DWLBC REPORT

Northern and Yorke Natural Resources Management Region Water Monitoring Review

2006/15

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

Northern and Yorke Natural Resources Management Region Water Monitoring Review

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Report DWLBC 2006/15

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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 continue 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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PREFACE

This report, written during 2004–05, provides a useful record of water monitoring activities in the Northern and Yorke Natural Resources Management region.

Implementation of the *South Australian Natural Resources Management Act 2004* and subsequent publication of the South Australian Natural Resources Management Plan 2006 (NRM Plan; DWLBC 2005a,b) have resulted in fundamental changes in the frameworks for monitoring and evaluation in South Australia. This in turn has meant that the roles, responsibilities and constitution of state and regional agencies and organisations may have changed over time and these changes may not be fully reflected within this publication.

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

EXECUTIVE SUMMARY

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

The review covers information on the six themes of water resources data — surface water quantity, surface water quality, groundwater quantity, groundwater quality, aquatic ecosystems and catchment characteristics. These are convenient thematic divisions of the total resource for monitoring and fit the current division of responsibilities between agencies. However, a more unified approach is a key goal of the South Australian Government's NRM Plan 2006, which is for:

> 'Communities, governments and industries with the capability, commitment and connections to manage natural resources in an integrated way'.

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

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

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

- Fulfil the basic requirements of the National Monitoring and Evaluation Framework and National Water Initiative (NWI).
- Meet the needs of the National Land and Water Resource Audit (NLWRA) and for Natural Heritage Trust (NHT) funded programs.
- Comply with the State Monitoring and Evaluation Framework for Natural Resources Management.
- Satisfy the requirements for regional resource condition assessment and management.
- Satisfy the requirements of the state *Environment Protection Act 1993*.

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

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

1. INTRODUCTION

1.1 BACKGROUND

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

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

As part of the State Water Monitoring Review, this project has dealt with surface and groundwater resource monitoring for the Northern and Yorke Natural Resources Management (NYNRM) region covering five major themes — surface water quantity; surface water quality; groundwater quantity; groundwater quality; and aquatic ecosystems. Resource data and information management and catchment characteristics are also discussed.

1.2 AIM

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

1.3 METHODOLOGY

In each catchment or region, the review process focused on the five monitoring themes listed in Section 1.1, and involved the following steps:

- Review of roles and responsibilities of major stakeholders for water monitoring.
- Review of current surface water, groundwater and aquatic ecosystems issues.
- Review of current water monitoring activities and metadata.
- Mapping of location of surface water and groundwater monitoring sites.
- Workshops for key stakeholders to identify the purpose of, and agency responsible for, current monitoring sites.
- Identification of gaps and any duplication in monitoring.
- General suggestions for a future water monitoring strategy.

1.4 ROLES OF MAJOR STAKEHOLDERS

The major stakeholders in water monitoring in South Australia have been identified in Kneebone (2000). That report made recommendations as to the water monitoring roles to be undertaken by each agency. The systemic model shown in Table 1 summarises the recommendations made in that report.

For the purposes of this review, the term 'stakeholders' will refer to the organisations listed in Table 1.

1.5 STUDY AREA

The Northern and Yorke NRM region (NYNRM) consists of parts of the Adelaide Plains, northern Barossa Valley, and Yorke Peninsula. It reaches the Southern Flinders Ranges in the north and its eastern border follows the North Mount Lofty Ranges. It includes all catchment areas for the Light River, Wakefield River, Broughton River, Mambray Coast and Willochra Creek (Fig. 1). Part of the southern Lake Frome Basin is also contained within the area.

The region includes diverse landforms and climatic variation from the higher relief and rainfall areas of the North Mount Lofty and Southern Flinders Ranges, as well as arid inland plains. The region also features significant coastal areas.

Most of the NYNRM is dedicated to agriculture and has a highly productive cropping and grazing industry. The region includes the major wine growing area of the Clare Valley, and other areas are establishing their own wine growing credentials. Other industries such as fishing, aquaculture, mining, forestry, horticulture, and tourism also form part of the regional economy.

Water resources in the region are limited in capacity and extent, and resource development is concentrated in the few areas where water of a suitable quality is available. Information on the main water resources currently developed is adequate for a precautionary approach to management. However, there are insufficient data available to assess the development potential of, and impact on, smaller surface and groundwater resources.

