastal and marine areas, and disrupt natural coastal and marine processes. The introduction of pests and diseases also places considerable stress on the natural environment. Due to lack of research and the added difficulty of monitoring in an aquatic environment, it is difficult to determine just how much of the marine habitat has been, and is being, lost.

Western Cove appears to have lost considerable seagrass through eutrophication. The EPA estimated in 1996 that as much as 2695 ha of seagrass have been damaged or lost in the cove, and recent remote sensing work indicates that there is actually very little seagrass left (Bryars et al. 2003; EGI 2002a,b). Nutrient and sediment loading via the Cygnet River is considered the major pollution source (Bryars et al. 2003). Another potential source is the septic tank effluent disposal system (STEDS) south of Brownlow. After heavy rain, overflow from the STEDS lagoons formerly ran onto the coastal flats, which are flooded during high tides. The problem has recently been rectified by installing an additional irrigation system. Urban runoff from Kingscote may also contribute to the pollutant loading in the bay.

2.4.2 SOURCES OF STRESSORS

2.4.2.1 Water management for water supply

Management and use of water for domestic, agricultural and industrial supplies affect the hydrology of the watercourses in the area. Water supplies are obtained though storage of surface water at the Middle River Reservoir and farm dams, and extraction of groundwater.

On-stream dams, while the most common in the region, create problems for downstream users and ecosystems. They have little flexibility for management, capturing all flow until full. Direct extraction of water from permanent or near-permanent pools can have severe impacts on dependent plants and animals if pool levels fall below critical levels.

2.4.2.2 Agricultural land uses

Agricultural land uses on KI are dominated by grazing of livestock and cropping, with viticulture, citrus and almond orchards, and afforestation being other major types of agricultural practices. Agricultural runoff normally contains elevated concentrations of nutrients and other chemical constituents (e.g. pesticides). Irrigation of agricultural areas often alters the hydrology of adjacent streams, resulting in modifications to surface and groundwater hydrology and water quality. Catchment clearance for agricultural production potentially facilitates the invasion of exotic plant and animal species, reduces the abundance of habitats and target species in the landscape, and fragments natural habitats.

Plantation forestry can have a significant impact on regional water resources. Plantation forests intercept and use more rainfall than traditional agricultural land uses. Hence a change of land use to plantation forest can reduce the surface water yield from catchments, leading to reduced stream flow, reduced groundwater recharge, and the creation of changes and pressures on water-dependent ecosystems. In addition to the potential environmental consequences, in areas where the available water resources are approaching the allocation limit or are already fully allocated, any reduction in the availability of water resources may impact on existing users of that resource.

2.4.2.3 Salinisation

Dryland salinity is a significant environmental concern. The impact of vegetation clearance in some catchments has resulted in the transport of excess salt and water run-off into creeks and streams. Saline groundwater is also seeping into creeks where ancient bedrock soils have been dissected. With the availability of detailed PIRSA soil mapping, it is possible to directly correlate highly salinised landscapes with catchment boundaries and individual streams. For example, ~12% of the Cygnet River Catchment includes soils with moderate to very high salt levels in the topsoil and subsoil. On the Cygnet and Menzies floodplains, large areas are visibly salt-affected as a consequence of water logging, saline watertable rise, and seepage and saline run off from further up the catchment (Kinhill 2000). The Cygnet River Catchment retains only ~20% of its native vegetation and is becoming salinised at an estimated rate of 3% per year (Day 2000a,b). Of the combined catchments of the rivers of southwestern KI where less than 30% of the original vegetation remains, ~12% is currently affected by dryland salinity. Saline seepage into streams in this region through dissected stratum is also most evident in early summer when aquifer hydrostatic pressure is topped up by winter recharge. Ephemeral tributaries fed by springs and localised runoff show evidence of considerable salt flow contamination and concentration by evaporation over summer. Figures are not yet available for these catchments but, as an example, the salinity seeping into Bugga Bugga Creek is in the order of 35 mS/cm or 24 000 mg/L (Mooney & Grinter 2000).

2.4.2.4 Effluent discharges

Point source discharges of effluent from septic tank effluent disposal system can alter stream, river and coastal water quality, affecting the aquatic ecosystem by altering productivity, decreasing oxygen concentrations, and altering the species composition of macro-invertebrates.

3. ROLES AND RESPONSIBILITIES OF STAKEHOLDERS

Monitoring and assessment provides an integral function in water resource management by validating the environmental outcomes of management program outputs. It provides the essential feedback about the effectiveness of state and regional efforts to manage water resources and aquatic ecosystem health.

Given the complexity of water resource programs, there are significant data needs among the many agencies and entities involved in the management, protection and restoration of water resources.

The state has a responsibility to meet its data needs in a cost-effective manner, and needs to continue to develop and encourage uniform methods and consistent quality assurance procedures among programs to enhance the value of shared data. The following sections address the specific data needs. The statement is not intended to be all-inclusive, but rather an outline of priority needs and uses of water resource data and information in state programs.

3.1 LEGISLATIVE REQUIREMENTS AND BUSINESS NEEDS

The two Acts that primarily define and shape the state's legislative reporting and planning responsibilities associated with water resource management are the *Natural Resources management Act 2004* and the *Environment Protection Act 1993*. Accordingly, the roles of major stakeholders in water monitoring are outlined below.

3.1.1 LEGISLATIVE MANDATES

Natural Resources Management Act 2004

Monitoring of the state's water resources has been conducted by various state agencies for most of the last century. These efforts have largely been directed at characterising aquatic resources and water quality problems of the state, and this basic direction remains valid today.

The South Australian Natural Resources Management Act has established a clear mandate for promoting sustainable and integrated management of the state's natural resources. The stated purpose of the Act is '... 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…' (Item seven, Natural Resources Management Act, p.20). It provides for the protection and management of catchments and the sustainable use of land and water resources and, insofar as is reasonably practicable, seeks to enhance and restore or rehabilitate land and water resources that have been degraded.

Under the Act, a structure for the state natural resources management is established, which includes an NRM Council, eight regional NRM Boards, and sub-regional NRM Groups. Each of these organisations has clearly stated functions regarding water resource monitoring, which are summarised below.

The State Government Minister:

10(1)a to keep the state and condition of the natural resources of the state under review; and

10(1)e to compile, maintain and update information in relation to the state's natural resources; and

10(1)f to promote public awareness of the importance of the state's natural resources and to encourage the conservation of those resources.

The NRM Council:

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*, which must:

74(3)(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.

74(6) The NRM Council must review the State NRM Plan at least once in every five years.

The regional NRM Board:

29(1)b

(i) to prepare a regional NRM Plan in accordance with this Act; and

(ii) to implement that plan; and

(iii) to keep the plan under review to ensure that the objects of this Act are being achieved.

The regional NRM Plan must:

75(3)e

set out the method or methods that the board will use:

(i) to monitor the state and condition of natural resources for the purposes of this Act, and related trends; and

(ii) to assess the extent to which it has succeeded in implementing the plan, with particular reference to the monitoring and evaluation of the effectiveness of natural resources management programs and policies implemented at the regional and local level; and

(iii) to assess the extent to which the board has succeeded in achieving its goals.

The Act also requires each NRM Board to prepare a water allocation plan for each prescribed water resource in its region.

76(4) A water allocation plan must:

a include 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

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 which 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:

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

the rate of use of the water is sustainable.

Environment Protection Act 1993

In 1993, South Australia passed the Environment Protection Act. The Act established the South Australian Environmental Protection Authority (SA EPA) and authorised it to conduct activities as necessary to carry out purposes of the Act, including monitoring of environmental quality. The following items delineate the functions of water monitoring requirements of the EPA.

The objectives of the Act:

10(1)(b)

- 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; and
- to provide for reporting on the state of the environment on a periodic basis.

The Function of the EPA:

10(1)(g) to institute or supervise environmental monitoring and evaluation programmes.

The State of Environment report must:

(a) include an assessment of the condition of the major environmental resources of South Australia; and (ab) include a specific assessment of the state of the River Murray, especially taking into account the *Objectives for a Healthy River Murray* under the *River Murray Act 2003*; and

(b) identify significant trends in environmental quality based on an analysis of indicators of environmental quality; and

(c) review significant programs, activities and achievements of public authorities relating to the protection, restoration or enhancement of the environment; and

(d) review the progress made towards achieving the objects of this Act; and

(e) identify any significant issues and make any actions that, in the opinion of the Authority, should be drawn to the attention of the Minister.

3.2 OVERVIEW OF AGENCY ROLES

There are numerous agencies and organisations carrying out water monitoring activities in South Australia's waters at the local, state and federal level. The state, primarily through DWLBC, EPA, DEH and regional NRM boards, carries out the function of monitoring the conditions and trends of both the quality and quantity of water resources. There are many other organisations or groups that have an interest in collecting water monitoring information, sharing this with state agencies or are interested in obtaining state agency data. These groups include health, public works and planning departments in local governments, certain businesses and selected non-governmental environmental organisations (including citizen volunteers), and some university and school programs. The federal agencies serve as important partners but, with the exception of BoM, their focus is primarily research and special projects or regional programs conducted in connection with federal agency missions. This section focuses on those programs conducted by DWLBC, EPA, SA Water and KINRMB.

The newly released *State Natural Resource Management Plan 2006* (South Australian Government 2006) introduced a monitoring and evaluation framework for NRM. This framework acknowledges the role of state agencies, regional NRM Boards and other bodies in delivering a coordinated approach to monitoring and evaluation. In specific, the South Australian Government will:

- coordinate and facilitate natural resources information
- be responsible for managing an integrated and coordinated natural resource information system in partnership with relevant bodies
- take responsibility for coordinating and establishing consistent standards for that system across the state to ensure that natural resource information is relevant, can be stored and is accessible where appropriate
- be responsible for evaluation and reporting at a state scale and, as necessary, on scales appropriate to NRM programs and projects delivered by agencies.

The South Australian Government, in partnership with regional NRM Boards, will:

- develop an integrated and agreed natural resources information system that contains a master copy of natural resource information for use in NRM
- encourage regional data collection and management systems that integrate with the agreed natural resources information system

- maintain existing regional resources information centres (e.g. the South East Resource Information Centre)
- support and encourage the development of new regional NRM information centres
- develop an operational plan for South Australia's Monitoring and Evaluation Framework that contains:
    - operating principles and guidelines
    - consistent standards for data collection and management
    - specific indicators
    - aggregation models
    - evaluation protocols that allow for reporting at different scales (including annual reporting) to contribute to revisions of all NRM plans and fulfil relevant Australian Government bilateral requirements
    - evaluation methodology
    - reporting formats.

Regional NRM Boards will:

- take responsibility for data collection in their region in accordance with priorities and protocols developed as part of the operational plan and at scales needed to inform their regional NRM Plan and component programs and projects
- be responsible for evaluation and reporting at a regional scale and at scales appropriate to individual programs and projects.

The following section outlines the current roles of agencies and organisations involved in monitoring on KI, and identifies the key data and information needs of water resource programs.

3.3 MAJOR STAKEHOLDERS

DWLBC, EPA, DEH, SA Water, BoM and KINRMB have important roles in water monitoring in the KI region. Their current roles and activities are summarised in Table 2, which also identifies the involvement of other agencies. The roles of the key agencies are further discussed below.

3.3.1 DWLBC

As the state's principal natural resources agency, DWLBC's water monitoring interests are focused on:

- status and trends of surface and groundwater quality and quantity
- providing data and information to update Australian rainfall and runoff for flood frequency analysis
- identifying existing and future risks of damage to, or degradation of, water resources
- evaluating living resource habitat
- ensuring the environmental water requirements of water-dependent ecosystems.

Table 2. Current activities in water monitoring in the KINRM Region.

Category	Parameter	Agency	Geographic scope	Sampling frequency
Water availability	Streamflow	DWLBC, SA Water, KINRMB	Catchment	Continuous
	Surface water level	DWLBC, SA Water, KINRMB	Catchment	Continuous
	Surface water storage	SA Water	Catchment	Continuous
	Groundwater levels	DWLBC, KINRMB	Catchment	Monthly
	Precipitation	BoM, DWLBC	Regional	Continuous daily
	Evaporation	BoM	Regional	Continuous daily
Water withdrawal	Farm dam	DWLBC, KINRMB	Catchment	Once
	Consumption use	SA Water	Regional	Continuous
Water quality	Chemical			
	Heavy metals	EPA, KINRMB	Regional	Monthly
	Nutrients	EPA, KINRMB	Regional Catchment	Monthly Composite
	Suspended solid	EPA, KINRMB	Catchment	Composite
	Pesticide (sediment)	EPA	Catchment	Snap-shot
	pH	EPA, KINRMB	Regional Catchment	Monthly Continuous
	Physical			
	Temperature	EPA, DWLBC, KINRMB	Regional Catchment	Monthly Continuous
	EC (salinity)	DWLBC, EPA, KINRMB	Regional Catchment	6-monthly Continuous
	Turbidity	EPA	Regional	Monthly
	Biological			
	Macro-invertebrates	EPA KINRMB	Regional Catchment	6-monthly Once
	Indicator bacteria	EPA	Regional	Monthly
Aquatic ecosystem (watercourse)	Buffer Zone	EPA KINRMB	Regional Catchment	Once Once
	Vegetation			
	Exotic species			
	Bank stability			
	Habitats			
	Macro-invertebrates			
	Stock assessment			
	Groundwater depth			
	Groundwater EC			
	Fish			
	Frog			

Category	Parameter	Agency	Geographic scope	Sampling frequency
Aquatic ecosystems (wetlands)	**Physical parameter** • Distribution and size • Land use • Description of site • Size	KINRMB DEH	Regional Regional	Snap-shot
	Biological parameter • Vegetation • Biological threats • Flora and fauna	DEH	Regional	Snap-shot
	Chemical parameter • DO • Conductivity • Turbidity • pH • Temperature	DEH	Regional	Snap-shot
Aquatic ecosystems (coast and marine)	Ambient water quality	EPA	Regional	Monthly
	Benthic biota*	PIRSA	Site-specified	Annually
	Microbiological* Phytoplankton*	PIRSA	Site-specified	Various
	Water quality and ecology	DEH	Site-specified	Various
Land use	Land-use type	PIRSA, DWLBC	Regional	–

*Industry sector based environmental monitoring programs.

3.3.2 EPA

As the state's principal environmental protection regulatory agency, EPA's water monitoring interests are related to providing the information necessary to manage the state's pollution control programs, including:

- discharge permit development
- assessment of water quality standards
- verification of permit compliance
- protection of public health and safety
- remediation of spills and historical pollution problems
- determining the status of living aquatic resources
- community monitoring (transferred or will transfer to DEH).

3.3.3 DEH

DEH is responsible for environment policy, biodiversity conservation, heritage conservation, environmental sustainability and animal welfare, and is a custodian of information and knowledge about the state's environment. The department also manages the state's public land — land held in the conservation reserve system and as Crown lands. DEH's monitoring activities are predominantly for wetlands and marine and coast ecosystems.

For wetlands:

- Collate monitoring, survey, and management information for wetlands across the state and link these data to information from associated water resources that wetlands rely upon.

For marine and coast systems:

- Identify indicators and assessment methodologies to enable effective monitoring and reporting of the ecological, social and economic changes in the coast and marine environment for State of Environment reporting.
- Determine risks to South Australia's coastal assets from physical changes through surveys and monitoring.

3.3.4 SA WATER

SA Water is responsible for storage, treatment and distribution of bulk water; provision of reticulated, potable and public water supplies; and collection, treatment and disposal of sewage. SA Water's comprehensive water quality monitoring program, from catchment to customer tap, provides key information to assist the management of the water systems and to ensure that performance standards are met. It comprises both routine and event-based monitoring programs.

The key objectives of the monitoring programs are to:

- determine the quality of water provided to customers
- determine compliance with guidelines and performance standards
- identify long-term trends in raw and stored water quality
- provide key information to facilitate effective operation of treatment systems
- provide key information to facilitate effective drinking water supply operation and distribution
- identify emerging issues with the total water system.

3.3.4.1 BoM

BoM is one of the major water resource data collection agencies in 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) in South Australia. BoM also has a significant role in providing rainfall and general climate data for water resource management purposes. It has the following basic objectives:

Climate record — To meet the needs of future generations for reliable homogeneous climatological data.

Scientific understanding — To advance the science of meteorology and develop an integrated comprehensive description and scientific understanding of Australia's weather and climate.

Community welfare — To contribute effectively to national goals through the development and provision of meteorological and related services.

International cooperation — To meet Australia's international obligations and advance Australia's interests in and through international meteorology.

3.3.5 KINRMB

At the regional level, KINRMB has the vision to:

'Address the full range of environmental and natural resource management issues relevant to Kangaroo Island, including conservation of biodiversity; sustainable agriculture; sustainable management of soil, water and vegetation; sustainable use of wildlife and environmental protection. Furthermore, the Kangaroo Island Natural Resources Board Inc. shall oversee the responsibilities for these issues across terrestrial, coastal and marine environments of Kangaroo Island' (KINRMB 2004).

The board aims to manage the region's water resources, both qualitatively and quantitatively, to sustain:

- natural ecosystems and biological function
- primary industries
- secondary processing industries
- human consumption
- other municipal, tourism and domestic uses
- features of cultural and heritage significance.

Since its establishment, KINRMB has made a significant commitment to monitoring, assessing, and tracking the conditions in rivers and coastal waters that are part of the catchment within its service area.

3.4 SYSTEMATIC MONITORING MODEL

Based on the model developed for the Adelaide and Barossa Catchment area by Sinclair Knight Merz (SKM 2002), a systematic monitoring model was developed for the KINRM Region to indicate the information needs of the various agency bodies with an interest in water-related monitoring data (Table 3). The definition of leading agency is based on:

- legislative requirements
- business needs
- institutional expertise.

Table 3. Systemic model for water monitoring

Classification	Parameter	Purposes	Lead agency	Collaborative agency	Interested agency
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 or weir capacity	Reservoir operation.	SA Water	NRMB, DWLBC	EPA, BoM
	Evapotranspiration	Catchment hydrological model.	BoM	DWLBC, NRMB, SA Water	EPA, DEH
	Stormwater	Additional water supplies. Aquatic ecosystem health assessment. Water quality assessment.	NRMB	DWLBC, EPA, local council	DEH, SA Water, BoM
	Effluent	Additional water supplies. Receiving water bodies assessment.	SA Water	DWLBC, NRMB, DEH, local council	PIRSA, SA Forestry

Classification	Parameter	Purposes	Lead agency	Collaborative agency	Interested agency
Water availability (continued)	Soil moisture	Catchment hydrological model.	PIRSA	DWLBC, NRMB	EPA, DEH
	Groundwater level	Water allocation. Environment flow. Groundwater-dependent ecosystem health assessment. Water quality assessment. Dryland salinity management. Surface–groundwater relationships.	DWLBC	EPA, NRMB, PIRSA, SA Water	DEH
	Climate change	All aspects of natural resource management.	BoM	PIRSA, DWLBC, DEH, EPA, NRMB, SA Water	
Water withdrawal	Extraction	Water allocation. Environmental flow. Catchment water budget.	DWLBC	SA Water, NRMB, SA Forestry	EPA, DEH
	Water use	Water allocation. Environmental flow. Efficient use of water resources. Catchment water budget.	NRMB	DWLBC, SA Water, SA Forestry	EPA, DEH
	Farm dam	Catchment hydrological model. Environmental flow.	DWLBC	NRMB, PIRSA, EPA	SA Water, DEH
Return flow	Irrigation drainage	Catchment hydrological model. Environmental flow. Salinity management.	PIRSA	DWLBC, NRMB, SA Water, EPA	DEH
	Effluent	Additional water supplies Aquatic ecosystem health assessment Water quality assessment	SA Water	EPA, NRMB, DWLBC	DEH
	Deep drainage	Dryland salinity management. Groundwater quality assessment.	PIRSA	DWLBC, NRMB	EPA

Classification	Parameter	Purposes	Lead agency	Collaborative agency	Interested agency
Water quality	Pesticides, organics, metals, nutrients, DO, pH, turbidity, temperature, structure of aquatic communities, habitat, macro-invertebrates, indicator 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. Dryland salinity management.	DWLBC	EPA, NRMB, PIRSA, SA Water	DEH
Aquatic ecosystems (watercourse)	Buffer zone, vegetation, exotic species, bank stability, pool distribution, macro-invertebrates, stock assess, groundwater depth and EC, fish, frogs	River health assessment. Habitat assessment. Biodiversity conservation. Environmental flow.	DWLBC	DEH, EPA, KINRMB	SA Water, SA Forestry
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.	DEH	DWLBC, EPA, NRMB	PIRSA
		Environmental value assessment.			DWLBC, EPA
		Aquaculture-based monitoring.	PIRSA		

- Lead agency: Under legislative mandate, and is responsible for:
  - developing monitoring strategy, plan, and protocols
  - data custodian, and supervising data quality assurance
  - supporting monitoring undertaken by other parties.
- Collaborative agency: Need information for business operation, contribute to monitoring through joint funding, advice and consultation, etc.
- Interested agency: In the best interests of the business that monitoring is undertaken.

4. CURRENT MONITORING SYSTEMS

4.1 DEFINITIONS OF WATER RESOURCE MONITORING

'Water monitoring' is the effort to obtain information to address specific characteristics of water resources and dependent ecosystems (physical — including quantity, chemical and biological). It is required for differing reasons (human health, ecological conditions, defined uses, management measures). These 'characteristics' may include direct measures of water parameters or conditions as well as summary 'indicators' such as keystone aquatic species.

Water monitoring is often 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 these aspects of monitoring as follows:

- 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). Reviews typically address the questions:
    - Is the information being provided sufficient to meet foreseeable needs?
    - Are any gaps or redundancies emerging?