Pressure on the water resources of the region has in some cases led to a need for legislative regulation to ensure long-term sustainability. These include the surface and groundwater resources of the Clare Valley (Prescribed Wells Area (PWA)); groundwater resources in the Baroota area (Notice of Intent to Prescribe/Notice of Restriction); and the Upper Wakefield River (Notice of Intent to Prescribe).

Outside of these areas, isolated pockets of development are found based on poorly understood smaller surface and groundwater resources. Recent assessment work has identified a number of these areas where closer scrutiny of resource development may also be required. These include the southern Willochra Creek and upper Broughton River Catchments. Ongoing work continues to assess the capability of local resources to meet increasing demand.

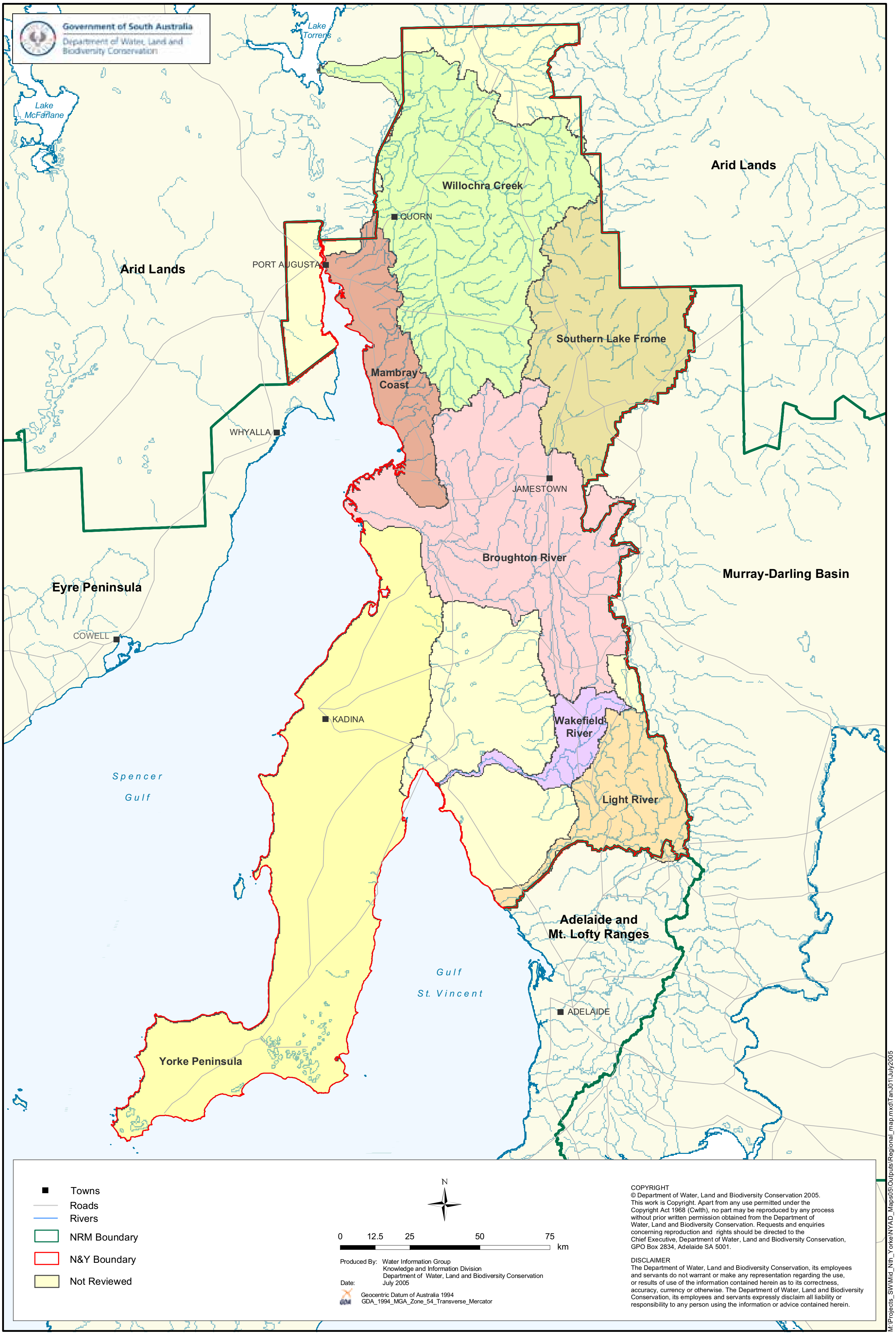

Figure 1. Northern and Yorke NRM Region Boundary

The semi-arid nature of much of the region has given rise to a great diversity of largely ephemeral, water-dependent ecosystems that derive their unique character from periodic drying. A number of important groundwater dependent ecosystems are also recognised, though few of these areas are currently protected for permanent conservation.