The main reason for the monitoring of water quality has traditionally been the need to verify whether the observed water quality is suitable for intended uses. The use of monitoring has also evolved to determine trends in the quality of the aquatic ecosystem and how it is affected by the release of contaminants, anthropogenic activities, and waste treatment operations. More recently, monitoring has been undertaken to estimate nutrient or pollutant (e.g. salt) fluxes discharged by rivers or groundwater to lakes and oceans.

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 (see Fig. 1). 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, Table 4 provides the types of monitoring that can be defined.

Table 4. General classification of water monitoring (after MacDonald et al. 1991)

Type	Definition or purposes
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 activities were carried out as planned.
Effectiveness monitoring	Used to evaluate whether the specified activities had the desired effect.
Project monitoring	Assesses the impact of a particular activity or project.
Validation monitoring	Dealing with the quantitative evaluation of a proposed water quality model to predict a particular water quality parameter.
Compliance monitoring	Used to determine whether specified water quality criteria are being met.

4.2 MONITORING METHODS EMPLOYED

4.2.1 SURFACE WATER QUANTITY

DWLBC 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 streamflow 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. It makes these data available to the public via the Internet — the Surface Water Archive <http://e-nrims.dwlbc.sa.gov.au/swa/mapindex.htm>. The South Australian Government maintains a network of ~250 hydrometric stations across the state (as per HYDSTRA, October 2005). Data collected by other agencies, such as SA Water and the CWMB, 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 streamflow, or discharge in a manner that produces a relationship between water level and discharge. The stations are equipped with electronic sensors and data loggers (Fig. 6). By electronically recording continuous water level at these structures, a mathematical relationship of stage or level versus flow can be used to calculate discharge.

According to business requirement, DWLBC classified the stream-gauging stations into six types (App. A), each having an assigned priority level, unique purpose and minimum parameter requirements.

Figure 6. Photos show the stream-gauging station on Rocky River (AW513501), an underwater sensor and data logger.

4.2.2 SURFACE WATER QUALITY

In its capacity as the state water pollution control agency, the EPA is responsible for assessing the conditions of surface waters on a state-wide basis in accordance with the SA *Environment Protection Act 1993*. The EPA conducts the AWQMP, 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.

Parameters monitored in these programs can be classified as physical, chemical or biological. The choice of water quality parameters was based on those required to support the designated environmental values of the targeting water body. Guidelines for these parameters are contained in the *Australian guidelines for fresh and marine waters* and the *Australian guidelines for the recreational use of water*.

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, total P,). Biological parameters include an estimate of algal biomass (chlorophyll *a*), microbiological parameters (faecal coliforms, *Escherichia coli*, faecal streptococci 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 National Association of Test Authorities, Australia (NATA) accredited laboratories, such as the Australian Water Quality Centre (AWQC). The macro-invertebrate sampling is consistent with AusRivAS methodology (see below).

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 streamflow gauging stations using an EC probe, which continuously measures EC along with temperature.

4.2.3 GROUNDWATER

Fluctuations in groundwater levels reflect changes in groundwater storage within aquifers. Two main types of fluctuation can be identified — long-term, such as those caused by climatic 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. Since groundwater levels generally respond relatively slowly to external changes, continuous records from water level recorders are often not necessary. Systematic observations at fixed time intervals are considered 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 resolved.

Groundwater monitoring can be divided into three main stages:

1. Reconnaissance, with the objective of a preliminary appraisal of the available water resources (e.g. aquifer geometry).
2. General investigations, to obtain information for planning future urban, industrial, and agricultural development (e.g. groundwater flow processes and water budget).
3. Intensive studies of the aquifer(s) (e.g. groundwater recharge rate). This level of the investigation requires the greatest effort and is necessary for areas of present or potential intensive development.

During each stage, the information required includes:

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

Data on water level and 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, existing wells should be carefully selected and incorporated into the observation network.

In South Australia, monitoring wells 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 are submitted as a condition of the permit. These data are then recorded on the SA Geodata database. Observation wells used for monitoring purpose 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 wells provides the information to DWLBC for entry into the state database. The timeframes for forwarding the information to DWLBC vary. Some groups may forward the information immediately after wells are read. Other groups may collate results and forward periodically (e.g. on an annual basis). There are also situations where the information is provided in a purely informal fashion, having been collected for another organisation.

The Obswell searchable interface is linked to SA Geodata and provides access to monitoring well information. Information on the networks and individual wells 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 region are listed in the text. Wells are read periodically at intervals particular to the well or network.

4.2.4 AQUATIC ECOSYSTEMS

4.2.4.1 AusRivAS

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 has two streams, bioassessment and physical assessment. These correspond to rapid biological assessment protocols, and rapid geomorphic, physical and chemical assessment protocols, respectively.

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

The model works by evaluating the measurements of physical and chemical parameters, and predicting which families should be present given the conditions identified. A ratio of observed to expected animals present gives an indication of the ecological condition of the site in question.

4.2.5 COMMUNITY MONITORING

4.2.5.1 Waterwatch

The government-resourced, community based Waterwatch program has sites throughout the state. The program is largely education-based monitoring and community capacity building. School or community groups and 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.

4.2.5.2 Frog Census

This program is also community based and is coordinated by DEH (previously by EPA). The protocol involves the identification of frog species present by 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 on the distribution and abundance of frogs in South Australia can be gleaned.

5. MONITORING PROGRAM MANAGEMENT

A number of state agencies (DWLBC, EPA, SA Water, DEH, PIRSA and KINRMB) and one federal agency (BoM) are currently conducting ongoing monitoring programs in the KINRM Region. These programs vary in their strength and focus.

Although the agencies are largely aware of the ongoing programs maintained and run by other groups, the design of individual agency's monitoring networks does not necessarily consider other programs. The two key barriers to cooperative monitoring identified by this review are outlined as follows.

1. Organisations have diverse missions for water monitoring

The drivers for organisations to monitor water resources vary widely (refer to Appendices 3–6 for stated missions). These lead to different data needs and priorities, that may affect an organisation's ability and willingness to coordinate monitoring strategies and to share available data.

For example, the EPA's primary interest in water quality data arises from its responsibility to ensure that waters are in compliance with the state's water quality standards. Accordingly, its monitoring approach generally focuses on determining whether certain thresholds are achieved or exceeded. The degree to which measurements are on one side or the other of these thresholds is generally of less consequence. On the other hand, DWLBC's monitoring program is orientated towards obtaining precise measurements of water quality and then tracking changes in these values over time (the status and trends). Accordingly, its monitoring techniques allow for collecting specific measurements, hence tend to be more expensive. For example, DWLBC's salinity and water quality monitoring program may use relatively expensive meters to measure parameters such as temperature, dissolved oxygen, pH, and electric conductivity. These meters require more calibration and maintenance to ensure accuracy than the test kits used by others seeking to determine compliance with the state water quality standards.

Another example is the rainfall monitoring networks run by BoM and DWLBC, which monitor the same parameter for a different purpose. BoM measures rainfall to analyse the seasonal climate patterns and provide flood warning. DWLBC is concerned with evaluating the volume and distribution of rainfall events as they relate to the management and allocation of the consequential surface water resources, and groundwater recharge rates, which requires a higher degree of data reliability and accuracy.

2. Organisations often use inconsistent monitoring protocols

When organisations differ in their overall approaches toward monitoring, the varying procedures they use to monitor may result in data that cannot be easily compared. However, as the AWQC is being contracted for laboratory analysis for water samples collected by various organisations, the real barrier originates from sampling protocols.

Within the KI region, the main concern arising during the review process has been the lack of connection between DWLBC's stream-gauging network and the EPA's AWQMP. This makes the inter-reference of the two datasets impossible, and largely limits the potential broader use of the collected information.

Ideally and theoretically, for stream and river monitoring, the water quality information should be associated with flow and/or water level data. The combination of quality and quantity data helps to answer critical questions for integrated catchment management:

- tracing pollutant movement within the catchment
- identifying the source of pollutants
- estimating pollutant loadings from the catchment
- comprehending the environmental water requirements of aquatic ecosystems.

5.1 PRINCIPLES OF LONG-TERM MONITORING

For a monitoring program to be successful, it must be both focused and relevant to regional issues. Because of limitations of funding and other resources, monitoring cannot be all things to all people, but rather must adhere to an agreed set of principles. The following principles for water monitoring in the KINRM Region are modified and adopted from a range of monitoring, evaluation and reporting frameworks, namely *National Natural Resource Monitoring and Evaluation Framework* (NRMMC 2002), *Monitoring*, *Evaluation and Reporting Framework for the South Australian Murray-Darling Basin* (McKane et al. 2005), and *Sustainable Water Resources Audit Program* (Commonwealth of Australia 2001).

1. Monitoring is focused on the development of data that will provide information on status and trends of water resources in the KINRM Region.

To understand the need for changes in natural resource management in the region and the effect of such changes, it is important to be able to define current conditions in the water resources, including their natural variability in space and time, and to recognise any long-term changes in these conditions. This review was conducted with the two-fold intent of helping to define both the current state of selected environmental variables and their rate of change, if any. These variables represent important aspects of the resources to monitor over time in order to assess the integrity of the ecological system.

2. A variety of special investigations will be needed, both in the short and long term, to fill key data gaps.

Regional monitoring alone cannot be expected to determine cause and effect relationships among human actions and responses in water resources. Rather, results of monitoring will most likely provide an indication of change (or conversely, no change) in some parameters of interest over a specified area and period, with the cause of that change being uncertain (see Fig. 1 in section 1.1). Likewise, the monitoring program cannot encompass all possible known or unknown stresses such as contaminant sources, and such a program is therefore designed to highlight general areas of concern rather than specific sources.

There is a need for short and long-term investigations of specific issues in the KINRM Region, especially focusing on the mechanisms by which certain environmental processes occur, such as groundwater and surface water interactions. In many cases, the results of these investigations may be critical to understanding or implementing certain aspects of the monitoring program itself, and this report includes suggestions for several such investigations (refer to the sections for monitoring themes: surface water, groundwater, and aquatic ecosystems). Such studies ideally will provide information for management purposes and to improve or modify the monitoring program. A commitment from key organisations and agencies to seek funding for special studies will therefore be critical.

3. Commitment to development of an integrated framework utilising ongoing programs will be necessary.

One of the key objectives of the review is to bring together diverse monitoring networks to enhance the overall understanding of the water resources in the KINRM Region. Numerous organisations and units within organisations have collected and continue to collect data in the region, but no institutional framework exists to provide a linkage for these various data collection and assessment efforts.

With this in mind, the suggestions have been proposed with the intent of utilising existing and planned monitoring programs as the cornerstone. In this way, duplication of effort will be minimised and available resources maximised. Existing programs that have been reviewed and considered are listed in Table 2 and explained in detail in the topical sections. Additional monitoring beyond the scope of this review will likely be needed by most agencies to meet their specific organisation's objectives. Suggestions proposed in this review therefore provide a basis for developing a long-term monitoring strategy and framework, and present a regional context for utilisation of the more detailed state-agency-specific data.

In most cases, standardised approaches to sampling and analysis are highlighted in the review, and their use by the respective agencies is highly encouraged; however, some agencies may be reluctant to change methods because such changes would make it difficult to compare newly collected data to historic data collected by different methods. In these cases, it is critical to collect adequate quality control data in order to evaluate the comparability of data among agencies. Furthermore, it is equally critical to report and review quality control data on a regular basis to ensure that data being collected are of known quality and can be interpreted in conjunction with other monitoring data.

4. Establishment of a mechanism for coordinating regional monitoring will be necessary.

This review provides a basis to develop a framework for long-term coordinated monitoring in the KINRM Region. However, such monitoring is not likely to be fully implemented without a dedicated mechanism to help promote it. This mechanism may take the form of a separate oversight entity or a well-developed and supported series of agreements among organisations, but in either case it will require diligence. There will be needs for securing funding, developing interagency agreements, contracting for special studies, developing or reviewing quality assurance plans, verifying that agreed upon monitoring takes place, communicating and discussing study findings, and determining new studies or adjustments to monitoring. All of these activities will require a substantial commitment of time and resources.

5. A strategy for management of data is necessary to ensure access to essential information.

A common problem in comparing or analysing data among different agencies and investigators is lack of compatibility of the data management systems. In South Australia, historical data are located in diverse paper reports or computer systems, and in some cases metadata (information defining the type, objectives, and quality of data themselves) are not readily available. State agencies are discussing and considering proposals to establish a state water data warehouse, but these historical data may not be available from a common electronic source in the short term. It is important that newly collected data be maintained in a format that is accessible by other participating agencies. It is also advisable to summarise the data and make it available to the public.

Further discussion of data management, including the current state databases, is provided in Chapter 10.

6. A periodic assessment of monitoring data and re-evaluation of monitoring programs will be required to ensure long-term success.

As a mechanism to ensure continued attention and commitment to regional monitoring, to keep the monitoring programs appropriately focused, it is essential to regularly review the progress and findings of these programs. While it is widely recognised that monitoring is necessary to understand the effects of changes in water resources, there is often a lack of follow-up to monitoring efforts, and hence funding for monitoring programs has been reduced or eliminated because their potential benefits have not been realised. Periodic reassessments will provide a continued emphasis on monitoring and opportunities to educate agencies as well as the public about the benefits of the monitoring program.

7. Successful monitoring will require active participation of key agencies and individuals.

In South Australia as well as elsewhere, there are many agencies and organisations involved in jurisdiction or influence of one or more aspects of water resource management. Each has specific purposes for its involvement, and sometimes these purposes conflict among different organisations. Although not all of these organisations have been directly involved in the NRM Board or development of monitoring programs, the number of organisations involved remains large, and avenues for input from other organisations must remain open. In this setting, a monitoring program can be most successful if it has the involvement and support of the many agencies charged with its implementation or affected by its findings. Training in the use of common methodologies among monitoring organisations may at times be necessary. Managers and scientists representing affected agencies and other organisations will need to periodically review the objectives, technical merits, and findings of monitoring program, incorporating input from the public wherever possible.

5.2 OVERALL ISSUES FOR CONSIDERATION: MONITORING PROGRAM MANAGEMENT

A number of organisations are currently contributing to water monitoring in the KINRM Region. To increase efficiency, minimise redundancy, and improve data quality and comparability, the following monitoring program management issues were proposed for discussion and consideration among participating organisations.

Some suggestions come directly from the principles listed in section 5.1, and data management issues are discussed in detail in chapter 10.

1. Establishing a mechanism for coordinating and supporting the long-term execution of the KINRM Region monitoring plan, and tracking major changes in management or land use in the region in relation to monitoring.

A process for coordination and discussion of monitoring issues is critical to the long-term success of any regional, integrated monitoring effort among agencies. The KINRMB may be the most appropriate coordinator because it provides a forum for public deliberation that is not associated with the mandates of any particular state agency. The board can also be instrumental in securing additional grant funding (e.g. NAP and NHT) or other sources, helping to ensure that member agencies participate actively in various aspects of the monitoring programs.

2. Creating a periodic reviewing process for the regional monitoring efforts, with suggested annual and five-year intervals, to determine if monitoring elements are being carried out, evaluate monitoring data and results, and modify the design and priorities of the monitoring as needed.

If monitoring is to remain viable, it must be flexible enough to adapt to changes in regional priorities or other aspects of natural resource management. Changes to monitoring will need to be made based on data and information gleaned from previous monitoring efforts. Periodic, planned re-evaluation of monitoring programs is therefore suggested, at two different time scales.

Annual reviews would be used to assess and communicate the progress of monitoring, the quality of data collected, and any immediate findings such as violations of water quality standards or emergence of new issues. A work plan for the following year, with priorities and agency responsibilities for upcoming monitoring actions, would also be determined.

Every fifth year the reassessment would include a more substantial analysis of data by the participating organisations. Topics for analysis would include, in addition to the annually examined aspects of the plan, an evaluation of trends in the data, effects of resource management, synthesis of data from multiple monitoring tasks (e.g. the relation of sediment transport to nutrient loading), and suggestions for modifications to the monitoring program.

Changes in regional water management priorities, such as groundwater development, could be reflected in changes in the long-term monitoring program. This larger reassessment will also provide an opportunity to communicate to water resource managers and policy makers, and to the public, the findings and benefits of the area's monitoring efforts. For some measurements, such as water quality parameters collected continuously (temperature, salinity, or others), and water use, five-year intervals might be long enough to observe trends or make conclusions about water resource processes or relation of management actions to water resource conditions. For other issues, such as impacts of climate change on water availability, real trends may take decades or more to observe.

3. Establishing common protocols that enable data comparison among agencies and which are consistent with objectives for data collection.

The use of common, clearly defined protocols for sample collection, processing and laboratory analysis is important wherever possible to ensure the comparability of data collected by different organisations or over time within an individual organisation.

4. Developing quality assurance plans for each major monitoring element.

Quality assurance (QA) plans will be critical to the success of monitoring. Good quality control (QC) data, and assessments of those data, can allow the comparison of data among agencies and over time, whereas poor QA and QC data can prevent such comparisons.

The development and utilisation of good QA plans will be particularly important where protocols are not completely in agreement among different organisation involved in data collection. Such situations could arise if one organisation has an interest in using a particular protocol, because of historical or geographically widespread databases of data collected (e.g. BoM's daily rainfall observation network) with that specific protocol, or because of legal or agency specific mandates. In these cases, it will be especially important to verify that data collected by multiple organisations using differing protocols are comparable. A good QA plan can help quantify accuracy, representativeness, and biases among the different methods to understand the limitations of data comparisons.

5. Establishing a data management strategy that allows data and metadata to be shared among agencies and other interested parties.

An agreed strategy for data management would enhance the ability of different organisations to have access to monitoring data. Matters requiring discussion will include both programmatic and institutional issues as well as technical issues. Programmatic and institutional issues include funding and staffing, and agreement on data sharing and data standards. Technical issues include system location, operation and maintenance, compatibility, database design (e.g. centralised or dispersed), and data accessibility.

6. Enhancing the capability of information delivery to increase availability of information, reports, and other products to other agencies and the public.

One of the measures of success of the monitoring program is the degree to which the data collected, and the findings resulting from them, are used. Users of data could include the data collection agencies themselves, other organisations involved in monitoring, academic researchers, water and natural resource managers in the region, state and national policy makers, and the public. Managers, policy makers and the public are most likely to use conclusions drawn from raw data (Fig. 7). From raw data to reports, while the volume of information is condensed, the value increases. This value-adding process can dramatically increase the number of users.

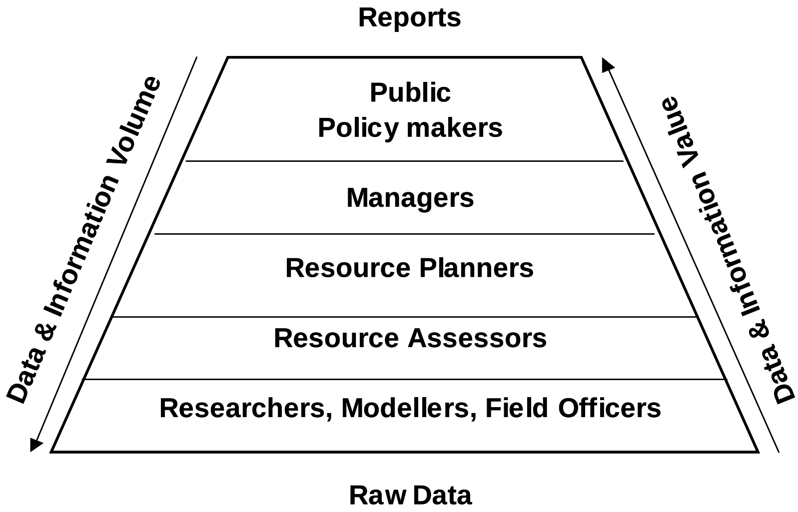

Figure 7. Relationship between data and information, and end users

This suggestion is differentiated from suggestion 5 by its emphasis on results and analysis in order to provide information to the public. Suggestion 5 is more orientated towards the mechanics of making monitoring data available among agencies or other researchers for the purposes of analysis.

7. Analysing collected data and information to identify knowledge gaps or other research deficiencies that limit or prevent success of monitoring efforts.

Analysis of the collected data in a systematic way would provide many benefits to future monitoring as well as to water and natural resource managers in the region. Results from these studies could be used individually and collectively to:

- help answer the questions they were originally intended to address
- formulate hypotheses regarding water quality processes or sources of contaminants in the basin

- evaluate the value of those data as components of future monitoring
- evaluate the quality assurance practices of the collecting organisation and the reliability of the data
- provide data for determination of the status of a resource or a baseline for future determinations of trends
- identify important data gaps in the current monitoring programs in order to make appropriate modifications for future monitoring.

6. CURRENT SURFACE WATER MONITORING

6.1 WATER QUANTITY

As pressure on existing water supplies continues to grow, water quantity data are increasingly important. Much as debits, credits and savings in a financial budget need to be quantified to maintain fiscal responsibility, the region's water availability, supply and use need to be comprehensively quantified to ensure sustainable water resource management.

Changes in climate and, to some degree, variations in urban growth patterns, agricultural practices, and energy needs, result in fluctuating water demands both annually and regionally.

Information on and knowledge of water availability and withdrawal, and the distribution and variability in space and time of these fundamental parameters, is an essential prerequisite for a number of activities, ranging from the forecasting of floods, to the management of water resources, and assessment of the potential climate change impacts. The collection and continuous supply of reliable and timely data, as well as the establishment and maintenance of historical data series, are basic requirements for acquiring information for planning and management purposes.

Streamflow gauging stations, rainfall observation stations and evaporation observation stations operated by DWLBC, SA Water, KINRMB and BoM form the water quantity monitoring network in the KI region. Details of the stations, including locations, monitoring parameters, and data management, are described below.

6.1.1 THE CURRENT STREAM-GAUGING STATIONS

The stream-gauging network is a vital decision support system in which streamflow data are collected at the gauges and then transmitted to a data collection centre and placed in a database managed by DWLBC. Data from the database are made publicly available via the Internet, and in paper copy. The stream-gauging network represents an extensive data collection, data storage and management, and information distribution system that supports many information and assessment needs for environmental management purposes, as well as modelling, model calibration, and research.

There are currently six stream-gauging stations in the KI region, including one reservoir gauge. The locations of individual hydrometric stations are presented in Figure 8. Table 5 shows the details of site operation such as data ownership, funding body, and period of record.

Except for A5131002 at South Coast Road within the Timber Creek Catchment (established 24/6/2004), data collected from all other gauges are published on the State Water Achieve website. The station at Playford Highway in the Cygnet River Catchment (AW513507) is the only one equipped with a telemetric modem.

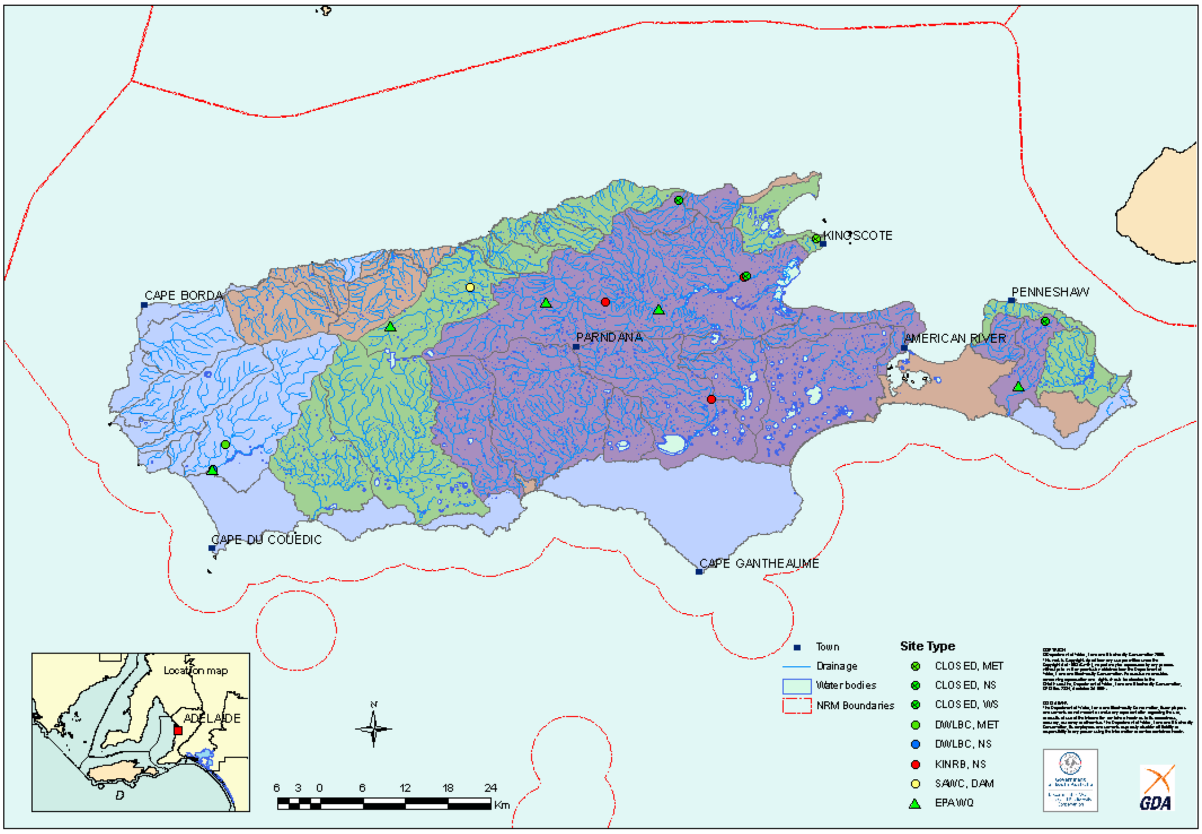

Figure 8. Current and historic surface water quantity and quality monitoring sites in the KINRM Region.

Table 5. Current and historic stream-gauging stations in the KINRM Region.

Site no.	Name	Start	End	Type[1]	DWLBC category[2]	Custodian	Funding
A5131001[3]	Cygnet River @ Huxtable Forest	Jul-2002		NS	Base	DWLBC	KINRMB
A5131002[3]	Timber Creek @ South Coast Road	Jun-2004		NS	Project	DWLBC	KINRMB
A5131014[4]	Cygnet River @ U/S Koala Lodge	Jul-2002		NS	BOF	DWLBC	KINRMB
AW513500	Smith Creek @ AMTD 1.6 km	Jan-1950	Oct-1960	NS		DWLBC	Closed
AW513501	Rocky River @ U/S Gorge Falls	Jun-1969		NS	Rep	DWLBC	DWLBC
AW513502	Middle River @ Middle River Dam	Jun-1969		Dam	System I/O	DWLBC	SA Water
AW513503	Willson River @ SE Penneshaw (Dam 1)	Apr-1988	Dec-1992	WS		DWLBC	Closed
AW513507	Cygnet River @ Playford Highway	May-1999		NS	BOF	DWLBC	KINRMB

1 NS: Natural Stream; WS: Water Supply Systems.

2 See Appendix A for further details on DWLBC's category definitions.

3 Combination station, recording EC, temperature, and water level.

4 Combination station plus composite sampler installed at 2002.

Gauge station AW513501 at Rocky River, covering a catchment area of ~190 km^2, has the longest record of water level. The gauge is paired with the meteorological station (AW513505, established in May 1999). The data collected from these two gauges are used beyond the regional water resource assessment and management due to the unique pristine conditions of the catchment. For example, the World Meteorological Organisation (WMO) recognised them as its benchmark sites to monitor the long-term impacts of climate variability and change on Australian water resources; data are also used for the analysis of freshwater flow to ocean.

The gauge located at Cygnet River @ U/S Koala Lodge (A5131014) was equipped with a composite sampler. The data are used to calculate nutrients and sediment loadings to Nepean Bay, where seagrass meadow loss is a significant environmental issue.

The dam gauge (AW513502), covering ~101 km^2 of the Middle River Catchment, is being operated by SA Water. The main purpose is for reservoir operation. Other stream gauges have relatively short operation times.

Three of the stations can record multiple parameters (water level, EC and temperature). These are A5131001 at Huxtable Forest in the Cygnet River Catchment; A5131002 at South Coast Road in Timber Creek Catchment; and A5131014 (with composite sampler) at upstream of Koala Lodge in the Cygnet River Catchment.

6.1.2 WATER USE INFORMATION

Water for domestic use in the KINRM Region is sourced mainly from surface water. Residents of Kingscote, Parndana and Cygnet River are provided with water from the Middle River Reservoir and water treatment plant, while the community of Penneshaw receives its water from an innovative seawater desalination plant. Residents on the remainder of the island generally rely on farm dams or rainwater tanks for their supply.

Apart from SA Water's metering data of the portable water supply, information and data on other water uses and consumption is limited or not available.

6.1.3 RAINFALL MONITORING

BoM maintains and operates an extensive nation-wide network of daily read rain gauges and pluviometers. In the KINRM Region, there are currently 21 daily rainfall monitoring sites (Fig. 9), of which five are pluviometers (Fig. 10) and three are automatic weather stations (AWS).

The AWS are designed to serve the dual purposes of providing real-time data for the bureau's forecasting, warning and information services, as well as high-quality data for the bureau's climate database. Some AWS reports are updated every 10 minutes, while others are updated every 30 minutes, and a few are updated hourly. AWS can provide multiple data on a range of meteorological parameters including air pressure, air temperature, wet bulb temperature, relative humidity, wind speed, wind direction, and rainfall. AWS have a number of advantages over conventional manual recording. In general:

- AWS are more consistent in their measurement
- AWS provide data at a significantly greater frequency (some provide data every minute)
- AWS provide data in all weather, day and night, 365 days per year
- AWS can be installed in sparsely populated areas.

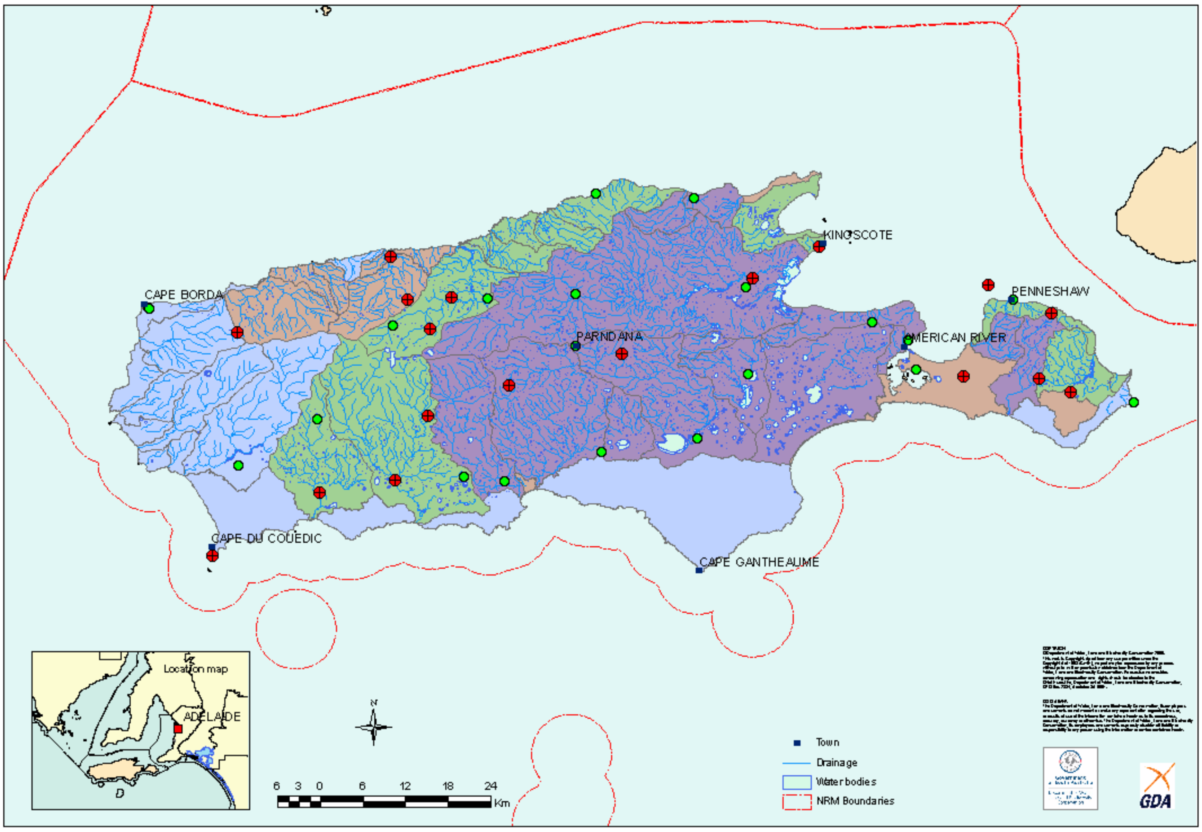

Figure 9. BoM meteorological monitoring network in the KINRM Region.

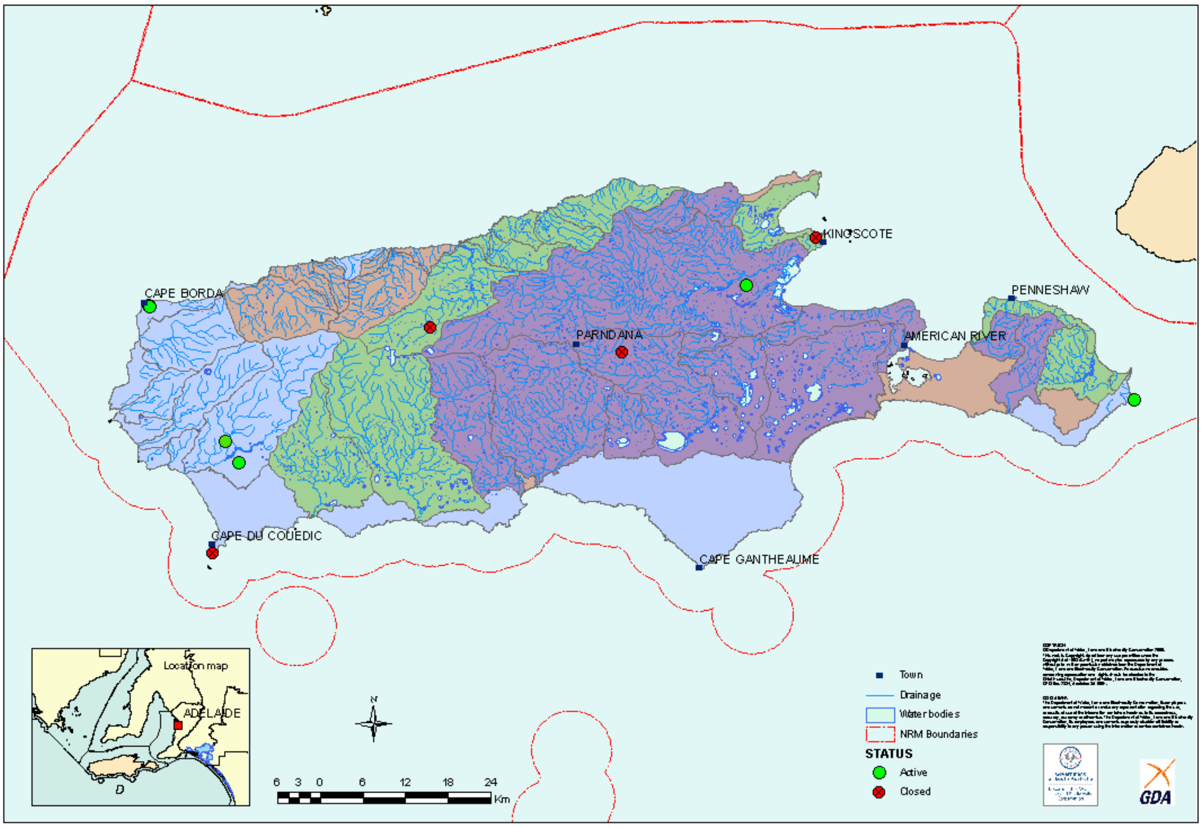

Figure 10. Rainfall intensity (pluviometer) monitoring in the KINRM Region.

In addition, BoM's Hydrological Services Program combines its own data, together with the state's stream-gauge data, to forecast water supplies and floods.

DWLBC used to have two pluviometers in the KI region. AW513504 at Kingscote Depot was closed at 1994, but the AW513505 Rocky River Catchment pluviometer at Shackle Road is still operating (Fig. 7).

6.1.4 EVAPORATION MONITORING

There is currently no evaporation monitoring in the KI region since BoM closed the station (22814, Parndana East Research Station) in 1984.

6.2 WATER QUALITY

Basic state-wide, long-term water quality monitoring activities in South Australia are primarily conducted by two agencies. The EPA's water quality monitoring programs principally address regulatory issues (e.g. permit compliance and modelling, evaluation of water quality standards) and ambient water quality. Programs run by DWLBC principally concentrate on salinity and aquatic resource issues. Within the KI region, both EPA and DWLBC have ongoing water quality monitoring programs, but program goals are designed to address specific agency responsibilities.

In addition to the long-term regional-scale monitoring, DEH, KINRMB and other community groups are also conducting site-specified water quality monitoring projects (Table 6).

6.2.1 RIVERS OF LIFE — KINRMB

From 2004, KINRMB has conducted a National Action Plan for Salinity and Water Quality (NAP) project to assess and monitor the surface and groundwater resources on KI. The project (now called Rivers of Life) was divided into two stages:

Stage 1 — Water resources assessment and monitoring.

Stage 2 — Development of a Regional Water Management Plan.

Stage one of the project assessed water resources (surface and groundwater, aquatic ecosystems) in six 'representative catchments' — Cygnet River, Timber Creek, Stunsail Boom River, Harriet River, and Rocky River Catchments.

The WRAP had two key components: collating and summarising current data and information, and undertaking baseline monitoring to eliminate the major knowledge deficiency. The baseline monitoring included:

- aerial videography survey of riparian structure and impacts
- geomorphological survey of watercourse conditions
- hydrological investigation (surface and groundwater):
    - installation of two stream gauges equipped with EC probes
    - farm dam mapping
    - preliminary study of environmental water requirements
    - preliminary investigation of surface and groundwater interactions

Table 6. Summary of relevant water quality monitoring activities in the KINRM Region

Program or project	Funding sources	Duration	Spatial coverage	Description
Ambient water quality monitoring	EPA	2003–ongoing	Regional	Water quality and sediment monitoring across KI. Detailed chemical assessment.
Ambient water quality monitoring	DEH	1999–ongoing	Catchments	Water quality of Rocky River (reference data) and Timber Creek.
Salinity and water quality monitoring	KINRMB	Ongoing	Regional	Temperature and salinity are recorded continuous at three gauges.
Pesticides snapshot	EPA	2003	Regional	Collected six sediment sample and analysed for 66 pesticides and herbicides.
Nepean Bay ambient water quality monitoring	EPA	1999–ongoing	Nepean Bay	To assess water quality, both spatially and temporally, across Nepean Bay, monitoring of epiphytic algal growth on seagrass.
Frog census	EPA	1994–ongoing	Regional	Frog monitoring.
South West KI ambient water quality	Landcare	2004–ongoing	Catchments	Water quality monitoring including nutrients in southwest catchments.
Dryland salinity modelling and monitoring	PIRSA	Ongoing	Regional	Dryland salinity modelling and monitoring.
NRM coast and marine program	KINRMB	2004–ongoing	Coastal	Assessing coast and marine biodiversity and condition.
Fish monitoring	NFA*	2003–ongoing	Regional	Comprehensive fish monitoring across KI.
AusRivAS	EPA	1997–ongoing	Regional	Bioassessment of riverine condition.
Seagrass monitoring	EPA	?	Nepean Bay	Seagrass decline. Comprehensive scientific study.
Water resource assessment project	KINRMB	2002–2004	Regional	Water resources (surface and groundwater, aquatic ecosystems) assessment in six representative catchments.
Rivers Of Life	KINRMB	2004–2008	Regional	Assessment of fresh water resources.
Kangaroo Island integrated catchment management	KINRMB	?–2004	Eastern catchments	Water quality monitoring to determine the source and impacts of nutrients on seagrass in Nepean Bay.

*Native fish Association (SA).

- water quality (physical, chemical, and biological — macro-invertebrates and fish) measurement
- ecological integrity investigation.

The project engaged several state agencies (DWLBC, DEH and EPA) and environmental companies (Earth Tech, Native Fish SA, and AWQC). The baseline monitoring methods are compliant with the common practices used by individual state agencies, and databases are consistent with major state databases (e.g. HYDSIS, EDMS) — i.e. ready to be transferred into the state information management system.

6.2.2 AMBIENT WATER QUALITY AND AQUATIC ECOSYSTEM MONITORING — EPA

In 2003, the EPA expanded the coverage and parameters of its AWQMP. It has four programs, namely: Rivers and Streams, Marine and Estuarine, Inland Waters (lakes), and Groundwater. Within the KI region, five fixed stream-monitoring sites were established in 2003 (Table 6, Fig. 7), representing the Rivers and Streams Monitoring Network.

The site in Rocky River Catchment was established for reference purposes as the catchment is located entirely within the Flinders Chase National Park and is considered un-impacted or minimally impacted by human activities. The data collected enable the condition of waters that are subjected to human-induced pressures and management initiatives to be assessed against an appropriate natural variability.

The monitoring program was designed to answer the following questions at the state scale:

1. How does the water quality in the state's river and streams compare with national water quality guidelines?
2. What is the condition of macro-invertebrate ecosystems in the state's rivers and streams?
3. Are current strategies reducing the impacts of agricultural land use on the state's rivers and streams?

A range of chemical, physical and biological parameters was currently measured at all sites.

Monthly sampling for:

- nutrients: nitrates and total nitrogen (TN), total phosphorus (TP) and soluble phosphorus (SP), total organic carbon (TOC), and silica
- heavy metals
- major ions
- salinity
- physical: temperature, turbidity, and dissolved oxygen (DO)

Biannually sampling for macro-invertebrates.

AusRivAS methodology (described in section 6.2.4) was followed for macro-invertebrate sampling and recording.

6.2.3 COMPOSITE SAMPLING — EPA AND KINRMB

In 2002, in conjunction with KINRMB, the EPA installed an automated composite sampler at the stream gauge on the Cygnet River @ U/S Koala Lodge (A5131014) to estimate nutrients and sediment loadings to Nepean Bay. Water samples collected are analysed at the AWQC.

Composite samples are taken by extracting a set of water from the stream every time a predetermined volume of flow passes the sampling point. Each sample is placed in a single container. The container is blended at the end of sampling period (normally two to six weeks), and a portion of water is taken for laboratory analysis.

Composites are appropriate for inorganic contaminants (e.g. nutrients and salt), and persistent, non-volatile organic compounds such as PCBs in all media and biota under the following conditions (Correll 2001):

- the distribution of contaminants is expected or known to be random
- the variability is expected or known to be low
- laboratory costs are substantially greater than field sampling costs.

6.2.4 PESTICIDE SNAPSHOT — EPA

During mid-2003, the EPA conducted a snapshot survey of pesticides across the state to determine if they were present in the state's water, and provide the basis of an initial pesticide environmental risk assessment.

The project collected and examined six sediment (stream and estuary) samples across KI. The results show that a range of historically used insecticides was found in the sediment from the Cygnet River Estuary and the Middle River (where the potable water reservoir is located). Furthermore, the Cygnet River Estuary exceeds the sediment quality guidelines for a number of pesticides. These highlight that further risk assessments should be conducted in the Cygnet Catchment.

6.2.5 AUSRIVAS PROGRAM

Since 1994, scientists from the EPA and AWQC have been assessing the ecological health of rivers and streams throughout South Australia. As part of this work, 38 sites on KI have been assessed (Fig. 11), 10 of which were established as reference sites and the remaining 28 as test sites. Most of the field survey was completed in 1997 and 1998.