Watercourses in the NYNRM are generally ephemeral, with seasonal flow patterns. Despite periodic drying streambeds, banks and riparian zones are important aquatic habitats and in many cases examples of these habitats can be found in relatively unspoiled and natural condition.

Permanent aquatic habitats, such as groundwater dependent permanent surface water pools and baseflow reaches, occur throughout the region. These areas are invariably of great value to ecology and the economy, and warrant particular conservation attention. In currently designated conservation areas, very little of the important aquatic habitats are included or found.

1.6 HOW TO USE THIS REPORT

This report divides the NYNRM region into separate geographical areas, with the five monitoring themes identified above (Section 1.1) considered for each region. Geographical regions are mainly based on surface water catchment boundaries, as these are the most easily recognisable. The Willochra Creek Catchment is presented first, followed by the Broughton River, Wakefield River, Light River and Mambray Coast Catchments. Consideration of the Yorke Peninsula follows, and finally the southern Lake Frome Basin.

A brief introduction to the unique physical and geographical features of each catchment area is presented in Section 2. Risk factors relevant to water monitoring programs are also considered in this section.

Current monitoring is presented in Sections 4–9 with a discussion of current activities and a map of current and historical sites for each theme and each region. Further information on surface water monitoring site histories, such as parameters monitored and periods of record, are provided in Appendix A.

A summary of the key suggestions for future water monitoring developed from this review process is presented in tabular form in Section 11 (Tables 4–29). This simple presentation of the results of this review is intended to assist in the planning of future water monitoring activities. These tables summarise gaps in monitoring, suggestions for improvement developed during this review, prioritisation and agency(ies) responsible in relation to each monitoring category, as well as references to further elaboration within the text of this report.

2. CATCHMENT DESCRIPTION

2.1 WILLOCHRA CREEK CATCHMENT

2.1.1 PHYSICAL FEATURES

The Willochra Creek Catchment (Fig. 2), covering an area of over 6000 km^2, is ~250 km north of Adelaide in the Southern Flinders Ranges and includes Mount Remarkable. Topography strongly influences rainfall, with the southern parts of the catchment featuring a relatively high rainfall of over 600 mm, decreasing to under 250 mm with distance away from the ranges across the Willochra Plain and to the north (Risby et al. 2003). Low ranges including the Pekina and Yourambulla Ranges bound the catchment to the north and east. The main townships of the catchment include Murray Town, Booleroo Centre, Melrose, Wilmington and Quorn.

Figure 2. Kanyaka Creek surface water gauging weir in the Willochra Creek catchment (source: DWLBC).

2.1.2 SURFACE WATER

The main stream within the catchment is Willochra Creek, an ephemeral semi-arid river that flows from the base of Mount Remarkable around Melrose, northward through the Willochra Plain to Partacoona Station. The flow direction then trends northwesterly through the

Southern Flinders Ranges. The stream discharges to the saline Lake Torrens, north of the NYNRM region boundary. Campbell Creek and Spring Creek sub-catchments in the southwest of Willochra Catchment produce more runoff than all other sub-catchments within the catchment.

2.1.3 GROUNDWATER

The Willochra Plain overlies considerable groundwater resources of variable quality known generally as the Willochra Basin (Magarey & Deane 2004), where a confined Tertiary aquifer is overlain by a Quaternary aquifer. Water quality and yield are generally poor, with the exception of the Spring Creek area, where irrigation quality water is available (Magarey & Deane 2004).

2.1.4 AQUATIC ECOSYSTEMS

A range of high-value aquatic ecosystems throughout the Willochra Catchment are identified by Risby et al. (2003). These include permanent pool habitats in upper catchment tributaries and gorges of the lower Willochra, baseflow reaches and saline riparian wetlands in the lower catchment.

Riparian species, notably River Red Gums, are generally found to be isolated in distribution and in a degraded condition, often infested with the weed mistletoe. The condition of these species may have been impacted by reduced flows down Willochra Creek itself.

2.1.5 CATCHMENT CHARACTERISTICS

There is significant variation in catchment characteristics between the southern and northern sections of the catchment, for example differences in rainfall, topography, land use, evaporation and baseflow. In the northern section, watercourses are sustained by baseflow for ~80% of the year, whereas this is not the case in the southern section. The connectivity between the southern and northern parts of the catchment is largely absent with the exception of large flood events.