Aside from macro-invertebrate registration, the survey covered a wide range of features of the investigated streams including habitat features (stream depth, width, riparian vegetation, bank stability, etc.); macrophytes (floating, submergent and emergent); and water column (chemical, physical and biological parameters) and substrate composites. AusRivAS presents the most comprehensive biological dataset for the KI region considering the geological coverage, parameter range, and data-presenting methodologies. Details of the AusRivAS program, including sampling site selection, parameter measured, field survey techniques and laboratory analysis methods can be found at <http://ausrivas.canberra.edu.au/>.

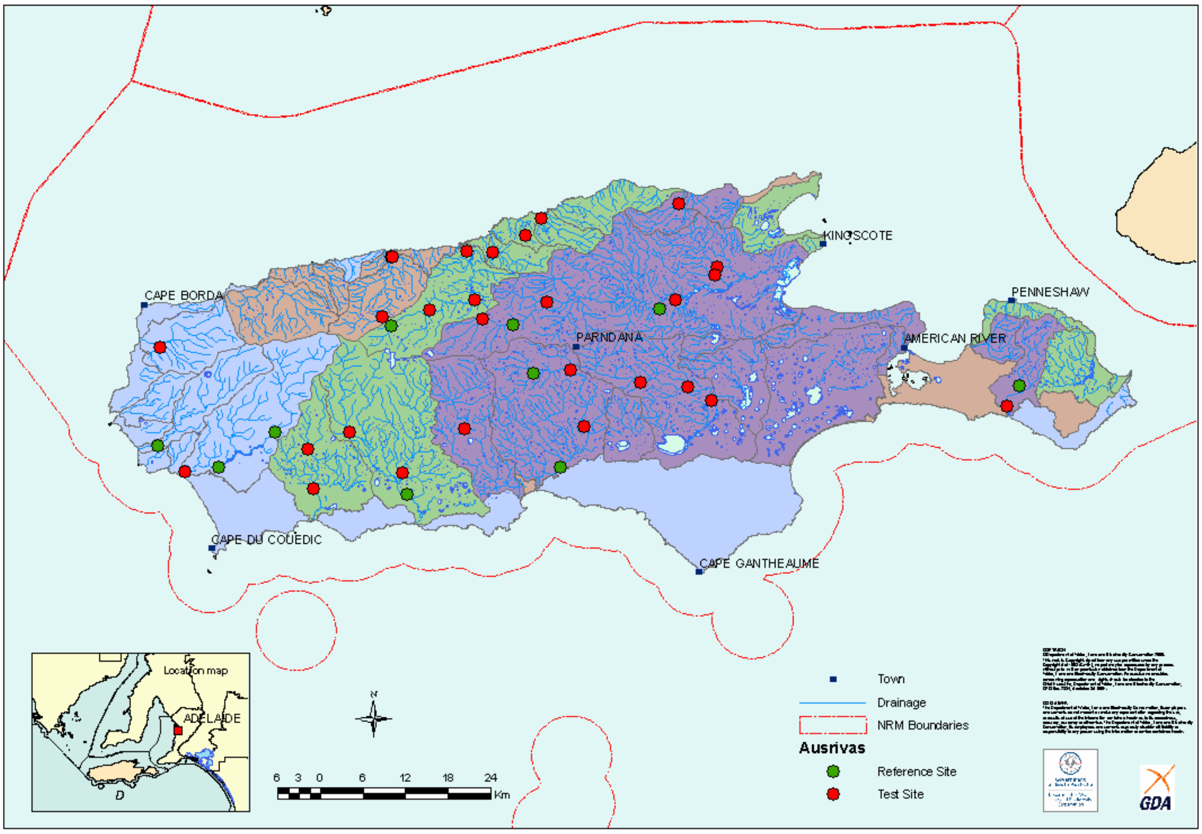

Figure 11. AusRivAS sampling sites in the KINRM Region.

6.2.6 SALINITY AND WATER QUALITY MONITORING — DWLBC AND KINRMB

Ongoing continuous surface water salinity monitoring has occurred only recently in the KINRM Region. In 2002, two steam-gauging stations — A5131001 (in the upstream) and A5131014 (downstream) — were established on the Cygnet River to continuously measure water level, temperature and EC to provide a better understanding of salt movement within the catchment, and the salt loading to Nepean Bay. On the Timber River, station A5131002 built in 2004 is also equipped with EC and temperature probes. All the three stations were funded by KINRMB and managed by DWLBC.

6.2.7 AMBIENT WATER QUALITY MONITORING — DEH

Originally set up as part of a platypus trapping project, DEH has monitored selected water quality parameters at five sites along the Rocky River since 1998 — Rocky River gauging station, East Melrose, Snake Lagoon Crossing, Main Platypus Pool and Rocky River Bridge. Monthly samples are taken for conductivity, DO, pH, salinity, temperature and turbidity.

As part of the effort to understand the mechanisms of increasing salinity in Timber Creek and Murray Lagoon, DEH has taken quarterly measurements of water quality parameters from these areas since 1996. The project monitors seven sites along the creek and three wells around the lagoon. The monitored parameters are pH, salinity, temperature, conductivity, and depth of water below surface (wells only).

6.3 GAPS AND OVERLAPS IN MONITORING

6.3.1 WATER QUANTITY

To accurately establish and model a catchment water cycle, some key hydrological processes have to be adequately monitored or understood (Fig. 12). These include rainfall and evaporation, surface runoff and subsurface lateral flow, groundwater flow, and stream flow.

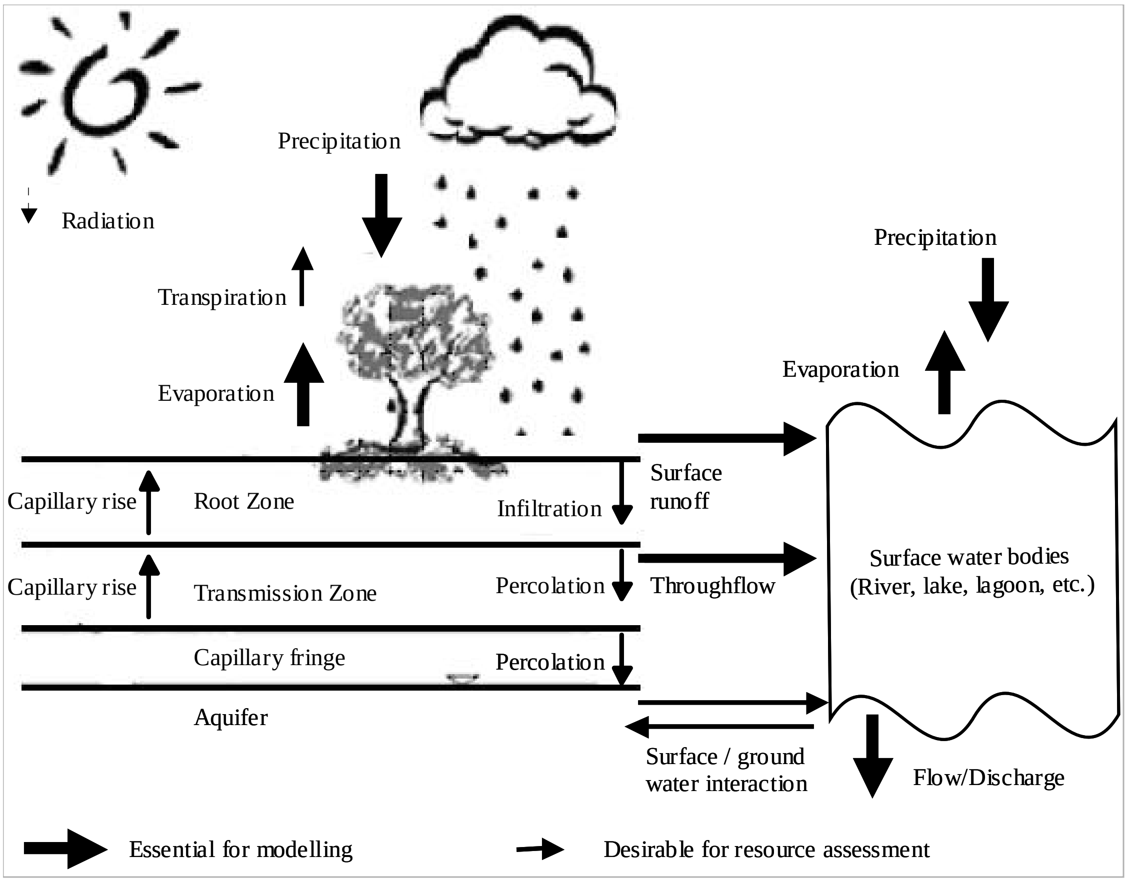

Figure 12. Hydrological processes at catchment scale (after Famiglietti & Wood 1994).

Precipitation and evaporation data can be obtained from the meteorological observation network. Information about other processes is obtained either through modelling (e.g. surface runoff, groundwater recharge–discharge) or through monitoring (e.g. streamflow). The following sections discuss the availability of the information and data, and the adequacy of monitoring in the KI region.

6.3.1.1 Meteorological Monitoring

The BoM precipitation observation network in KI is considered adequate for its designed objectives, such as the monitoring of seasonal climate patterns and provision of flood warning. However, rainfall data are also frequently used to model both surface water and groundwater responses, which require a higher degree of data reliability and accuracy.

Mainly for convenience of access, the current BoM network tends to be concentrated in populated regions or communication routes (e.g. road and rail) that are in conflict with hydrologically significant regions of high elevation and steep topography (Figs 8 and 9). Consequently, the daily rainfall observation is biased towards the lower, flatter regions and is not well suited to the estimation of total catchment rainfall.

Evaporation accounts for as much water loss from farm dams as extraction for irrigation, stock, and domestic use. It is also important in hydrological models for evapotranspiration losses and for monitoring climate change. The closure of M22814 at Parndana Research Station in 1984 is considered to present a significant gap in monitoring due to the high density of farm dams in the eastern part of the island.

There is a possibility of using monitoring data at Mount Bold Reservoir (M23734) and South Para Reservoir (M23820) for hydrological modelling. By analysing the available data from 1969 to 1984, D. McMurray (DWLBC, written communication, 2005) found that monthly means at South Para Reservoir and Mount Bold Reservoir are generally less than 10% different to those of Parndana Research Station during the hotter months (November to March). Based on this, McMurray concluded that evaporation in KI over the summer period could be the same as determined for the Mount Lofty Range. However, in McMurray's research, a double-mass analysis was not conducted to check the uniformity of recordings.

6.3.1.2 Stream-gauging Network

The importance of a comprehensive stream-gauging network is recognised by many agencies as vital to the proper management of the state's water resources. A comprehensive stream-gauging program provides hydrologic information needed to help define, assess, manage and use the state's water resources. A gauging program provides a continuous, well-documented, well-archived, unbiased and broad-based source of reliable water data that may be used for a variety of purposes including:

- determining the availability of water for municipal, industrial and irrigation uses
- setting and assessing water allocation plan
- managing drought and flooding
- setting permit requirements for discharge of treated effluents
- studying urban hydrology (e.g. storm water monitoring)
- computing the loads of sediments and other pollutants, such as salt and nutrients
- setting and monitoring in-stream flow requirements (environmental flow) to provide health habitats
- evaluating surface and groundwater interaction
- determining water withdrawal information, including farm dams
- monitoring compliance with minimum flow requirements
- licensing hydropower facilities
- designing highway bridges and culverts
- evaluating interstate water-use issues
- estimating streamflow in ungauged streams.

In South Australia, the stream-gauging network was designed primarily for water resource planning, especially for water supply. The resources and funding for stream gauges at strategic state locations are relatively stable and secure. Gauges designed for other purposes however, may be subject to closure due to the shifts in emphasis of responsibility within governmental organisations.

To effectively address the multiple water resources management goals in the KINRM Region (e.g. *State Water Plan 2000* (DWLBC 2000); *KI integrated NRM plan* (KINRMB 2004)), an adequate stream-gauging network should include:

- gauges that represent most of the region's major catchments — issues to be considered including land-use type, catchment size, physiography and geology
- gauges that are stable for an extended period of time (10 years or more).

The following sections address these issues in more detail.

Operational Data

Station AW513501 at Rocky River has over 30 years (from 1970) of water level data. The data is of high quality — few breaks, continuous, well documented, and well archived (stored in HYDSTRA). Data generated from the dam gauge at the Middle River Reservoir (AW513502) however, has breaks in the systematic record.

The other four current stations have relatively short (less than five years) times of recording (Table 5). As for the two closed gauges, data from A513500 Smith Creek @ AMTD 1.6 km was not digitised and might be lost. The record for AW513503 Willson River @ SE Penneshaw is considered of very poor quality with an unsuitable flow control.

The water level and meteorological monitoring data for the Rocky River Catchment could be used as a reference for state and regional NRM programs, as the majority of land use (greater than 99.1%) is natural reservation park. The information and data gained from monitoring will advance the understanding of the natural hydrologic system on KI. The monitored conditions of water resources within the Rocky River Catchment could be logically utilised for setting Resource Condition Targets (RCT) and Management Action Targets (MAT) for other catchments within the KINRM Region, and even other regions. For example, the Rocky River and neighbouring South West River Catchments are dominated by fractured rock aquifers, have moderate precipitation levels (800–900 mm/y), and moderate relief (200–300 m), all very similar to the Mount Lofty Ranges catchments. The possibility of extending the information to the perturbed and complex catchments of the Mount Lofty Ranges is high.

Spatial Coverage

To effectively address water resources management goals, the stream-gauging network must have adequate spatial distribution (physiographic and geologic diversity), represent catchments of various sizes, and include major land-use categories.

The analysis of coverage of the stream-gauging network is presented in Table 7. It is clear that KI is not effectively covered, and the current network is not optimal; spatial gaps exist:

- Overall, only ~0.20% of land (941 km^2) is covered by the current gauges.
- Using the catchment group developed in section 2.2, 24 catchments within two of the groups, covering an area of 1372 km^2, are not gauged (the dam gauge at Middle River Reservoir is not considered as a representative station).

Table 7. Spatial analysis of current stream-gauging stations in the KINRM Region (Source: DWLBC GIS coverage; land-use data from PIRSA 2001)

Catchment name	Catchment size (km^2)	Mean rainfall (mm)	Main land use (%)					Drainage density (m/km^2)	Farm dam density (m^2/km^2)	Mean slope (degree)	Approximate gauged land (km^2)	% of total land gauged
			Cropping	M/pasture*	Grazing	P&R&W**	Water body***					
American River	12.8	500	81.1	0.0	12.9	0.0	0.0	554.0	4486.0	0.5	0	0
Bay of Shoals	62.8	453	58.6	15.4	15.3	0.3	3.7	693.8	3809.0	2.5	0	0
Birchmore Lagoon	18.3	500	79.3	0.0	12.1	0.0	6.4	995.8	5002.6	3.2	0	0
Breakneck River	92.0	740	0.0	0.0	0.0	100.0	0.0	811.2	4834.6	1.2	0	0
Cape Borda	26.2	600	11.1	0.0	13.8	60.4	0.0	1227.8	0.0	1.4	0	0
Cape Bouger	41.2	641	0.0	0.0	4.1	95.8	0.0	1030.3	5060.0	1.4	0	0
Cape Cassini	64.7	595	28.5	12.1	23.3	33.2	0.0	970.7	7020.7	1.6	0	0
Cape du Couedic	105.1	719	0.0	0.4	26.7	72.8	0.0	1044.9	5730.5	1.7	0	0
Cape Dutton	22.6	566	49.9	19.3	18.7	6.1	0.0	179.8	4564.7	0.9	0	0
Cape Forbin	21.5	659	26.5	18.0	54.9	0.0	0.0	695.9	4886.4	1.1	0	0
Cape Gantheaume	329.0	500	0.1	0.0	17.4	82.0	0.0	653.3	4267.5	1.8	0	0
Cape Hart	47.4	514	12.7	11.8	27.9	43.7	0.0	704.9	3416.8	2.2	0	0
Cape Kersaint	37.9	545	6.2	4.0	30.7	57.9	0.1	1196.5	5716.8	2.4	0	0
Chapman River	73.1	578	64.6	5.0	15.8	11.7	0.9	579.3	4634.3	1.2	0	0
Cygnet River	606.5	556	72.7	2.7	15.0	4.0	0.0	1034.0	3173.3	2.1	494.3[∇]	81.5
D'Estrees Bay	3.1	753	0.0	32.5	45.4	0.6	0.0	651.2	9752.3	2.4	0	0
De Mole River	104.5	550	35.4	0.0	45.0	17.6	0.0	309.3	2801.0	2.0	0	0
Deep Creek	31.5	500	76.7	4.0	16.9	0.1	0.0	823.1	4107.7	2.3	0	0
Elenoar River	262.5	571	75.2	2.0	15.4	5.1	0.0	733.2	1320.1	4.4	0	0
Emu Bay	9.6	474	21.7	37.3	35.2	0.0	0.0	841.4	9358.4	2.2	0	0
Gum Creek	33.1	601	35.7	17.2	14.6	30.0	0.0	860.7	6025.3	2.0	0	0
Harriet River	151.9	672	74.5	2.2	17.5	2.7	0.5	508.9	2435.6	4.3	0	0
Kangaroo Head	34.3	556	54.2	10.6	19.5	7.1	0.0	748.6	3631.3	1.6	0	0
King George Beach	5.6	554	64.4	8.8	13.2	0.0	0.0	1221.9	5230.0	2.7	0	0
King George Creek	40.5	627	54.5	5.0	16.4	9.0	0.0	1029.1	2584.4	1.6	0	0
Kingscote	6.5	450	34.3	4.5	6.3	0.0	0.0	603.3	2965.0	1.6	0	0
Knapsmans Creek	11.1	628	0.0	0.0	0.0	99.8	0.0	880.5	2031.3	1.9	0	0
Lake Ada	54.0	502	66.0	0.0	14.0	16.6	1.3	1248.5	5467.9	3.8	0	0
Middle River	145.7	684	49.6	6.2	21.2	15.9	0.1	1174.3	5140.0	2.6	101.0	69.7
Pebbly Beach	15.1	685	28.7	13.2	51.5	0.0	0.0	920.7	3237.0	5.1	0	0

Catchment name	Catchment size (km^2)	Mean rainfall (mm)	**Main land use** (%)				Water body***	Drainage density (m/km^2)	Farm dam density (m^2/km^2)	Mean slope (degree)	Approximate gauged land (km^2)	% of total land gauged
			Cropping	M/pasture*	Grazing	P&R&W**						
Pelican Lagoon	104.0	516	6.3	12.4	58.9	17.3	0.5	1010.2	2141.9	4.5	0	0
Porky Flat	30.2	565	2.7	20.3	49.5	26.5	0.0	914.7	4551.5	3.4	0	0
Ravine des Casoars	95.7	685	4.7	0.0	2.7	92.0	0.0	484.1	3153.1	1.3	0	0
Red Cliffs	67.4	497	68.3	2.2	21.6	5.1	0.0	0.0	577.7	4.7	0	0
Red House Bay	4.5	573	49.1	23.9	12.6	12.0	0.0	132.0	391.5	2.9	0	0
Rocky River	216.4	744	0.2	0.0	0.1	99.1	0.0	287.7	478.1	3.9	190.0	87.8
Salt Lagoon	240.1	500	72.2	2.7	14.3	6.2	3.0	1118.3	1015.0	5.0	0	0
Sandy River	15.3	673	0.0	0.0	0.0	100.0	0.0	0.0	172.8	1.8	0	0
Seal Beach	13.0	731	9.7	0.9	10.4	75.1	0.0	0.0	460.1	1.4	0	0
Smith Bay	30.2	464	79.5	0.9	13.1	0.0	0.0	831.1	375.2	2.5	0	0
Smith Creek	34.0	537	67.5	0.1	16.4	14.6	0.0	0.0	233.7	2.2	0	0
Snug Cove Creek	18.5	707	32.1	11.6	45.7	9.2	0.0	0.0	3712.4	5.4	0	0
South West River	154.5	713	43.5	5.1	25.7	23.9	0.2	699.6	38.9	1.9	0	0
St'sail Boom River	324.0	715	32.7	2.9	16.3	46.3	0.3	0.0	32.1	1.4	0	0
Timber Creek	245.8	508	71.4	0.7	10.9	14.5	0.2	841.9	0.0	1.8	158.6	64.5
Valley Creek	7.6	763	0.0	0.0	60.7	38.6	0.0	1171.5	827.6	4.0	0	0
Vennachar Point	29.9	615	0.0	0.0	0.0	99.0	0.0	0.0	2272.0	2.4	0	0
Vivonne Bay	4.0	500	23.2	0.0	75.0	0.0	0.0	0.0	13.3	2.6	0	0
West Bay	18.6	639	0.0	0.0	0.0	99.6	0.0	0.0	0.0	2.1	0	0
West Bay Creek	40.1	680	0.0	0.0	0.0	100.0	0.0	460.4	0.0	1.6	0	0
Western River	88.3	809	30.3	0.1	34.1	24.4	0.0	760.7	0.0	1.7	0	0
White Lagoon	87.9	500	86.7	0.1	6.2	0.0	4.9	334.1	0.0	2.5	0	0
Willson River	63.8	583	69.1	0.6	22.8	5.0	0.0	311.3	0.0	1.4	0	0
Other+	9.2	673	1.1	8.2	19.6	69.0	0.0	883.9	0.0	1.7	0	0
Average (total)	4412.6	600	35.4	6.0	21.1	32.4	0.4	651.3	2835.9	2.4	941.3	0.2

* Modified pasture.

^ Including national parks, national feature protection areas, strict native reserves, and other reserve areas.

ˣ Including lakes, wetlands, streams and reservoirs.

+ Areas within the KINRM Region but not named in the state catchment shape file.

▽ Best guess.