2.1.6 RISK FACTORS

The lack of suitable hydrological data for the Willochra Catchment reduces the accuracy and reliability of hydrological analysis and results necessary for sound management decisions.

The construction of farm dams and diversion of water for flood irrigation appear to be reaching sustainable limits. The construction of contour banks further reduces runoff, thus impacting on streamflow regimes and the environment. Vegetation clearance, channel modification and both point source and diffuse pollution are further risks that can adversely impact on the sustainability of surface water resources and water-dependent ecosystems.

Flood Irrigation is carried out mostly in the southern section of the catchment along Willochra Creek and its tributaries where the land is relatively flat. In-stream diversion structures capable of diverting water for the purpose of flood irrigation have also been located in the Wild Dog Creek sub-catchment through the use of aerial photography.

Diversion structures such as locks constructed for the purpose of flood irrigation can severely restrict flows downstream. If flood irrigation occurs annually and not opportunistically (when conditions are well above average), it is highly likely that water will not be available for downstream environments. Even if flood irrigation occurs only in high rainfall years, high flows considered important for maintaining environmental water requirements (EWR) will still be reduced. There has already been a reduction in permanent pools (Risby et al. 2003) possibly exacerbated by the practice of flood irrigation.

2.2 BROUGHTON RIVER CATCHMENT

2.2.1 PHYSICAL FEATURES

The Broughton River Catchment (Fig. 3) is ~130 km north of Adelaide and is the largest river system contained wholly in South Australia. The catchment has two distinct landscape features — the hills and valleys of the Southern Flinders Ranges and northern Mount Lofty Ranges; and the flat coastal plain. Rainfall is strongly influenced by this variation in topography across the catchment and ranges from 700 mm at Wirrabara to 325 mm at the coast (Favier et al. 2004).

Figure 3. Broughton River monitoring site at Mooroola (source: DWLBC).

The Clare Valley Prescribed Water Resource Area (PWRA) straddles the divide between the Broughton and Wakefield Catchments and is the most developed region in terms of water resource use and management.

2.2.2 SURFACE WATER

The total median discharge from the Broughton Catchment is estimated to be 46 500 ML, with high variability being a feature of flows. Recorded annual flows range from 4260 ML to over 100 000 ML (Favier et al. 2004).

The Broughton River starts at the junction of Yakilo Creek and the Hill River, and flows west past the towns of Yacka, Koolunga and Redhill before it discharges into Spencer Gulf at Port Davis. Major tributaries to the Broughton include Rocky River and Hutt River.

Whilst significant permanent baseflow reaches and springs occur within the Broughton Catchment, the system is ephemeral with only seasonal flow.

2.2.3 GROUNDWATER

Groundwater resources in the Broughton Catchment are sourced from both fractured rock and sedimentary aquifers. The major groundwater resources are those from the Booborowie Valley sedimentary aquifer which supports a significant irrigation industry and the fractured rock aquifer (FRA) in the Clare Valley region. FRA provide good quality water at high yield in places, but the nature of FRA makes them highly unpredictable and difficult to exploit. Outside the Clare Valley, FRA provide isolated supplies but this is not common.

2.2.4 AQUATIC ECOSYSTEMS

A diverse range of aquatic and water-dependent ecosystems occur within the Broughton Catchment. Important riverine habitat has been mapped by Favier et al. (2004) — ecological assets include baseflow reaches, permanent pools and springs.

2.2.5 CATCHMENT CHARACTERISTICS

The catchment features significant vineyard development in the Clare Valley. Irrigation development outside of this region is relatively limited but has been increasing and expanding in recent years, with vineyards and olives being the main crops. The Booborowie Valley area supports an irrigated lucerne seed and fodder industry, and has done so for over 30 years. Other land uses in the region include broad-scale cereal cropping and grazing.

2.2.6 RISK FACTORS

Key issues that pose a threat to EWR of the Broughton Catchment include the impact of farm dams and groundwater extraction in the Clare Valley; potential water resource development (e.g. dams and groundwater use) in other areas of the catchment; a lack of control over development outside of the Clare Valley PWRA; impacts of the Beetaloo Reservoir on flows along Crystal Brook; and potential impacts of groundwater use for lucerne crops on groundwater dependent ecosystems in the Booborowie Valley.

Burgeoning irrigation development in the north of the catchment, particularly in the area of the Rocky River sub-catchment, has the potential to develop to unsustainable levels. Increased information and assessment work needs to be undertaken to determine the level of risk.

A lack of monitoring data from the areas coming under development pressure makes assessing potential impacts difficult.

2.3 WAKEFIELD RIVER CATCHMENT

2.3.1 PHYSICAL FEATURES

The Wakefield River (Fig. 4) is situated in the Mid-North of South Australia ~100 km north of Adelaide. It can be divided into two major landforms — a broad coastal plain of low elevation; and the ridges and valleys of the northern Mount Lofty Ranges.

2.3.2 SURFACE WATER

The Wakefield River, the major hydrological feature in this catchment, is an ephemeral watercourse characterised by sporadic flows and long no-flow periods. The river and its major tributary, Eyre Creek, flow in a predominantly southerly direction to the confluence with Pine Creek, where the Wakefield River turns in a westerly direction. Several other tributaries then join the river, most notably Skillogalee Creek, before it crosses the coastal plain eventually draining into the head of Gulf St Vincent at the Port Wakefield estuary.

Variations in the topography of the catchment greatly influence rainfall, which ranges from around 300 mm near the coast to more than 650 mm in the higher elevations where most of the runoff is sourced. The major tributaries of the Wakefield River contributing to runoff are the Eyre and Skillogalee Creeks which rise in the high rainfall areas around Mount Horrocks.

2.3.3 GROUNDWATER

Groundwater resources in the upper areas of the catchment are primarily contained within FRA. These aquifers are not uniform and provide yields and salinities that vary from irrigation quality to marginal stock water (Favier et al. 2000).

On the coastal plains, groundwater is contained within alluvial sediments and water quality is linked to flows, being generally highly saline. During periods of flow along the Wakefield River, this salinity may be ameliorated due to local recharge from the watercourse.

Due to the ephemeral nature of watercourses in the Wakefield River Catchment, groundwater is of particular importance for sustaining surface water aquatic habitats such as permanent pools during the long dry periods. Groundwater baseflows also contribute to improved water quality of these pools and are therefore of ecological significance.

Figure 4. Mid-Wakefield River sub-catchment ('Wakefield River @ upstream of The Rocks') (source: DWLBC).

2.3.4 AQUATIC ECOSYSTEMS

Favier et al. (2000) recorded that the Wakefield River is, in general, in a degraded condition. The most ecologically significant areas are found in remnant lignum (Muehlenbeckia spp.) and tea tree (Melaleuca spp.) swamps, low-lying salt marshes on the coastal floodplain, and extensive mangroves of the Port Wakefield area.

Geomorphological zones and their ecological significance are identified and described in Favier et al. (2000). The most functionally intact area of the Wakefield River described in that report is the geomorphic zone classified as the 'Mobile Zone', comprised of the Wakefield River from Robbins Ford to The Rocks. Permanent pools and baseflow reaches occur in a number of zones and in varying ecological states.

2.3.5 CATCHMENT CHARACTERISTICS

The Wakefield River is one of three main ephemeral rivers in the Mid-North of the state, with the Broughton River to the north and the Light River to the south. The Wakefield River flows in a southerly direction through Auburn and turns west to flow through Balaklava and into the Port Wakefield estuary. As the Wakefield River is ephemeral, it relies heavily on baseflow from groundwater, especially during summer.

On the coastal flats from Port Wakefield to Balaklava, the average annual rainfall is around 300 mm. Eastward from these plains the rainfall increases to 660 mm in the higher elevation around Watervale. This area of high rainfall supplies most of the water to the Wakefield River.

2.3.6 RISK FACTORS

Land-use change associated with European settlement has had a significant impact on riverine habitats. Examples include the clearance of native riparian and floodplain vegetation; the loss of in-stream complexity due to channelisation, incision, deposition of sediment and erosion; stock grazing; and the introduction of exotic plants and animals. The original flow regime of the Wakefield River system has been modified from a chain-of-ponds morphology to continuous channels in much of the catchment. This has been due to vegetation clearance, agricultural development, farm dams and groundwater extraction. The growth of weeds, the impact of reeds and poor water quality are also significant risk factors.

2.4 LIGHT RIVER CATCHMENT

2.4.1 PHYSICAL FEATURES

The Light River Catchment is characterised by hills and valleys of the Mount Lofty Ranges and flat coastal plains.

2.4.2 SURFACE WATER

Watercourses within the catchment are semi-arid, being characterised by low water volumes with occasional large, short-lived flows as a result of periodic storm events (Fig. 5). In the coastal area, the river breaks into a number of smaller channels. This area floods approximately every four years and water enters Gulf St Vincent through numerous tidal channels.