- All of the gauged catchments have a land area larger than 100 km^2, and none of the small (<10 km^2) and intermediate (10–100 km^2) sized catchments are gauged.
- The gauged catchments represent the two extreme ends of land uses. Rocky River Catchment has more than 90% of land located in natural reserve, representing the pristine conditions, whilst the majority of land uses (>90%) of the Cygnet River Catchment are for agricultural production (e.g. cropping, livestock grazing, and modified pasture), representing the most developed regions. None of the catchments with development levels between the two extremes of agricultural production land area (10–85%) is gauged.

Regional coverage can be improved by prioritising and targeting currently ungauged catchments within group 2 and 4, especially in group 4, such as the Stunsail Boom River, thereby increasing the percentage of drainage area covered by stream gauges (Fig. 5).

6.3.2 SURFACE WATER QUALITY

Data gathered through water quality monitoring is critical to making scientifically based determinations about the status of water resources, the extent of water quality impairments, and appropriate solutions. For example, a monitoring program might be able to demonstrate a relationship between changes in land management and the frequency of algal blooms in a catchment.

Apart from the Rocky River Catchment, within which the EPA has a long-term water quality monitoring site (Rocky River u/s @ Gorges Falls), and DEH has been monitoring limited parameters (Table 6) at five sites along the river since 1999, the KI region lacks systematic and/or long-term ambient water quality monitoring, and there are significant gaps in the available data.

However, a number of projects were recently initiated in the region. These vary in geographic coverage, management focus, and timeframes (Table 6). Due to the lack of an overarching monitoring framework in place, the monitoring programs have limited coordination and differ in sampling site selection, sampling procedure (composite and grab) and frequency (ranging from continuous to quarterly to semi-annually), analysis method, and data interpreting and reporting process.

6.3.2.1 AWQMP Network — EPA

The EPA's network in the KI region was designed to assess agricultural impacts on the state's rivers and streams. The specific objective determined the site selection, analytes, and monitoring frequency.

The network covers the two key bioregions on the island — brackish (Cygnet River and Willson River Catchments) and high altitude and rainfall (Rocky River and Middle River Catchments). The site in the Rocky River Catchment was set up as reference. Generally, the data collected by the network could be used to answer the three questions it was designed for (section 6.2.1) at a broad geographic scale (the state level). Data collected at one single site within a catchment is of limited value to identify the causes and sources of pollutions. To address catchment-scale water quality issues, additional monitoring sites are needed.

Based on the Rivers and Streams Survey started in the 1980s, the program selected a range of water quality parameters that represent the stresses resulted from agricultural activities. A recent report (EPA 2005) found that poor agricultural practices often resulted in pesticides and herbicides finding their way into waterbodies and, eventually, Nepean Bay. Regular sampling of agricultural chemicals may be needed.

6.3.2.2 Salinity Monitoring Program — DWLBC and KINRMB

The surface water salinity monitoring is bound up with the stream-gauging network. Three of the current ongoing stream-gauging stations are equipped with EC probes.

As discussed in the previous section, there are large coverage gaps in the current stream-gauging network, with intermediate levels of development not represented. Surface water salinity monitoring is therefore also deficient as there are no continuous data available outside the Cygnet River and Timber Creek Catchments.

6.3.2.3 Site-specified water quality monitoring programs — DEH

The monitoring programs were designed for specified objectives, i.e. to understand and manage the increasing salinity of Timber Creek and Murray Lagoon, which is a significant bird habitat and the largest Lagoon in the island. Consequently, only targeted parameters (salinity and temperature) are measured. Nevertheless, by combining with the data generated from other monitoring programs such as EPA's AWQMP in the Cygnet River Catchment, findings drawn from the collected data and information could be utilised in regional-scale water quality management plans.

6.4 FUTURE DIRECTIONS: SURFACE WATER MONITORING

6.4.1 STREAM-GAUGING NETWORK

To address the spatial inadequacy of the stream-gauging network, DWLBC (then DWR) proposed to upgrade the surface water monitoring network in the region as part of the National Action Plan for Water Quality and Salinity (NAP) in 2001. In addition to salinity, the proposal also took into account other water quality issues on the island.

Following a field reconnaissance trip, DWR recommended that five additional stream-gauging stations, five simple environmental water level sites, and five rainfall monitoring sites be constructed in the region (Fig. 13). Three of the recommended stream-gauging stations (two in Cygnet River, one in Timber Creek; Fig. 13, Table 5) were added to the current network.

As mentioned before, the functions of the stream-gauging network have been advanced from assessment of the availability and use of freshwater, flood warning, and hydro-engineering projects (e.g. hydropower, bridges) to supporting of a wide range of natural resource management. In South Australia, the following functions are particularly needed to be reinforced through the defining of the state network:

- improving the understanding of the role that groundwater depletion plays in determining the future flow of rivers and streams
- understanding how river flow influences the quality of aquatic and riparian habitat so that rivers and streams are managed for the benefit of people and the natural environment

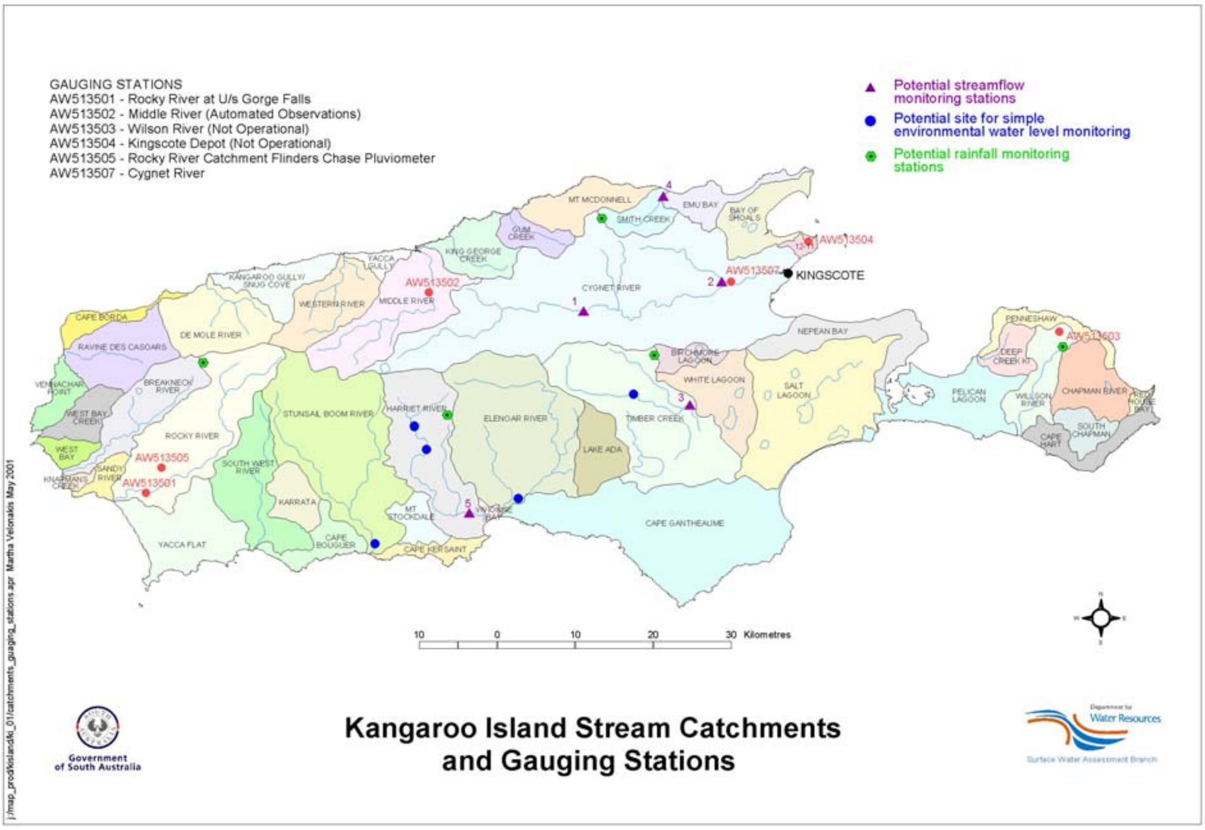

Figure 13. Proposed surface water monitoring network in the KIRNM Region by DWR, 2001.

- understanding how recent changes in climate influence soil moisture and the magnitude and timing of stream flows
- assessing changes in catchment water yields and quality (e.g. salinity, turbidity, and nutrient resulting from catchment management, especially altered land use)
- understanding processes that determine the effectiveness of a variety of new technologies designed to stretch the supply of freshwater (e.g. desalination, water re-use, and aquifer storage and recovery).

Recognising the multi-functions of a stream-gauging network, Table 8 presents a detailed recommendation for a completed network in the KINRM Region in priority order, summarised below:

- the six existing continuous gauges should be maintained
- the two closed (AW513500 at Smith Creek, AW513503 at Willson Creek) should be reactivated
- new gauges should be installed in eight catchments with the highest priority
- 15 catchments are considered as medium priority
- 25 catchments are considered as the lowest priority, and no stream gauging recommendations are made.

Table 8. Prioritisation of stream gauges for a stream-gauging network in the KINRM Region.

Catchment name	Catchment group	Priority	Gauge number	Gauge status	Minimally altered flow[3]	Salinity risk[4]	Potential growth[5]	Priority natural resources[6]	Geographic data gap[6]	Water quality[8]	Significant water usage[9]
Cygnet River	1	E[1]	AW513507	Current		A	✓	✓		✓	✓
		E	A5131014	Current							
		E	A5131001	Current							
Middle River	2	E	A5133502	Current	✓	B	✓	✓	✓		✓
Rocky River	3	E	AW513501	Current	✓	C	✓	✓			
Smith Creek	1	E	AW513500	Closed	✓	B	✓			✓	
Timber Creek	1	E	A5131002	Current		A	✓	✓		✓	✓
Willson River	1	E	AW513503	Closed[2]		B	✓	✓		✓	✓
Elenoar River	1	1				A	✓	✓	✓	✓	✓
Harriet River	1	1				B	✓	✓	✓		✓
South West River	2	1				B	✓	✓	✓	✓	✓
Stunsail Boom River	2	1				B	✓	✓	✓	✓	✓
Bay of Shoals	2	1				B	✓	✓	✓	✓	✓
Kingscote	2	1				A	✓	✓	✓	✓	✓
Pelican Lagoon	4	1			✓	B	✓	✓	✓	✓	
Salt Lagoon	1	1				A	✓	✓	✓	✓	✓
Birchmore Lagoon	1	2				A	✓	✓	✓	✓	✓
Cape Cassini	2	2				B	✓		✓	✓	✓
Cape Dutton	2	2				B	✓		✓	✓	✓
Chapman River	2	2				B	✓		✓	✓	✓
De Mole River	4	2				B	✓		✓		✓
Gum Creek	2	2				B	✓		✓	✓	✓
Kangaroo Head	2	2				B	✓		✓	✓	✓
King George Beach	2	2				B	✓		✓	✓	✓
King George Creek	2	2				B	✓		✓	✓	✓
Lake Ada	1	2				A	✓	✓	✓	✓	
Pebbly Beach	4	2				B	✓		✓		✓
Sandy River	3	2			✓	C		✓	✓		
Snug Cove Creek	4	2				B	✓		✓		✓
Western River	4	2				B	✓		✓		✓
White Lagoon	1	2				A	✓	✓	✓	✓	✓
American River	1	3			✓	C	✓		✓	✓	✓
Breakneck River	3	3			✓	C		✓	✓		

Catchment name	Catchment group	Priority	Gauge number	Gauge status	Minimally altered flow[3]	Salinity risk[4]	Potential growth[5]	Priority natural resources[6]	Geographic data gap[6]	Water quality[8]	Significant water usage[9]
Cape Borda	3	3			✓	B	✓		✓		
Cape Bouger	3	3			✓	C			✓		
Cape du Couedic	3	3			✓	C			✓		
Cape Forbin	4	3				B	✓		✓		✓
Cape Gantheaume	3	3			✓	C			✓		
Cape Hart	3	3			✓	B			✓		
Cape Kersaint	3	3			✓	B			✓		
Deep Creek	1	3				B	✓		✓	✓	✓
D'Estrees Bay	4	3				A	✓	✓	✓	✓	✓
Emu Bay	4	3				B	✓		✓	✓	✓
Knapsmans Creek	3	3			✓	C			✓		
Unnamed	3	3				B			✓		✓
Porky Flat	4	3			✓	B			✓		
Ravine des Casoars	3	3			✓	C		✓	✓		
Red Cliffs	1	3				C	✓		✓	✓	
Red House Bay	2	3				B	✓			✓	✓
Seal Beach	3	3			✓	B	✓		✓		
Smith Bay	1	3			✓	B	✓		✓	✓	
Valley Creek	4	3				B	✓		✓		
Vennachar Point	3	3				C		✓	✓		
Vivonne Bay	4	3				A	✓	✓	✓		✓
West Bay	3	3			✓	C			✓		
West Bay Creek	3	3			✓	C			✓		

1. **E** = Existing gauges determined to have the highest priority.
2. **Closed** = Discontinued gauge.
3. **Salinity Risk** = Based on Dooley et al. (2002). A = highest risk; B = high risk; C = natural conservation park.
4. **Minimally Altered Flow** = Catchments identified as having little to no withdrawals or diversions, and these locations may provide valuable background information.
5. **Potential Growth** = Catchments identified as having significant potential for future water withdrawal demands.
6. **Priority Natural Resources** = Catchments identified as having natural resource value such as Kangaroo Island Dunnart habitat, land of conservation value.
7. **Geographic Data Gap** = Catchments that have no gauging data.
8. **Water Quality** = Catchments where water quality, especially salinity, is an issue. Water quality parameters are (or are needed to be) measured or estimated, and streamflow is needed to calculate loadings to bays or other significant water bodies.
9. **Significant Water Usage** = Catchments where there is a high existing farm dam density.

6.4.2 METEOROLOGICAL MONITORING

The following suggestions were proposed to address the issues discussed in section 6.3.1.1:

- the daily rainfall observation sites need to be better distributed to match the stream-gauging stations
- the five potential rainfall monitoring sites (pluviometric stations) recommended by DWR (2000) should be constructed
- evaporation needs to be monitored to provide more comprehensive hydrological data; the potential sites are:
    - Rocky River Catchment at Shackle Road, co-locating with AW513505; the data could provide valuable reference information
    - Parndana Research Station, re-activating M22814
    - Birchmore Lagoon Catchment, co-locating with the recommended pluviometer (Fig. 10).

6.4.3 WATER QUALITY

4. Compiling databases of existing data and evaluating QA and QC data to determine if enough quality assured data are being collected, and if data are comparable between sites and agencies for basic water quality parameters such as salinity, temperature, pH, DO and turbidity.
5. Analysing existing data to determine baseline conditions across the island and looking for changes over time in basic water quality parameters.

These first two actions proposed are program management issues in nature. However, because of the complexity of water quality monitoring, particular attention is needed to improve the coordination of water quality monitoring in the region.

The analysis of existing data for the basic parameters would be an important step in the final design of an integrated monitoring network for the region. The first phase of that process would be to gather and analyse information on the quality of the existing data.

One major component of the ROL project is to collate and examine the existing data and information regarding the current condition of water resources across the island (refer to section 6.2.1). The results from the ROL will be very useful in terms of planning future monitoring program.

Once the quality of available data has been documented, an analysis of existing data would prove invaluable for several purposes. In addition to determining whether there have been detectable changes in water quality over time, or changes that can be linked to on-ground management actions, this analysis will help highlight strengths and weaknesses in the current monitoring network. Sites that are redundant or that otherwise provide little useful data, and sites that are critical and provide highly useful data, will be more evident after this type of analysis.

1. Establishing continuous monitors, including temperature, DO, pH, EC and turbidity, and auto-samplers at current and future stream gauges.

Some water quality parameters, such as temperature, DO and pH typically exhibit predictable diel patterns. Temperature, for example, increases during the day and decreases at night, particularly during summer. Exceptions are usually limited to situations where the measurement location is close to a large water source that remains at a relatively constant temperature, such as the outflow of a lake, reservoir or spring, or where regional groundwater input is important, so that the magnitude of diel cycling is less.

These diel patterns reduce the value of individual grab samples, especially those taken at midday when conditions do not reflect the extremes possible at a given location.

For long-term, routine sampling programs that do not specifically target daily maximum and minimum values, data are accepted for evaluation relative to standards in the current databases. However, for routine monitoring of water quality, when there are often several constituents being measured, or where work is scheduled to maximise the number of locations that can be sampled in a day, in situ measurements for these parameters are often taken without regard to the time of day. Consequently, data in many existing datasets are not adequate to assess adherence to standards or trends over time.

Data loggers that record DO, pH and temperature on an hourly (or 15-minute) basis provide data to more fully evaluate the status, trends and compliance of these constituents against standards, and the processes controlling water quality in streams. Status and compliance are easily determined by querying the resulting databases for the statistics of interest (e.g. maximums, minimums and daily averages), and comparing them to reference concentrations or standards. The status and trends of DO and pH can be further evaluated by determining the magnitude of daily fluctuation; the period of lowest (or highest) values during the year; comparisons of daily variability during key seasonal periods from year to year; trends in averages, maximums or minimums from year to year; and other metrics. Biological and physical processes, including the factors controlling DO and pH in a stream, also can be investigated by exploring relations of DO and pH patterns with such physical factors as temperature, streamflow and climatic conditions.

For EC and turbidity, composite samplers can provide a large amount of data for relatively little cost, although the maintenance and calibration needs can be substantial. Data can be useful for long-term trend analysis, for evaluating the short-term effects of specific events on water quality, for documenting compliance with standards, to support management needs, and for understanding the causes of short and long-term variations in salinity, sediment, and other chemical data, such as nutrients.

2. Conducting special studies to investigate:

- Relation of nutrients to streamflow, pH, DO, and perhaps turbidity and salinity level, and nutrient sources in the Cygnet River Catchment to support the integrated management of Nepean Bay; in the Timber Creek Catchment for the protection of Murray Lagoon; in the Rocky River Catchment to establish a reference condition. The results from interpreting the data from the current composite monitoring on the Cygnet River (A5131014, two years of data) would provide useful information for study design.
- Effects of different management alternatives on the Middle River Reservoir and downstream water quality.
- Groundwater inputs in the Rocky, Eleanor, Middle, Timber and Cygnet River Catchments, and their effects on water quality, especially salinity levels. The preliminary study of surface–groundwater interaction by ROL suggests that detailed investigation of paired (pristine and impacted) catchments would advance the understanding of water quality changes and trends.

- Pesticide on the landscape and its impacts on aquatic ecosystem — a further investigation of the EPA's pesticides snapshot survey.
- Effects of urban development and high flow events on nutrient concentrations and water quality.

The special studies suggested here target the current and potential water quality threats on the island and are proposed to address the data and information gaps in the region. Some of them are related and could be conducted with somewhat similar approaches. Nutrient and salinity concentrations and ancillary information (discharge, temperature, pH, and DO) would be analysed above, below, and including suspected sources (including key tributaries, and possibly including high, low and base flows). One suggested study is described in more detail below.

Nutrients in the Cygnet River Catchment. The eutrophication and seagrass loss in Nepean Bay are thought to be caused mainly by the sediment and nutrient loadings from the Cygnet River (EPA 2005). The Cygnet River Catchment covers ~11% of KI's surface area. The principal activity in the catchment is livestock grazing, mostly sheep, with some areas of mixed sheep, cattle and general livestock (Table 7). Fertiliser use, defecation from livestock, and high stocking rates in the catchment are likely to result in high nutrient potential in the landscape. Land clearing has greatly increased surface runoff. The augmented runoff exacerbates erosion on waterways and mobilises nutrients in the landscape (as dissolved forms and absorbed on soil particles).

Besides loading sediment and nutrients to Nepean Bay, the enhanced nutrient level has fundamental ecological consequences in the waterways and their associated aquatic ecosystems. The high nutrient level may stimulate benthic algal growth. The metabolic cycles (photosynthesis and respiration) can cause diel variations in DO and pH. Under natural conditions these cycles are moderate, and DO may respond more to physical processes such as aeration and temperature cycling than to biological processes. However, when algal growth becomes excessive, these cycles are unusually strong and cause conditions that do not meet the national water quality standards. Extreme examples of this phenomenon have been observed in many other South Australian water bodies with disturbances of the natural nutrient and flow regimes, including the River Torrens.

Aside from not meeting water quality standards, large fluctuations in DO and pH indicate possible ecological shifts away from the natural production and food webs of streams to systems that are disturbed. Nuisance species may dominate such streams and may not provide adequate food and habitat resources to support native species.

The study would involve at least two-year longitudinal intensive (fortnightly) measurements of nutrient concentrations, along with measurements of the minimums and maximums of DO concentrations and pH, and sampling of periphytic-algal biomass and speciation. The study would also make use of the monitoring data from the EPA AWQMP located at Bark Hut Road and Stoke Bay Road, and the composite monitoring at U/S Koala Lodge (A5131014), to assess variability of nutrient concentrations over time.

The findings would be used to determine the severity of pH and algal problems in the river, the presence of point or non-point nutrient sources, and the possible effects from different land and water management practices, as well as to provide data to support development of a catchment management plan for the KINRM Region.

Similar studies should also be conducted in the Timber River Catchment which is experiencing salinity and nutrient problems, based on the current DEH monitoring program.

7. CURRENT GROUNDWATER MONITORING

Groundwater is important as a significant water resource in its own right, and also because of its interaction with surface water. Groundwater recharges streams and rivers in some areas, while in others it is itself recharged by surface water.