Most watercourses cease to flow in summer and autumn, when the main channels dry back to form permanent pools. Some sections of watercourses dry up totally, for example the lower reaches of the Light River south of Mallala.

2.4.3 GROUNDWATER

The groundwater resources of the catchment are low yielding and generally highly saline (Vanlaarhoven et al. 2004). The use of groundwater is limited to stock and domestic. The resource supports key ecological processes through surface water expression as permanent pools or baseflow reaches.

2.4.4 AQUATIC ECOSYSTEMS

A number of inland aquatic ecological assets are identified, located and valued in Vanlaarhoven et al. (2004). Examples include permanent pools and baseflow reaches. Areas of good riparian vegetation are found in some areas which are also described in that report.

Figure 5. The Lower Light River during a major flow event, 1 km downstream of Port Wakefield Road crossing (source: DWLBC).

The Light River estuary is recognised as being of high conservation value for a number of reasons. Saline and freshwater wetlands are found in close proximity, providing habitat for a rich bird fauna and a high diversity of wetland plant species (Edyvane 1999). Bird species observed include those listed under state legislation and international agreements on the conservation of migratory birds.

Vanlaarhoven et al. (2004) reported that a large number and diversity of native fish were found in the estuary region. This contrasts with the remainder of the catchment and the Mid-North of the state in general, which features few native species.

2.4.5 CATCHMENT CHARACTERISTICS

The main agricultural activities in the catchment are cereal cropping and grazing. Historical poor land management practices such as extensive cultivation and fallow periods have changed soil structure, leading to increased runoff volumes and velocities in some places. This has in turn generated widespread erosion thought to have contributed to the deeply incised channels found today (Soil Conservation Council cited in Vanlaarhoven et al. 2004).

Water resource development is limited in the catchment due mainly to low volumes of flow and a groundwater system with naturally low yields and high salinities. Even though there is minimal use of water resources, riverine habitats have been significantly modified through vegetation clearance and agricultural development, resulting in altered flow regimes and ecological degradation.

2.4.6 RISK FACTORS

Vegetation clearance and agricultural development have resulted in an altered flow regime for watercourses in the catchment. Watercourse management issues identified include the conservation of important riparian habitats; protection of remnant vegetation; rehabilitation of good riparian vegetation; poor bank stability; and erosion heads. Local community concerns strongly reflect these issues.

Indications are that the quantities of baseflow may have decreased over the last 10–20 years. It is not yet clearly understood how changes to catchment hydrology (e.g. farm dam development) have affected groundwater recharge and discharge processes. This knowledge gap presents a risk to the sustainable management of these ecological and economic assets.

2.5 MAMBRAY COAST CATCHMENT

2.5.1 PHYSICAL FEATURES

The catchment area known as the Mambray Coast consists of the small ephemeral streams that drain the western slopes of the Southern Flinders Ranges into Spencer Gulf. The topography consists of the ranges themselves and the coastal plain between Port Pirie and Port Augusta.

2.5.2 SURFACE WATER

Permanent surface water is present in a number of springs and in the dominant surface water feature, the Baroota Reservoir. Springs present on watercourses tend to commence flowing during early winter as low-pressure systems begin to dominate weather patterns. This leads to significant areas of baseflow, especially in the Baroota Creek region.

Annual rainfall in the region ranges from below 300 mm to over 600 mm. During periods of significant rainfall, surface water runoff can be generated, but it is rare for these flows to reach Spencer Gulf. Streams become losing systems after leaving the hard rock watercourses of the ranges, and in the mid-catchment tend to dissipate underground, in turn feeding shallow riparian soaks and springs in the broad coastal plain.

2.5.3 GROUNDWATER

Groundwater is the dominant water source for landholders in the region and is used to water stock, with dams often not holding water for long periods of time. Good supplies are concentrated along north–south-trending fault lines, particularly in the area of Baroota Creek and the plains downstream of the Baroota Reservoir.

Groundwater is an important source for permanent surface water, and several springs in the central to southern upper region of the catchment are not known to have ever dried up.

2.5.4 AQUATIC ECOSYSTEMS

Significant permanent pools and seasonal spring-fed baseflow reaches provide extensive areas of surface flows. Eucalyptus trees lining lowland watercourses are considered to be water dependent.

It is likely that some level of groundwater permanently discharges to Spencer Gulf. While the ecological effects of such a discharge are unknown, it is likely to be of significance in helping to moderate the hypersaline conditions present in the upper Spencer Gulf.

2.5.5 CATCHMENT CHARACTERISTICS

Cereal cropping and grazing are the dominant land uses in the catchment, with the coastal and lowland areas more dedicated to cropping. Isolated irrigation development occurs in the Baroota Notice of Restriction Area, with vines and potatoes the typical crops.

Much of the slopes of the Southern Flinders Ranges in the catchment are protected by state conservation legislation. There are also small coastal parks in the catchment. Vegetation in these areas is considered to be representative of pre-European conditions.

2.5.6 RISK FACTORS

The key risk in this catchment would be associated with excessive use of groundwater resources. However, even outside of the Baroota Notice of Restriction area this currently seems unlikely.

2.6 YORKE PENINSULA

2.6.1 PHYSICAL FEATURES

Yorke Peninsula is a predominantly limestone undulating plain of generally low relief, featuring an extensive coastline that includes beaches, cliffs and rocky shores.

2.6.2 SURFACE WATER

There is little defined surface water drainage, with many watercourses terminating in land-locked saline wetlands. The most prominent drainage outlet is the ephemeral Winulta Creek.

Rainfall varies from ~380 mm/y in the north to ~500 mm/y in the lower southwest.

2.6.3 GROUNDWATER

Groundwater yield and quality varies considerably throughout Yorke Peninsula. The groundwater resources of greatest significance are the Carribie and Para-Wurlie Basins in the southwestern region. Water is generally of good quality within these two basins, with salinity levels often less than 1000 mg/L. Magarey and Deane (2004) provided a summary of the hydrogeology and water use of the peninsula.

2.6.4 AQUATIC ECOSYSTEMS

Seaman (2002) undertook a baseline inventory of wetlands in the Mid-North and Yorke region. Three wetlands on Yorke Peninsula have been found to be of high conservation value — Gum Flat, Native Hen Lagoon, and Chain of Lakes. However, that study did not include private property where many wetland areas of conservation value are likely to be found. It is also possible that some groundwater outflows to the near-shore marine environment may have ecological significance. Further mapping and assessment work to categorise and evaluate the conservation value of all wetlands present would be of benefit to water resources management and planning.

2.6.5 CATCHMENT CHARACTERISTICS

Yorke Peninsula includes significant coastal regions of high conservation and scenic value, particularly in the southwest. This area provides an easily accessible location for leisure and holiday activities and is well frequented, particularly by residents of nearby Adelaide. Tourism and seasonal residences such as holiday homes and shacks provide a major source of income in coastal towns and areas.

Yorke Peninsula is largely a region dedicated to cereal cropping but with some grazing.

2.6.6 RISK FACTORS

The high tourism value of coastal regions presents the risk of significant coastal development. Potential new developments and an increasing population in existing centres may place pressure on the limited groundwater resources of the peninsula.

Irrigation is not considered to be a major threat to groundwater resources on Yorke Peninsula due to the generally poor nature of soils present which results in relatively little agriculture.

2.7 SOUTHERN LAKE FROME BASIN

2.7.1 PHYSICAL FEATURES

The southern Lake Frome Basin is bounded to the west and south by the Broughton River and Willochra Creek Catchment divides, respectively, and to the east by the South Australian Murray-Darling Basin. To the northeast, it is bounded by the South Australian Arid Lands NRM Region, which also marks the start of pastoral country. Relief is generally low hills and undulating plains.

2.7.2 SURFACE WATER

There is little defined surface drainage outside of the higher relief areas. Once on the plains country, water dissipates without flowing to defined lakes or salinas.

Pekina Creek is the most well developed drainage for the region, rising in the hills forming the catchment divide between the Lake Frome Basin and Broughton and Willochra Catchments. Pekina Creek was formerly the site of a water supply reservoir, now abandoned due to siltation. The creek itself is thought to be a possible source of recharge for the Tertiary aquifer in the Walloway Basin. There is a small waterhole below the reservoir on Pekina Creek which may be pumped for emergency water supplies (Magarey & Deane 2004).

Farm dams are commonly marked on topographic maps but the impact, if any, of these on surface water runoff quantities is unknown.

2.7.3 GROUNDWATER

The most significant and only major water resource is the Walloway Groundwater Basin, lying around 260 km north of Adelaide. The basin has artesian and sub-artesian water available from several aquifers. The Tertiary aquifer predominates and the salinity of water in this resource is of the order of 1500–1700 mg/L (Magarey & Deane 2004). The township of Orroroo takes its water supply from this aquifer.

Other bores and wells sited throughout the region are used for stock and domestic supplies.