The yield potential of groundwater resources on KI was assessed as small and localised (Barnett & Dodds 2000). The previous groundwater assessments concluded that low salinity groundwater supplies on the island are very limited (Barnett 1977; Barnett & Dodds 2000). However, the groundwater resources (both availability and uses) have not been fully assessed, current data are incomplete and a reliable figure cannot be provided. A recent study (as part of the Rivers of Life Project) casts new light on the condition of the island's groundwater resources. The followings are comments from one member of the project team (P. Shand, DWBLC, as quoted by D. Thomas, DWBLC, written comm., 2006):

- The resources of KI remain unknown because a proper study has not been completed. Previous conclusions are based on small reconnaissance studies (mainly in the east), so may not be 100% valid.
- There are likely to be areas of freshwater in places where land-use change has not been significant (e.g. in the south and west of the Island).
- Fresh groundwater occurs beneath farm dams and may form an important resource in drought conditions; there may be potential for aquifer storage and recovery (ASR) in these leaky systems.

Without a strong driver for groundwater resource protection (public water supply in most cases), the groundwater monitoring network (quality and quantity) in the KI region is limited. Current on-going groundwater monitoring only happens in the Eleanor River Catchment due to an increasing awareness of dryland salinity resulting from changes in land uses. However, the investment strategy for 2004–07 under the *KI Integrated Natural Resource Management Plan* (KINRMB 2004), which introduces a requirement to monitor groundwater quantity as well as quality, will require that this level of monitoring network be expanded and reviewed.

7.1 GROUNDWATER QUANTITY

In South Australia, groundwater level monitoring is conducted for a variety of purposes that may differ between regions because of geographic differences in aquifer characteristics, climatic conditions, land-use patterns, and human interference. The intensity of monitoring also differs because of financial and institutional conditions, urgency, and management focus.

The objectives of the state groundwater level monitoring network include:

- investigation of aquifer characteristics and parameters (e.g. freshwater and saline)
- characterisation of the groundwater system (e.g. recharge and discharge areas, the directions of groundwater flow, both horizontally and vertically)
- quantification of the effects of groundwater withdrawals
- quantification of the effects of surface water management (including influences of channels, farm dams, reservoirs, irrigation schemes, etc.)

- quantification of the effects of groundwater management (e.g. the introduction of Prescribed Well Areas)
- establishing trans-boundary (state) effects, including investigating cross-boundary groundwater flow and the impacts of measures on both sides
- qualification of effects of on-ground salinity management
- protection of groundwater-dependent ecosystems, such as springs.

DWLBC has one Obswell network in the Eleanor River Catchment (Naroonda, Fig. 14) which includes 42 observation wells. The network was initiated at 1990 and completed in 1991. Since then, water level has been recorded at monthly intervals.

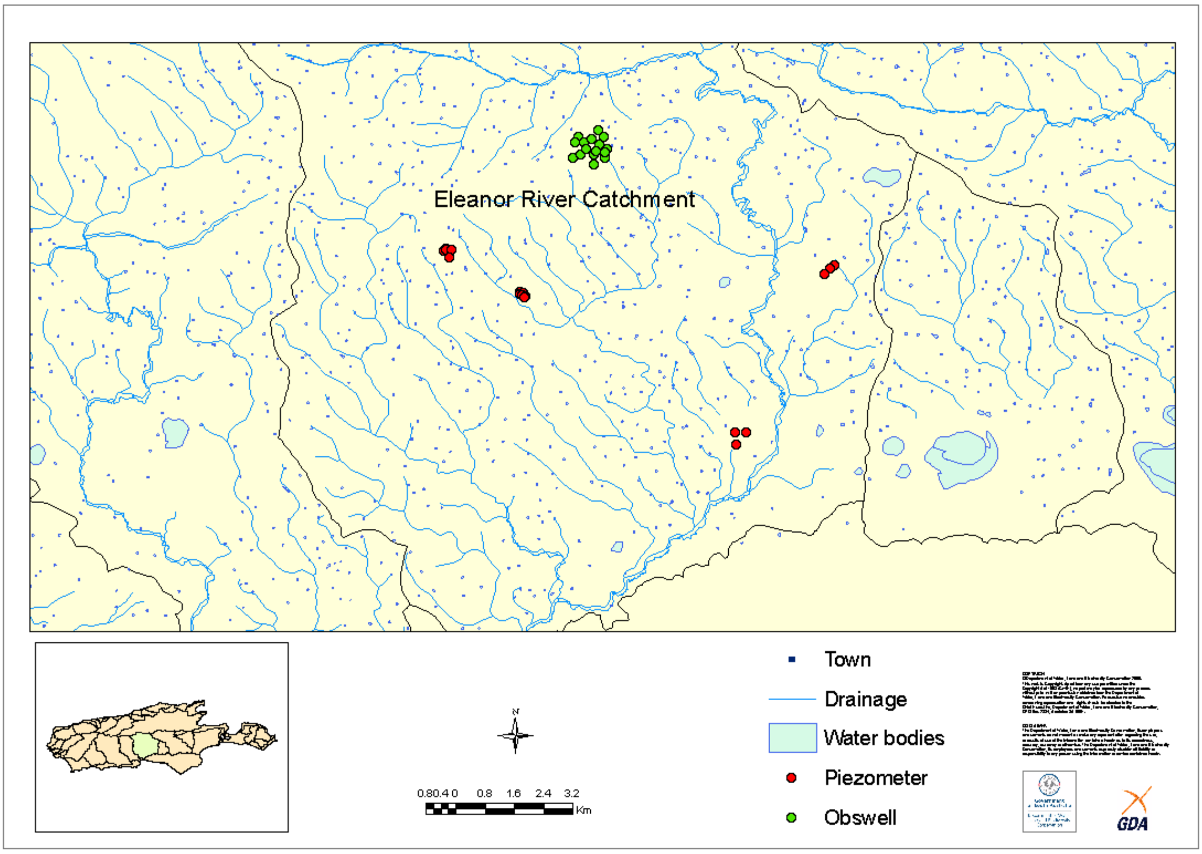

Figure 14. Water level monitoring in the Eleanor River Catchment (Obswell Network)

7.2 GROUNDWATER QUALITY

For monitoring groundwater quality, three types of monitoring networks can be distinguished in South Australia based on the designed objectives:

1. a baseline network for initial assessment and characterisation of groundwater quality for groundwater development
2. specific networks for monitoring effects on groundwater quality caused by diffuse sources of pollution, such as the AWQMP (groundwater) by EPA (no site on KI)
3. specific networks for monitoring effects of groundwater on dryland salinity and waterbody salinisation.

The KINRM Region has only type 1 and 3 networks, and the two networks are far from completed.

7.2.1 PIEZOMETER NETWORK

From 1990, piezometers were installed in a number of sub-catchments within the Eleanor River Catchment for monitoring dryland salinity (Fig. 14, Table 9); in most cases, these were at the request of Landcare Groups. Piezometers were monitored on a regular basis during 1992–96, but this was terminated when funding ran out. Monitoring was resumed by the KI Community Landcare Officers in 2004.

Table 9. Piezometer networks in the Eleanor River Catchment

Sub-catchment	No. of piezometers	Date installed	Current monitoring status
Naroonda	16	April 1990	4x/year
Crabb	8	May 1990	4x/year until Feb 2006
St Ives — west	7	March 1991	4x/year until Feb 2006
St Ives — east	8	May 1990	4x/year until Feb 2006
Blue gums	4	May 1990	4x/year until Feb 2006
Eleanor Downs	9	May 1990	4x/year until Feb 2006
Fogden	1	May 1990	4x/year until Feb 2006
Control sites	2	May 1990	4x/year until Feb 2006

Data source: Written correspondence (C Henscke, Rural Solutions SA, 2005).

7.2.2 RANDOM WATER QUALITY SAMPLING

There is no regular water quality monitoring by any state agency on KI (i.e. neither the AWQMP by EPA or DWLBC's Salinity Observation Network has a site in the region).

DWLBC oversees the state's salinity and other groundwater quality monitoring through a rotating network approach. A range of water quality parameters, including major ion, chloride, bromide, fluoride, nitrate, phosphorus, and pH, etc. is measured every seven to eight years. Groundwater levels are recorded for some observation wells. There are six observation wells in the KI region (Table 10, Fig. 15).

Table 10. Random groundwater quality monitoring in the KINRM Region

Unit No.	Name	OBS No.	Drill date	Easting	Northing	Chemical	Salinity	Level
6226-010	TCWQ 43	GOS1	–	679963	6041233	Y (1975)	Y (1975)	N
6226-018	TCWQ 44	MCD1	30/10/1958	663174	6016723	Y (1979)	Y (1986)	Y (1986)
6326-007	TCWQ 45	MNZ2	15/03/1962	725552	6043920	N	Y (1960)	N
6426-022	TCWQ 40	DUD1	–	762953	6039223	Y (1979)	Y (1986)	Y (1986)
6426-131	TCWQ 42	MCV1	25/07/1986	730588	6027834	Y (1979)	Y (1986)	Y (1986)
6426-354	TCWQ 41	MNZ1	–	739028	6052556	Y (1979)	Y (1979)	Y (1979)

Figures in parenthesises are the latest sampling years.

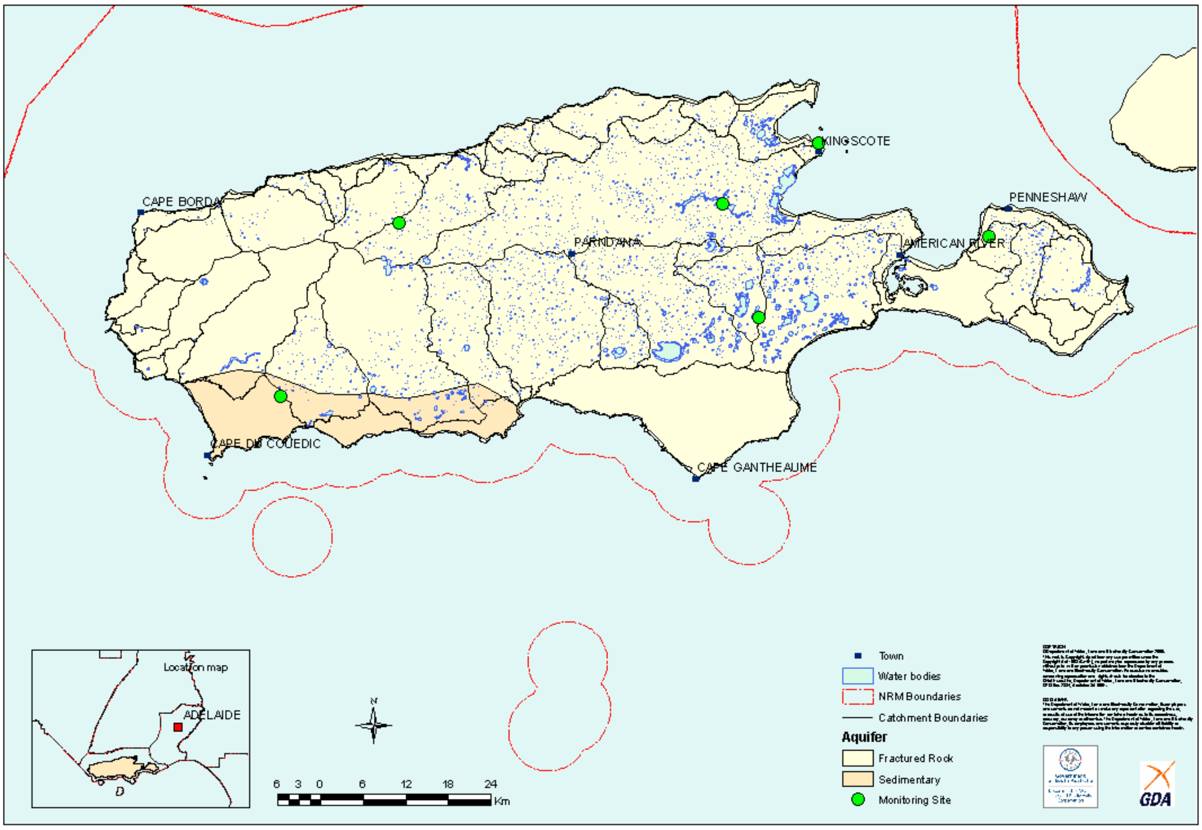

Figure 15. Random groundwater quality monitoring sites in the KINRM Region

7.3 GAP ANALYSIS

As mentioned before, without a strong driver, regional groundwater monitoring is limited in the KI region, and the monitoring networks are fragmented and localised. However, by no means can groundwater monitoring be overlooked in the region. In addition to groundwater-driven salinity issues (dryland salinity and salinisation of waterbodies), groundwater-dependent ecosystem degradation is also an important NRM focus.

On KI, there are permanent swamps (lakes) in hollows of the interior lateritic plateau (Murray Lagoon, Lake Ada, Lashmar Lagoon, Archway Lagoon), and river pools supported by local groundwater discharge in a few of the major streams such as the Cygnet River. These ecosystems provide important habitats for a rich abundance of fauna and flora. It is worth noting that the platypus, one of Australia's key fauna, has a strong dependency on the maintenance of river pools, if not flow, in the coastal rivers of southeastern Australia, including KI. This species, with the highest international scientific and public profile, is completely dependent on the continuous availability of river pools throughout the year. In much of its current habitat, groundwater is likely to play a role in this (e.g. Rocky River). A cessation of ponding in these systems induced by changes in groundwater availability may lead to its local extinction.

7.3.1 WATER QUANTITY

Different groups can be distinguished in relation to the purposes of groundwater level monitoring — (1) groundwater assessment, (2) sustainable development of groundwater resources, or (3) integrated water management.

In the KINRM Region, the monitoring needs are mainly focused on integrated water management, with the interactions between surface and groundwater as the main issue. This is because:

- groundwater assessment is relatively comprehensive
- the development of groundwater for public water supply is limited.

7.3.1.1 Data Availability and Quality

Groundwater levels provide critical and direct information about the hydrologic relationships of recharge to, and discharge from, storage within an aquifer, as well as the direction of groundwater flow. Long-term systematic measurements of groundwater level data are essential to develop groundwater models and to design, implement and monitor the effectiveness of groundwater management programs.

Systematic groundwater level monitoring on KI started at 1990 in the Eleanor River Catchment. Data collected are stored in SA Geodata and can be accessed publicly through the Obswell website. From July 1998 to March 2003, monitoring was not carried out for all the wells, which left a data vacuum for the period (Fig. 16). Despite the data breaks, most of the current observation wells have more than 10 years of data. The current monitoring networks can efficiently deliver information about seasonal fluctuations and long-term groundwater level trends in the monitored catchment (Fig. 16). The illustrated example shows that the annual water level is quite stable over the monitored period while the seasonal fluctuation can be expected due the rainfall pattern in the region.

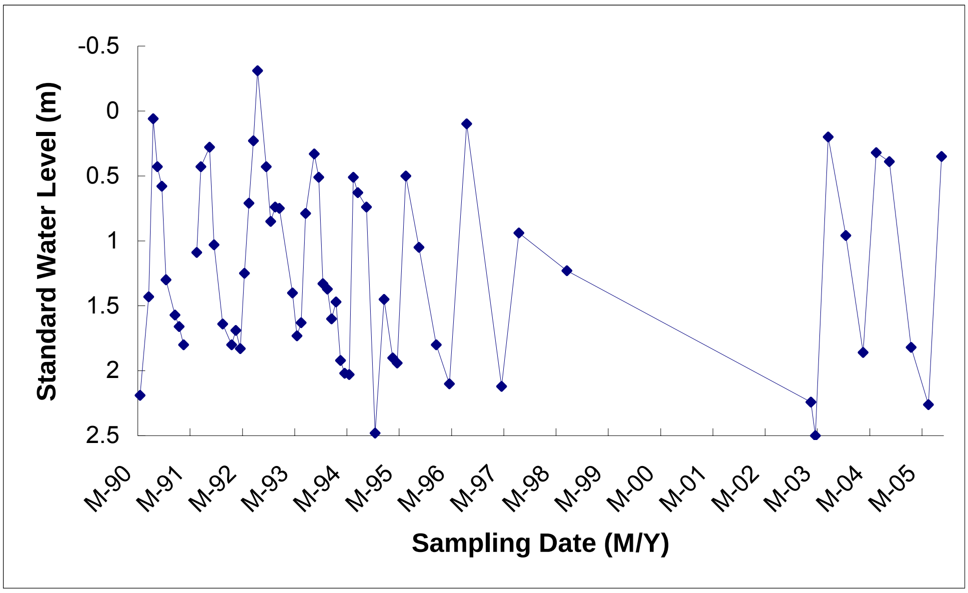

Figure 16. Groundwater fluctuations over 15 years in the Eleanor River Catchment (Data source: Obswell, well No SED002).

7.3.1.2 Spatial Coverage

The current monitoring network covers only a fraction of the Eleanor River Catchment. The spatial coverage can be explored by two approaches:

- only one of the two main types of aquifer is monitored — the sedimentary rock aquifer is not monitored
- the majority of the monitored aquifer is not represented by the current network.

Historically, there are more than 700 water wells, most of which are located in the eastern part of the island (Fig. 17), where agricultural activities are more intensive. The changes in land use and farm dam development may have profound impacts on groundwater table fluctuations, which in turn affect the hydrology of surface water bodies.

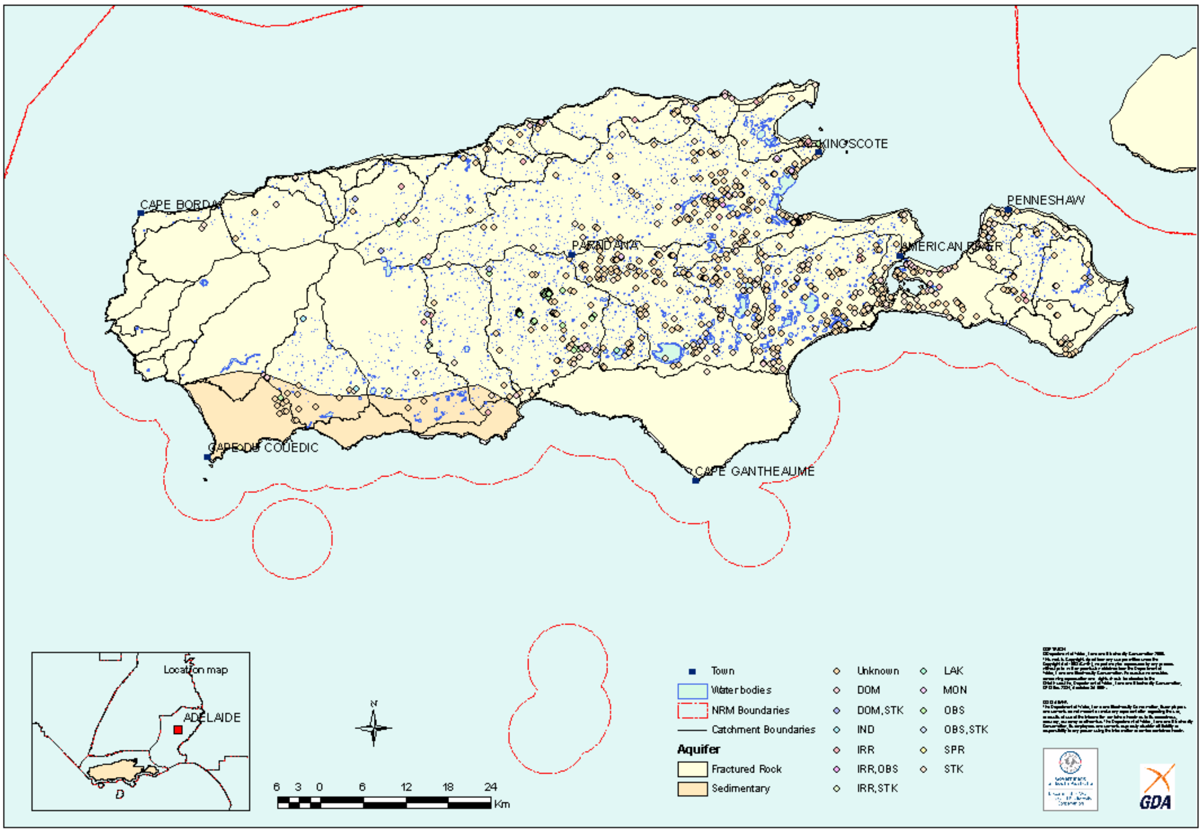

Figure 17. Historical and current water wells in the KINRM Region

7.3.2 WATER QUALITY

Similar to groundwater level monitoring, the current and future focus of groundwater quality monitoring is mainly for investigating the interactions between groundwater and surface water.

In the KINRM Region, the primary impacts on groundwater quality are agriculture-related runoff from cropland, pastures and barnyards; excessive nitrogen fertilisation of cropland; and land clearing and other agricultural practices that change soil composition, altering its ability to filter out pollutants. Because the major state groundwater quality monitoring networks (i.e. DWLBC's salinity Obswell, EPA's AWQMP (Groundwater), and SA Water's source water quality monitoring program) have no sites in the region, data and information about water quality are limited when providing answers to the following questions:

- What are the ambient groundwater quality conditions across the region, particularly for key pollutants such as nitrate, pesticides and pathogens?
- Is groundwater quality changing significantly over time, particularly in areas where land-use patterns are altered dramatically (e.g. the Cygnet River Catchment)?
- What is the quality of groundwater being withdrawn from private wells within shallower lenses?
- Where, how and when is groundwater interacting with surface water?

7.4 FUTURE DIRECTIONS: GROUNDWATER MONITORING

This section presents strategic issues for discussion for groundwater monitoring program responses to the key issues identified above. Several of the actions proposed have already been initiated. Others will require the consideration, approval and commitment of resources, new or reassigned, by stakeholders.

1. Conduct a bore survey across the island to update the assessment of its hydrogeology.
2. Establish additional observation wells to complete the network for water level monitoring to gather data to answer the following basic questions:
   - What are groundwater-level conditions like across the region?
   - What is the relationship between groundwater level and rainfall?
   - How do land-use changes affect the fluctuations of groundwater tables?
   - What are the impacts of groundwater-level fluctuation on groundwater-dependent ecosystems, such as river pools?
3. A water level monitoring network should be incorporated with ecological asset assessment.
4. Establish a groundwater quality monitoring network to investigation the impacts of agricultural activities (e.g. land clearing) on key catchments. Parameters such as nutrients, pesticides and ions should be sampled at least annually.
5. Conduct a special study on paired catchments to investigate the impacts of groundwater inputs on surface water quality (refer to section 6.4.3).
6. Establish a water level and water quality monitoring network in a pristine catchment (i.e. the Rocky River Catchment).

8. AQUATIC ECOSYSTEMS

8.1 CURRENT MONITORING

The surface water section covers monitoring of rivers and streams, including the biological component (currently macro-invertebrates). This chapter focuses on wetlands and other water-dependent ecosystems such as springs and waterholes.

As introduced in section 2.3.3, KI has a number of wetlands identified as of national significant. The wetland systems cover a wide range of aquatic ecosystems from freshwater to saline to estuary. The condition of these aquatic ecosystems varies from pristine bays and samphire flats to highly degraded saline lakes and lagoons. Furthermore, KI is one of the few remaining regions in South Australia with inland temperate freshwater wetlands in near-natural condition. The freshwater wetlands on the island are unique because many are independent of river systems, forming their own hydrological unit within the landscape.

At this time, there is no ongoing monitoring program covering these systems. The Wetland Inventory Project conducted by DEH (Seaman 2002) provides baseline information, and identifies the pressures on, and risks to, the health of these water-dependent ecosystems.

8.2 GAPS AND OVERLAPS IN MONITORING

While the threats to wetlands and other water-dependent ecosystems are identified as dryland salinity, vegetation clearance, livestock grazing, introduced plants and animals, and altered water regimes, the review realises that the following fundamental questions are remaining unanswered due to limited information and monitoring data:

- What is the distribution of each type of wetland?
- Are the wetlands fragmented?
- What are the sizes of the wetlands?
- What is the ecological connectivity among the habitat patches?
- How are the wetlands physically linked to the uplands and to Nepean Bay (for mangroves and samphire flats)?
- What is the status and trend in the salinity gradients?
- How does groundwater fluctuation impact on the wetland water regimes?
- How does surface water interception (farm dams, the Middle River Reservoir) affect wetland water regimes?
- How do ecosystem functions correspond to water regime changes?
- How does land-use change affect the annual sediment supply for wetlands, especially for mangroves and samphire flats?
- What are the concentrations of pollutants (nutrients, salinity, pathogens, pesticide residues, etc.) in wetlands?
- What are the distribution, species composition and abundance of wetland plant communities?

- What is the species richness for each major wetland type?
- What is the ratio of native to introduced species?
- What are the production rates of waterfowl forage plants and other key plant species?
- What is the distribution and abundance of invertebrates, especially fish and bird prey items?

8.3 FUTURE DIRECTIONS: AQUATIC ECOSYSTEM MONITORING

To answer the questions arising from the previous section, an integrated wetland monitoring program is critical. The current project — *A coordinated approach to wetland management*, managed by the KI Wetland Management Committee — provides an excellent opportunity. From the integrated water resource monitoring point of view, the following suggestions are made.

As a first step, it is suggested to map and register all surface and groundwater-dependent ecosystems

The current wetland baseline survey by KINRMB can be extended to map the location of all groundwater and surface water-dependent ecosystems, especially any with permanent surface expressions such as pools or baseflow reaches within the ephemeral or permanent drainages. This is background information that will provide for informed decisions as to what wetlands need to be monitored, and may also help to identify the best parameter choices, sampling frequencies, etc.

An integrated wetland monitoring program should have three components: early warning indicators, ecosystem or habitat-based indicators, and catchment parameters

The monitoring of water column physical and chemical parameters as a means of tracing early signs of wetland changes in relation to management impacts is widely accepted (Finlayson & Spiers 1999). Essential parameters to be collected consist of water level, EC, DO, temperature, turbidity and pH. Other parameters such as nutrients (especially TP and TN), heavy metals and chlorophyll-a may be important for some specified wetlands. Considering that the prevailing land uses on KI are cropping and grazing, TP and TN are recommended to be included.

Macro-invertebrates are the most extensively used biological indicators for monitoring and assessment aquatic ecosystem health in Australia (e.g. AusRivAS). However, further scientific research is required to:

- define sensitivity of macro-invertebrates to ecosystem changes
- define the link between macro-invertebrate biodiversity and ecosystem functioning
- clarify the value of using guilds or functional groups to monitor ecosystem processes
- identify keystone taxa for saline systems
- interpret the existence of redundant species
- relate the invertebrate composition and water quality, especially EC.

There are other biological parameters such as aquatic plants, phytoplankton and periphyton, and vertebrates that are commonly monitored.

Other parameters, that are more related to the impacts of catchment management, are also required to be measured. Land clearance, surface water allocation (including farm dams), groundwater recharge–discharge and extraction, land ownership changes and land-use changes all need to be documented and included in the monitoring program.

An example of an integrated wetland monitoring program, which includes a list of suggested parameters, is presented in Appendix 2.

Wetland monitoring should be included in the broad state water resource monitoring program

Many of the questions listed in the previous section can not be answered and explained by monitoring wetlands alone. Scientifically, the strong linkage between changes to wetland ecology and the surrounding environment, especially surface water drainage and groundwater recharge and discharge (including extraction), indicates that data and information collected by surface and groundwater monitoring should be documented and included in the wetland monitoring program. Legislatively, the ecosystem is defined as an important component of natural resources in the *Natural Resources Management Act 2004*, and is included in the state monitoring and evaluation framework. Consequently, it is logical and practical that:

1. The future expansion of the surface water and groundwater monitoring network should consider the requirements of wetland monitoring, i.e. the inlets of, and discharge areas to, important wetlands should be included in the monitoring network.
2. One outcome of the project *A coordinated approach to wetland management* should make suggestions for the long-term regional wetland monitoring strategy, which includes:
    - strategic monitoring sites
    - comparable monitoring protocols and procedures
    - comparable quality assurance procedures
    - long-term financial commitment
    - data and information storing and sharing mechanisms.

9. CATCHMENT CHARACTERISTICS

Catchment characteristics are relevant to all the above water monitoring themes. A clear example of the effect of land-use change on water quantity can be seen in the study by Ruprecht and Schofield (1989) of a pair of small catchments in southwestern Western Australia. By comparing the pair (one cleared, the other untouched), the study demonstrated that clearing native vegetation to establish agricultural crops resulted in an initial increase in the streamflow by ~10% of the annual rainfall. This was followed by a slow increase in the streamflow up to ~30% of the annual rainfall. The streamflow from the cleared catchment showed higher and sharper peaks, and an increase in the baseflow. The recharge to groundwater also increased in the cleared catchment, resulting in a rise in groundwater level.

Catchment conditions also contribute to water quality. A good example is the study of the nutrients and sediment output. According to Wasson (1994), in Australia the basin area has the largest influence on sediment yield, with large basins yielding the most sediment, whereas land-use pattern and cover plays the secondary role.

Although it is generally agreed that catchment characteristics affect water quantity and quality (both surface water and groundwater), there is no universally accepted definition, i.e. the list of catchment features for water resource management may vary from region to region, and from study to study. This review has identified a number of key catchment features that were broadly used in catchment assessment and hydrological modelling (Table 11). Note that not all the parameters are needed for a specified study.

The majority of the parameters listed in Table 11 are available datasets rather than ongoing monitoring programs. There is an increasing wealth of digital geospatial data available for regional use (i.e. at scales of 1:25 000 to 1:250 000). These data are being compiled and managed by state and national natural resource management agencies and land agencies, who recognise the importance of geospatial information for environmental management.

Table 11. Classification of catchment characteristics and data sources.

Characteristics		Parameters	Data source
Topography	Relief measures	Catchment relief Catchment relief ratio Longitudinal profile Valley side slope length and angle	Topographic maps, aerial images: Geoscience Australia, DEH
	Areal properties	Catchment area Drainage pattern Drainage density Elongation ratio	
	Linear measurements	Stream order Stream length	
Climate		Average annual rainfall Average monthly rainfall	BoM
Geology		Soil type and distribution Vegetation type and distribution	Geoscience Australia, PIRSA DEH, DWLBC
Land management practices		Land use Farm type including forestry farm Fertilisation Irrigation Farm dam Stocking density	PIRSA, DWLBC, CWMB, NRMB, NLWRA*, special studies

*National Land and Water Resource Audit

10. DATA AND INFORMATION MANAGEMENT

It is essential to effectively manage the large volume of existing information as well as any new information generated. This is a large and complicated task that all involved agencies are facing. Data and information management issues are briefly discussed when reviewing the individual water monitoring themes, i.e. surface water, groundwater and aquatic ecosystems. This chapter provides an overview of the state-of-affairs in information management across the state agencies, pinpoints the areas that need improvement, and suggests ways to enhance information delivery. This discussion is state-wide rather than regionally based.

10.1 CURRENT DATA AND INFORMATION MANAGEMENT

Generally, water information now exists in a multitude of formats located in a variety of places, both within and among agencies (Table 12, adapted from Phipps 2003). Over the years, there have been numerous discussions among water agencies about the feasibility of developing a shared water database at the state level. Despite efforts by DWLBC, EPA and DEH, etc., data today are primarily managed through separate program-specific databases. Monitoring data are increasingly, but not always, stored in electronic formats. It is used largely within individual programs. Within state government, there is no organised system to compile data across programs and archive data over time. The data management practices of programs vary widely. Most programs are focused on current issues, and older data in many cases is not available in electronic formats. Mechanisms to integrate and synthesise data across programs are not widely institutionalised.

10.1.1 SURFACE WATER

10.1.1.1 Water quantity

Data generated from hydrometric surface water monitoring across the state is stored in the HYDSTRA database managed by DWLBC. A portion of these data (those collected by DWLBC) is Internet accessible through the Surface Water Archive website. The rain gauge data from the groundwater program is currently not stored on HYDSYS, but it is intended to incorporate these data in the future.

BoM has a sophisticated information management system that enables nearly real-time meteorological information to be viewed and downloaded from its website <http://www.bom.gov.au/products/IDS65111.shtml>. In addition, data collected by pluviometers is entered into DWLBC's HYDSTRA database on a regular basis.

SA Water provides downloadable real-time water levels for a number of sites along the River Murray and 10 reservoirs in metropolitan Adelaide through its water data update website <http://www.sawater.com.au/SAWater/WhatsNew/WaterDataUpdate>.

Table 12. Summary of major water resource databases of South Australia.

Name	Agency	Source	Format	Comments
Australian Data Archive for Meteorology	BoM	BoM	Web-based, digital geospatial, CDROM	Historical and real-time
State surface water archive	DWLBC	DWLBC, BoM, SA Water, CWMB	Web-based, digital, geospatial, pre-formatted	Moderate data quality Long time delay Limited public access
Obswell	DWLBC	DWLBC, PIRSA, SA Water, CWMB, etc.	Web-based, digital, geospatial, pre-formatted	Data quality Time delay
Drill hole enquiry system	DWLBC	PIRSA	Web-based, digital, geospatial	Not specified for water
EDMS	EPA	EPA, SA Water, CWMB, and others	Digital, geospatial, non-digital reports	All environmental quality data Limited public access
National pollutant inventory	Australian DEH	EPA		
DFIS*	SA Water	SA Water	Digital, geospatial	Up-to-date
Water quality (SA Water)	SA Water	SA Water	Digital Spread sheet	Limited public access
Waterwatch	EPA or CWMB	Regional Waterwatch groups	Spread sheet	Poor data quality

* Digitised Facilities Information System

10.1.1.2 Water quality

The EPA has developed an environmental data management system (EDMS) to hold data generated by monitoring programs initiated by the organisation, data supplied as a condition of licence requirements on licensees, and data from other sources. The data comprise air, noise, soil, and water quality information, and are being used (chiefly by EPA) to assess trends, provide rapid assessments of environmental quality, provide information needed for State of the Environment reports, determine performance against national environmental protection measures, assess compliance with performance measures, and many other purposes. EDMS is not web-based but is publicly available on request.

Water quality data collected (or funded) by SA Water are stored in a separate database managed by AWQC; it is not web-based but the data are available on request.

Some of the CWMBs, particularly the Torrens and Patawalonga CWMBs, operate flow proportional composite water quality sample programs. These data are stored in HYDSTRA. Trend analysis of this data has been done and reports written, copies of which are filed in Libero, (DWLBC intranet).

10.1.2 GROUNDWATER

Most of the groundwater level and salinity data collected by various parties is stored on SA Geodata, a database maintained by PIRSA. The data are freely accessible via Obswell through the DWLBC website.

Groundwater GIS data, including groundwater provinces, basins, aquifers, and standing water level and concentration of total dissolved salts of the shallowest aquifer, can be downloaded from DWLBC website <http://www.dwlbc.sa.gov.au/subs/gis_data/data.html>.

In addition, SA Geodata contains data on all drillholes for the state, not just those related to groundwater. Access to this more extensive data is available through the Drillhole Enquiry System website <https://info.pir.sa.gov.au/des/desHome.html>. There is interest from all parties in seeing these data incorporated into SA Geodata.

10.1.3 AQUATIC ECOSYSTEM

Data related to aquatic ecosystems is kept by DWLBC, DEH and EPA. There is no centralised system of data management, or uniform standards for data collection. Data and information products are available on request to the individual agencies. Currently, DWLBC, together with the Flinders University of South Australia and the University of Adelaide, is undertaking a project to develop a best-practice framework for monitoring water-dependent ecosystems in South Australia.

10.2 FUTURE DIRECTIONS

There is an increasing demand and need for better access and use of natural resource data and information to support planning and decision-making processes underpinning natural resource management. This is the case across all levels of government, industry and the community.

No real effort has been made to organise data collected by various agencies and make it available in an integrated way — the present water information management system is fragmented. It is difficult to provide a clear picture of water resources covering the key aspects, especially at basin and regional level. The need to centralise state water data and information is well documented in the *Review of Water Resource Management Information in South Australia*:

‘Access to water information is required across government and between stakeholders, investors and the general public. Information is currently difficult to access and an overall information management system for South Australia’s water information is lacking’ (Phipps 2003, p.3).

10.2.1 DATA QUALITY

Quality assurance is an important component of the major monitoring programs. It is important to ensure that the data generated by monitoring and used to support decision-making in water resource management programs are valid and appropriate. Although all state monitoring programs have quality assurance plans that address how the quality of data is assured, data quality issues are identified in major databases (refer to previous sections of this report), raising the need to review the current quality control and assurance programs. It is suggested that:

1. The database custodian agencies — DWLBC, EPA and BoM — should complete a review of standard methods and standard operating procedures (SOP) for water resource monitoring, and make actions as appropriate to promote data consistency and comparability.

2. SOP and quality assurance plans should be well documented and publicly accessible.
3. Database custodian agencies have the expertise and authority to ensure that data suppliers and/or contractors follow SOP.

10.2.2 REAL-TIME DATA

DWLBC and other key agencies (SA Water and BoM) have facilities (telemetry) to provide real-time monitoring data within NRM regions. In the KINRM Region, SA Water has telemetric facilities for monitoring its water production wells and delivery system (pipelines and storages), and BoM can provide real-time meteorological data (BoM has six automated weather station on KI).

However, DWLBC has no telemetric facility for stream gauges and the Obswell network. The gathering of telemetric data, including water quantity and quality measurements, is a common practice and core for contemporary water monitoring. The procurement and installation of telemetric device for the existing and new stream gauges and observation wells in the KI is therefore highly desirable.

The provision of real-time water quality estimates analogous (e.g. salinity, pH and DO) to those for streamflow is a valuable adjunct to traditional streamflow information and, to the extent that resources permit, this capability should be expanded to KI as quickly as possible.

10.2.3 DATA MANAGEMENT

The integrative nature of water resources demands a centralised data warehouse designed to support organisational decision making. It can be updated automatically and structured for rapid online queries. A warehouse stores historical and consolidated data (e.g. flow records, water levels and water quality parameters, etc.) in a common format. Due to the high capital requirement and maintenance cost however, the review recognises that it might be more practical to take an evolutionary approach for data management, i.e. a step-by-step capacity-building process.

The following actions are needed:

1. Develop an integrated Internet webpage to facilitate data and information exchange, distribution and access, i.e. develop a state water data and information clearinghouse.

A clearinghouse is a decentralised system of servers located on the Internet that contains descriptions of available digital data known as metadata. Metadata are collected in a standard format to facilitate query and consistent presentation across participating sites. A clearinghouse uses readily available web technology for the interested parties or individuals to query, search and present search results. By utilising a standard method for these functions, a clearinghouse allows individual agencies, consortia and geographically defined communities to collectively promote their available digital spatial data.

As the hosting department of the SWMCC, DWLBC should be the leader in making water information and data easily accessible through the Internet. Moreover, through operating and maintaining the State Surface Water Archive and Obswell, DWLBC has accumulated necessary skills and expertise. However, commitments should be made by all concerned state and regional agencies to cooperate fully in development of the webpage. Information should be publicly accessible to the greatest extent possible.

2. Develop metadata to accompany all geospatial and temporal data collected by various programs.

Metadata should be developed to accompany all geospatial and temporal data, and in line with the *South Australian spatial information metadata guidelines* (ANZLIC 2000). This will benefit water resource managers by facilitating information discovery, networked GIS mapping, and assessment and consideration of information uncertainties.

11. PRINCIPAL FINDINGS AND STRATEGIC DIRECTIONS

11.1 PRINCIPAL FINDINGS

A number of agencies (DWLBC, BoM, EPA, SA Water, PIRSA and KINRMB) currently undertake water resources monitoring for quality and quantity assessments, and there is limited or no coordination between monitoring programs run by the different organisations or different groups within the same organisation. This review identifies the following links that should be established among the current monitoring programs to make better use of the available resources:

- stream-gauging network (DWLBC and KINRMB) and AWQMP (EPA).
- meteorological monitoring stations of BoM and DWLBC.
- DEH water quality monitoring and EPA AWQMP.
- KINRMB piezometer and Obswell.
- stream-gauging network and Obswell.

The current water monitoring network has significant gaps:

- spatial coverage is incomplete for both groundwater and surface water
- some essential parameters (both water quantity and quality) are not monitored.

Without substantial improvement, it cannot properly serve the function to evaluate change in resource conditions in relation to state and regional RCTs.

The majority of the components of the hydrological cycle are inadequately monitored (both spatially and temporally) to allow the development of basin-based hydrological models. These components include water levels or streamflow, evaporation, soil moisture, water use, and surface water – groundwater interactions.

Assessment of the impacts of catchment best management practices on water resources is limited by three factors:

- insufficiency of water balance data for most of the catchments, primarily due to a lack of stream-gauging stations in appropriate locations
- errors and breaks in current databases (e.g. Obswell, Surface Water Archive)
- deficiency of systemic and/or long-term ambient water quality data.

General information on catchment characteristics is available from various sources. The issue is actually how to use the available information for water resource management. The link between land and water resource conditions on KI is yet to be established.

Information delivery needs to be enhanced as this is an important and highly valued component of an integrated water monitoring program. A state agency (potentially DWLBC through the State Monitoring, Evaluation, and Reporting Policy Group) should provide access to a broader range of geospatially linked data (unit values, channel cross-sections, remotely sensed images, velocity fields, stream network position, and catchment attributes) to enable richer data interpretation than presently occurs.

11.2 STRATEGIC DIRECTIONS

During this review, several common ideas arose within each of the monitoring themes. These have been grouped together into overall strategic actions. Specific actions were also developed for each monitoring theme. The following paragraphs summarise these strategic directions.

11.2.1 OVERALL STRATEGIC DIRECTIONS

Action 1: Developing a water monitoring review process for identifying and coordinating monitoring efforts.

If monitoring is to remain viable, it must be flexible enough to adapt to changes in regional priorities or other aspects of natural resource management. Most changes to monitoring will need to be made based on information gleaned from previous data-collection efforts. Periodic, planned re-evaluation of the monitoring program is therefore suggested, at two different time scales.

Annual reviews would be used to assess and communicate the progress of monitoring, the quality of data collected, and any immediate findings such as violations of water quality standards or emergence of new issues. A work plan for the following year, with priorities and agency responsibilities for upcoming monitoring actions, would also be determined.

Every fifth year, the reassessment would include a more substantial analysis of data by the participating organisations. Topics for analysis would include, in addition to the annually examined aspects of the plan, an evaluation of trends in the data, effects of resource management, synthesis of data from multiple monitoring tasks (e.g. the relation of sediment transport to nutrient loading), and actions for modifications to the monitoring program.

Action 2: Creating and implementing a communication plan for monitoring information.

A communication plan would be developed to coordinate communication efforts, identify needs, provide tools and strategies, and identify resources, partners and opportunities.

Action 3: Establishing common protocols that enable data comparison among agencies and that are consistent with objectives for data collection.

The use of common, clearly defined protocols for sample collection, processing and laboratory analysis is important wherever possible to ensure the comparability of data collected by different organisations or over time within an individual organisation.

Action 4: Developing quality assurance plans for each major monitoring element.

QA plans will be critical to the success of monitoring. Good QC data, and assessments of those data, can allow the comparison of data among agencies and over time, whereas poor quality control can prevent such comparisons.

Although all state monitoring programs have QA plans, data quality issues are identified in major databases. The database custodian agencies, namely DWLBC, EPA, BoM and NRMB (CWMB), should complete a review of standard methods and SOP for water resource monitoring and take actions as appropriate to promote data consistency and comparability. SOP and quality assurance plans should be well documented and publicly accessible. Database custodian agencies should have authority and expertise to ensure that data suppliers and/or contractors follow the SOP.

Action 5: Establishing a data management strategy.

In order for monitoring data to be used to assess status and trends, compliance, and management effectiveness, those data will need to be available. An agreed strategy for data management would enhance the ability of different organisations to have access to monitoring data. Issues requiring discussion will include both programmatic and institutional, as well as technical. Programmatic and institutional issues include funding and staffing, and agreement on data sharing and data standards. Technical issues include system location, operation and maintenance, compatibility, database design (e.g. centralised or dispersed), and data accessibility.

Action 6: Working to increase availability of information, reports, and other products to other agencies and the public.

One of the criteria of success of the monitoring program is the degree to which the data collected, and the findings resulting from them, are used. A good monitoring program not only satisfies the data requirements of the data-collection agencies themselves, but also services a range of audiences including scientific researchers, resource managers, policy makers and the general public; each audience has different needs. For example, water mangers and policy makers are most likely to use interpretations resulting from the monitoring program such as reports rather than raw data. Including these end users as part of the data-collection and interpretive process increases the relevance of the monitoring program and the likelihood of its continued support by the involved organisations and public alike. This suggestion is differentiated from Suggestion 5 by its emphasis on results and analysis in order to provide information to the public. Suggestion 5 is more orientated towards the mechanics of making monitoring data available among agencies or other researchers for the purposes of analysis.

Action 7: Establishing a link between the state water monitoring networks and KINRMB monitoring and evaluation requirements. The outcomes of Rivers of Life would fill some of the vacuum.

The need for resource condition and trend monitoring is a very strong subject reflected in the theme-specific actions. One specific element was the need to develop a monitoring framework for assessing the processes towards the RCTs specified by KINRMB and the effectiveness of management actions, and the possibility of adopting and tailoring the current monitoring network.

11.2.2 SPECIFIC ACTIONS — AQUATIC ECOSYSTEMS

Action 1: Mapping all groundwater and surface water-dependent ecosystems to gain a preliminary understanding of the ecology of the systems.

This understanding is important to develop an aquatic ecosystem conceptual model, and identify risks and threats, which could then provide for informed decisions as to what wetlands need to be monitored, and help identify the best parameter choices, frequencies, etc.

Action 2: Developing an integrated aquatic ecosystem monitoring program, which includes three essential components — early warning indicators, ecosystem or habitat-based indicators, and catchment parameters.

Action 3: Considering aquatic ecosystem monitoring within the broad state water resource monitoring framework.

11.2.3 SPECIFIC ACTIONS — GROUNDWATER

Action 1: Establishing additional observation wells to complete the network for water quality monitoring, especial in the Rocky River Catchment, to establish reference resource condition for both the KINRM Region and the State.

Action 2: Establishing new observation wells (water level) in fractured rock aquifers.

Action 3: Installing continuous water level loggers in selected observation wells.

Action 4: Standardising the groundwater sampling technique for chemical analysis.

11.2.4 SPECIFIC ACTIONS — SURFACE WATER

Action 1: Re-defining the objectives and focus of DWLBC's stream-gauging network to mirror its modern natural resource management goals.

Action 2: Establishing stream-gauging stations, staff gauges or water level recorders in priority catchments.

Action 3: Incorporating auto-samplers, DO and pH probes with the current and future stream gauges.

Action 4: Considering collocating EPA's AWQMP and DWLBC's gauging-station network.

Action 5: Conducting special studies to investigate:

- Relation of nutrients to streamflow, pH, DO, nutrient sources, and perhaps turbidity and salinity in the Cygnet River Catchment to support the integrated management of Nepean Bay; in the Timber Creek Catchment for the protection of Murray Lagoon; in the Rocky River Catchment to establish a reference condition.
- Effects of different management alternatives on the Middle River Reservoir and downstream water quality.
- Groundwater inputs in the Rocky, Eleanor, Middle and Cygnet River Catchments, and their effects on water quality, especially salinity levels.

- Further study pesticides on the landscape and the impacts on aquatic ecosystems based on the results and conclusions from EPA's Pesticide Snapshot survey.
- Effects of urban development and high flow events on nutrient concentrations and water quality.

Action 6: Analysing evaporation data from BoM to develop an evaporation pattern across the region.

Action 7: Periodically updating the farm dam distribution maps (DWLBC).

Action 8: Incorporating soil moisture monitoring in evaporation monitoring sites.

Action 9: Further investigating the link between surface water and groundwater.

Action 10: Establishing water level recorders for regionally important aquatic ecosystems (e.g. Murray Lagoon).

APPENDICES

A. MONITORING STATION CATEGORIES

Stream-gauging station category (modified from Greenwood 2001)

Station category	Purpose	Minimum parameters	Duration	Frequency	Priority
Base station	To monitor outflow from the major yielding section(s) of the catchment.	Rainfall Water level, stream flow Stream salinity (EC and temp.)	On-going indefinitely (at least 25 years)	Download Quarterly	High
Basin outflow station	Streamflow leaving the catchment (e.g. flows into the ocean, inland lakes or interstate).	Water level, stream flow Stream salinity (EC and temp.)	Done as required for auditing and statutory reporting (5–10 years)	Download Quarterly	High
System inflow–outflow	Relates to streamflow 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, stream flow	Medium term (10 years)	Download Quarterly	High
Representative stations	Streamflow from areas representing particular features (e.g. hydrological characteristics, vegetation types or land-use practices). Can be independent of catchment.	Water level, stream flow Stream salinity (EC and temp.)	Medium term (10 years)	Download Quarterly	High–medium
Project station	Hydrological information not normally obtained from the monitoring network. Virtually any project of interest (e.g. surface – groundwater interactions).	Project specific	Usually short term (five years) but variable	Project specific	Medium–low
Environmental station	Sites considered significant for monitoring the water requirements of aquatic ecosystems.	Water level, stream flow Stream salinity (EC and temp.) Other parameters as required	Short–medium term (5–10 years)	Project specific	Medium–low

B. A HYPOTHETIC WETLAND MONITORING PROGRAM

Spatial scale Monitoring element Sample parameters	Method	Type[1]	Frequency[2]	Lead agency[3]
Regional climate				
Rainfall	Pluviometer	ST	Continuous	BoM
Evaporation	Evaporation pan	ST	Continuous	BoM
Regional geology				
Topography	Survey	ST	O	PIRSA
Soil type	Survey	ST	O	PIRSA
Regional hydrology				
Streamflow	Gauging station	ST, CO, EV	Continuous	DWLBC
Groundwater depth	Observation bore	ST, CO, EV	Monthly	DWLBC
Salinity gradient	Observation bore	ST, CO, EV	Annually	DWLBC
Landscape ecology				
Surrounding land use	Remote sensing	ST, EV	E5	DWLBC
Habitats patch size and distribution	Remote sensing	ST, EV	E5	DWLBC
Farm dam size and distribution	Registration	ST, CO	Update annually	EPNRMB
Wildlife species rich and abund.	Various	ST, EV	Annually	DEH
Site hydrology				
Pond water level	Staff gauge	ST, EV	Continuous	DWLBC
Groundwater depth	Piezometer	ST, EV	Continuous	DWLBC
Salinity gradients	Piezometer	ST, EV	Annually	DWLBC
Water quality				
Temp., turbidity, DO, EC, pH	Data logger	ST, CO, EV	Monthly	EPA
Nutrients, heavy metals, TOC, faecal coliform, chlorophyll a	Grab sampling, lab	ST, CO, EV	Monthly	EPA
Substrate				
Sediment rate	Sediment trap	ST, EV	E2	PIRSA
Root zone salinity	Lab	ST, EV	Annually	PIRSA
Root zone density, pH, grain size	Lab	ST	E2	PIRSA
Habitat				
Size	Remote sensing	ST, CO, EV	E5	DEH
Bank or channel stability	Field survey	ST, EV	E5	DEH
Buffer size and condition	Field survey	ST, EV	E5	DEH
Riparian and aquatic plant distribution	Remote sensing	ST,CO, EV	E5	DEH
Biological				
Plant species richness	Transect plot	ST, EV	E5	DEH
Macro-invertebrate species richness	AusRivAS	ST, EV	6-monthly	EPA
Vertebrate species richness	Various	ST, EV	Annually	DEH

1. Monitoring type: ST, Status and Trend; CO, Compliance; EV, Evaluation
2. Frequency: O, one time effect; Ex, Every x years.
3. See Table 3 for definition of lead agency.

C. WATER MONITORING IN THE KINRM REGION BY DWLBC

Agency Mission

- Integrated management of all of South Australia's natural resources.
- Improved health and productivity of our biodiversity, water, land and marine resources.
- Community, industry, governments and other stakeholders working together to achieve high-quality natural resources management outcomes.
- There is greater capability and willingness to invest in natural resources management to provide a sustained funding base.
- Wise resource allocation provides for the best environmental, social and economic outcomes.

Water Quantity Data

The department measures surface water level, flow, rainfall and rainfall intensity through its Hydrometric Surface Water Monitoring network. A network of observation wells was constructed to monitor groundwater levels.

Water Quantity Parameters, the Frequency and Geographic Scope of Collection by DWLBC

Data type	Geographic scope			Frequency of Collection			
	Regional	*Catchment*	*Project specific*	*Continuously*	*Monthly*	*Other*	*Not collected*
Water availability							
Runoff							✓
Streamflow	✓	✓	✓	✓			
Water level	✓	✓	✓	✓			
Water storage			✓			✓	
Aquifer recharge			✓			✓	
Groundwater levels	✓		✓		✓		
Precipitation	✓		✓	✓			
Evapo-transpiration							✓
Soil moisture							✓
Water withdrawal							
Withdrawal							✓
Consumptive use							✓
Return flow							✓

Water Quality Data

The current focus of DWLBC's 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 streamflow-gauging stations using an EC probe.

Water Quantity Parameters, the Frequency and Geographic Scope of Collection by DWLBC

Data type	Geographic scope			Frequency of collection			
	Regional	*Catchment*	*Project specific*	*Continuously*	*Monthly*	*Other*	*Not collected*
Chemical							
Pesticides							✓
Organics							✓
Metals							✓
Nutrients							✓
DO							✓
Physical							
pH							✓
Temperature	✓			✓			
Salinity(GW)	✓					✓	
Salinity (SW)	✓			✓			
Turbidity							✓
Biological							
Structure of aquatic communities							✓
Habitat							✓
Macro-invertebrates							✓
Indicator bacteria							✓

Storage Method and Accessibility

DWLBC's surface water data (quantity and quality) are stored in a database called HYDSYS. The analysed and raw data from HYDSTRA are fed into the State Surface Water Archive, which is a clickable, GIS-based free-access website. The groundwater data are stored in Obswell, which provides on-line access to the state's observation bore monitoring data. 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.

D. WATER MONITORING IN THE KINRM REGION BY EPA

Agency Mission

The EPA's mission is to protect and restore the environment as the basis for a sustainable future.

Water Quantity Data

The EPA does not collect water quantity data, except in rare circumstances.

Water Quality Data

The EPA monitors the state's waters to provide information on their condition and to identify important trends and issues through its AWQMP. The EPA also undertakes 'hot spot' monitoring to determine whether there has been a breach of the *Environment Protection Act 1993* (particularly the general environmental duty). In addition, many licensed activities that discharge to water bodies are required as a condition of licence to undertake monitoring of the discharge and report the results to the EPA.

Water Quantity Parameters, the Frequency and Geographic Scope of Collection by EPA

Data type	Geographic scope			Frequency of collection			
	Regional	*Catchment*	*Project specific*	*Continuously*	*Monthly*	*Other*	*Not collected*
Chemical							
Pesticides			✓		✓	✓	
Organics			✓		✓	✓	
Metals	✓	✓	✓		✓		
Nutrients	✓	✓	✓		✓		
DO	✓	✓	✓		✓		
Physical							
pH	✓	✓	✓		✓	✓	
Temperature	✓	✓	✓		✓	✓	
Salinity(GW)	✓	✓	✓		✓	✓	
Salinity (SW)	✓	✓	✓	✓	✓	✓	
Turbidity	✓	✓	✓	✓	✓	✓	
Biological							
Structure of aquatic communities							✓
Habitat			✓			✓	
Macro-invertebrates	✓	✓	✓			✓	
Indicator bacteria			✓			✓	

Storage Method and Accessibility

Water quality data on rivers and streams, groundwaters, lakes, and marine and estuarine waters are stored in EDMS (Environmental Data Management System), which the EPA is planning to make Internet accessible in the near future. Information held in EDMS is used to prepare the *State Water Plan*, the *State of Environment Report*, and other reports published by DEH that assess the state and condition of the water body.

STEDS stores water quality and quantity data under licence reported to EPA.

Other datasets held by the EPA include information on environmental authorisations, frog surveys, riparian assessments, sea grass coverage, reef condition and information on marine biota (e.g. heavy metals in mussels and dolphins).

E. WATER MONITORING IN THE KINRM REGION BY SA WATER

Agency Mission

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 our customers, the government and the community
- foster our people's talent and commitment.

Water Quantity Data

SA Water collects water quantity data largely in association with its water distribution projects. For example, it keeps track of rainfall amounts, reservoir storage, and inflow and outflow as part of operating specific projects.

Water Quantity Parameters, the Frequency and Geographic Scope of Collection by SA Water

Data type	Geographic scope			Frequency of collection			
	Regional	*Catchment*	*Project specific*	*Continuously*	*Monthly*	*Other*	*Not collected*
Water availability							
Runoff							✓
Streamflow		✓	✓	✓			
Water level		✓	✓	✓			
Water storage			✓			✓	
Aquifer recharge							✓
Groundwater levels							✓
Precipitation							✓
Evaporation							✓
Soil moisture							✓
Water withdrawal							
Withdrawal		✓				✓	
Consumptive use	✓					✓	
Return flow							✓

Water Quality Data

SA Water has a comprehensive water quality monitoring program which covers the system from catchment through to customer taps. It comprises both routine and event-based monitoring programs. Routine monitoring is based on the guidelines outlined in the *Australian Drinking Water Guidelines* and incorporates regular monitoring and subsequent assessment of all aspects of the system. Event-based sampling detects potential water quality problems arising from weather or rainfall-triggered events.

In the KINRM Region however, only drinking water quality monitoring is conducted.

Storage Method and Accessibility

There is an informal arrangement with DWLBC to store surface water quantity information on the HYDSTRA database (but not in the Surface Water Achieve). The groundwater levels data are stored in Obswell.

All water quality data collected by SA Water is held on a central database generated by the AWQC, and made publicly available though its annual report. In addition, as a condition of licence, SA Water is required to monitor the quality and quantity of discharges from sewage treatment works to receiving water bodies. Results are reported to the EPA and Department of Human Services (DHS) and are publicly available via the EPA.

F. WATER MONITORING IN THE KINRM REGION BY KINRMB

Agency Mission

The KINRMB has a stated vision:

'Address the full range of environmental and natural resource management issues relevant to KI, including conservation of biodiversity; sustainable agriculture; sustainable management of soil, water and vegetation; and sustainable use of wildlife and environmental protection. Furthermore, KINRMB shall oversee the responsibilities for these issues across terrestrial, coastal and marine environments of KI'.

Water Quantity data

Water Quantity Parameters, the Frequency and Geographic Scope of Collection by KINRM Board

Data type	Geographic scope			Frequency of collection			
	Regional	*Catchment*	*Project specific*	*Continuously*	*Monthly*	*Other*	*Not collected*
Water availability							
Runoff							✓
Streamflow	✓	✓	✓	✓			
Water level		✓	✓	✓			
Water storage							✓
Aquifer recharge							✓
Groundwater levels			✓				
Precipitation							✓
Evaporation							✓
Soil moisture							✓
Water withdrawal							
Withdrawal							✓
Consumptive use							✓
Return flow							✓

Water Quality data

Water Quality Parameters, the Frequency and Geographic Scope of Collection by KINRM Board

Data type	Geographic scope			Frequency of collection			
	Regional	*Catchment*	*Project specific*	*Continuously*	*Monthly*	*Other*	*Not collected*
Chemical							
Pesticides			✓		✓		
Organics							✓
Metals			✓		✓		
Nutrients		✓	✓		✓		
DO		✓	✓		✓		
Physical							
pH		✓	✓		✓	✓	
Temperature		✓	✓	✓	✓	✓	
Salinity(GW)		✓	✓		✓	✓	
Salinity (SW)		✓	✓	✓	✓	✓	
Turbidity		✓	✓		✓	✓	
Biological							
Structure of aquatic communities							✓
Habitat		✓					
Macro-invertebrates		✓					
Pathogen		✓					

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

~	approximately equal to
δD	hydrogen isotope composition
$\delta^{18}O$	oxygen isotope composition
^{14}C	carbon-14 isotope (percent modern carbon)
CFC	chlorofluorocarbon (parts per trillion volume)
EC	electrical conductivity (µS/cm)
pH	acidity
ppm	parts per million
ppb	parts per billion
TDS	total dissolved solids (mg/L)

GLOSSARY

ADAM — Australian Data Archive for Meteorology.

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

AWQMP — EPA's Ambient Water Quality Monitoring Program.

ANZECC — Australian and New Zealand Environment Conservation Council.

ARMCANZ — Agriculture and Resource Management Council of Australia and New Zealand.

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

Aquatic ecosystem — 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.

Aquiclude — In hydrologic terms, a formation that contains water but cannot transmit it rapidly enough to furnish a significant supply to a well or spring.

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.

AWS — Automatic Weather Station.

AWQMP — Ambient Water Quality Monitoring Program. Run by the South Australian Environment Protection Authority (EPA) since 1996.

Benthic zone — The lowest level of a body of water, such as an ocean or a lake. It is inhabited mostly by organisms that tolerate cool temperatures and low oxygen levels, called benthos or benthic organisms.

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.

Biota — All of the organisms, including animals, plants, fungi, and microorganisms, found in a given area.

BoM — Bureau of Metrology.

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

Compliance monitoring — Monitoring conducted in order 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 or introduced 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.

CWMB — Catchment Water Management Board.

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 and would likely include detection limit precision, accuracy, bias, and so forth.

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

DEH — Department for Environment and Heritage, South Australian Government.

DFIS — Digitised Facilities Information System.

DHS — Department of Human Services, South Australian Government.

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.

D/s — Downstream.

DO — Dissolved Oxygen.

DOC — Dissolved Organic Carbon.

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

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.

EDMS — Environmental Database Management System, administered by the Environment Protection Authority, South Australia.

Effectiveness monitoring — Documents how well the management practices meet intended objectives. Monitoring evaluates the cause and effect relations between management activities and conditions of the natural resources.

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 Australian Government.

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 runoff from the land.

EWS — Engineering and Water Supply Department, South Australian Government.

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.

Geomorphic — Related to the physical properties of the rock, soil and water in and around the stream.

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 and chemical theatre in which the ecological play takes place; it is a template for the biota, their interactions, and their evolution.

Hydric — Having or characterised by excessive moisture — 'hydric soil'.

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

Hydrophytic — Of or related to a hydrophyte, a plant adapted to growing in water, waterlogged soil or on a substrate that becomes inundated on a regular basis.

HYDSTRA — A time series data management system that stores continuously recorded water-related data such as water level, salinity and temperature. It provides a powerful data analysis, modelling and simulation system. Contains details of site locations, setup and other supporting information.

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

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

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

KI — Kangaroo Island.

KINRMB — Kangaroo Island Natural Resource Management Board.

Macro-invertebrate — Aquatic invertebrates including insects (e.g. larval Ephemeroptera and Trichoptera), crustaceans (e.g. amphipods), molluscs (e.g. aquatic snails) and worms (e.g. Platyhelminthes) that inhabit a river channel, pond, lake, wetland or ocean.

MAT — Management Action Targets.

Metadata — Information that describes the content, quality, condition and other characteristics of data.

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 Accreditation and Testing Authority.

Native species — Any animal and plant species originally in Australia. Also defined as 'indigenous species'.

NHT — Natural Heritage Trust.

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 (e.g. pollution that results from water runoff from urban areas, construction sites, agricultural and silvicultural operations, etc.).

NRHP — National River Health Program.

NRM — Natural Resource Management.

NRMB — Natural Resource Management Board.

Obswell — Observation Well Network.

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, South Australian Government.

Pluviometer — An automated rain gauge consisting of an instrument to measure the quantity of precipitation over a set period of time.

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.

Prescribed water resource — A water resource declared by the Governor of South Australia to be prescribed under the *Water Resources Act 1997*. Includes underground water 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 Resources Act 1997*. See also 'Prescribed water resource'.

QA — Quality assurance.

QC — Quality control.

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 comprise 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 contain ocean-derived salt in excess of 0.5 parts per thousand.

SA Geodata — A collection of linked databases storing geological and hydrogeological data, which the public can access at the front counters of PIRSA and its regional offices. Custodianship of data related to minerals–petroleum and groundwater is vested in PIRSA and DWLBC, respectively. DWLBC should be contacted for database extracts related to groundwater.

SARDI — South Australian Research and Development Institute, a Division within PIRSA.

SA Water — South Australian Water Corporation.

SOP — Standard Operating Procedures.

Sub-catchment — The area of land determined by topographical features within which rainfall will contribute to runoff 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.

Surface Water Archive — An internet-based database linked to HYDSTRA operated by DWLBC. It contains rainfall, water level, streamflow and salinity data collected from a network of surface water monitoring sites located throughout South Australia.

SWMCC — State Water Monitoring Coordination Committee (1999–2005).

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.

Turbidity — The cloudiness or haziness of water (or other fluid) caused by individual particles that are too small to be seen without magnification, thus being much like smoke in air.

U/s — upstream.

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 Resources Act 1997*.

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

Water column — a section of water extending from the surface of a body of water to its bottom. In the sea or ocean, it is referred to as 'pelagic zone'.

Water-dependent ecosystems — Those parts of the environment, the species composition and natural ecological processes, which 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 hardness — A measure of the amount of metallic salts (normally Ca and Mg) found in water. Hard water can inhibit the action of some surfactants and reduce the effectiveness of the cleaning process.

Water quality criteria — Comprised of both numerical and narrative criteria. Numerical criteria are scientifically derived ambient concentrations developed by the Environment Protection Agency (Australian 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 ground waters, 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.

WDE — Water-dependent ecosystem.

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