2.7.4 AQUATIC ECOSYSTEMS

The area has not been investigated for water-dependent ecosystems. It is likely that the drainage lines from the higher country may have small permanent pools similar to the one at Pekina Creek. The area between the former reservoir and the township is a popular walking trail and features some aquatic habitat.

2.7.5 CATCHMENT CHARACTERISTICS

The region is in marginal cropping country, with the main land use being grazing.

3. ROLES AND RESPONSIBILITIES OF STAKEHOLDERS

3.1 LEGISLATIVE REQUIREMENTS

This section refers to the State Water Monitoring Review and defines the roles and responsibilities for the major agencies involved in water monitoring state wide. Agencies discussed are not necessarily involved in water monitoring in the NYNRM region.

Two Acts define most of the state's legislative reporting and planning responsibilities associated with water resource management. These are the *Natural Resources Management Act 2004* and the *Environment Protection Act 1993*.

The roles and responsibilities discussed in this section are those defined by these Acts, and not by the author.

3.1.1 LEGISLATIVE MANDATES

Natural Resources Management Act (SA) 2004

The monitoring of South Australia's water resources has been conducted by various state agencies for most of the last century. These efforts were directed at characterising the aquatic resources and water quality problems of the state and this basic aim remains valid today. The South Australian *Natural Resources Management Act 2004* establishes 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…'

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's natural resources management was established including an NRM Council, eight regional NRM Boards (NRMB) and sub-regional NRM groups. Each of these organisations is provided by the Act with clearly stated functions regarding water resource monitoring, which are summarised below.

The State Government Minister is required:

s.10 (1) a	to keep the state and condition of the natural resources of the state under review
s.10 (1) e	to compile, maintain and update information in relation to the state's natural resources

s.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's role is:

s.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

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

Under this section of the Act, the NRM council must prepare and maintain a plan to be called The State Natural Resources Management Plan (also referred to as the Sate NRM Plan in this report). The State NRM Plan must:

s.74 (3) a — (i) assess the state and condition of the natural resources of the state

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

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

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

The regional NRMB have a responsibility to:

s.29 (1) b — (i) prepare a regional NRM Plan in accordance with this Act

(ii) implement that plan

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

The regional NRM Plan must:

s.75(3) e — set out the method or methods that the board will use to:

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

(ii) 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

(iii) 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 (WAP) for each prescribed water resource in its region. A WAP must:

s.76 (4) 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,

include an assessment as to whether the taking or the use of water from the resource will have a detrimental effect on the quantity or quality of what is available from any other water resource

s.76 (4) 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
- the rate of use of the water is sustainable.

Environment Protection Act (SA) 1993

The *Environment Protection Act 1993* establishes the South Australian Environmental Protection Agency (EPA) and authorises it to conduct activities as necessary to carry out the purposes of the Act, which include the monitoring of water quality. The following items delineate the water monitoring requirements of the EPA.

The objectives of the Act are to:

s.10 (1) b (i) 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,

(ii) provide for reporting on the state of the environment on a periodic basis.

The function of the EPA is to:

s.10(1) g institute or supervise environmental monitoring and evaluation programs.

3.1.2 OVERVIEW OF AGENCY ROLES

There are numerous agencies and organisations carrying out water monitoring activities in South Australia at the local, state and Commonwealth or national level. The state, primarily through DWLBC, the EPA, the Department for Environment and Heritage (DEH), and the NRMB, 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 or are interested in obtaining state agency data. These groups include health, public works and planning departments in local governments, certain businesses, selected non-governmental environmental organisations and some university and school programs. Commonwealth agencies serve as important partners but, with the exception of the Bureau of Meteorology (BoM), the focus of these is primarily on research and special projects, or on regional programs conducted in connection with Commonwealth agency missions.

This section focuses on those programs conducted by DWLBC, EPA, South Australian Water Corporation (SA Water), and NRMB. It outlines the roles of agencies and organisations involved in monitoring in SA, and identifies the key data and information needs of water resource programs. Detailed information about all the stakeholders, including mission statements, interests and responsibilities are provided in Kneebone (2000).

3.1.3 MAJOR STAKEHOLDERS

DWLBC, EPA, DEH, SA Water, BoM and NRMB have important roles in water monitoring in South Australia. The roles of the key agencies are discussed below.

Environment Protection Authority (EPA)

As the state's principal environmental protection and regulatory agency, the 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/or historical pollution problems
- determining the status of living aquatic resources
- community monitoring.

Department of Water, Land and Biodiversity Conservation (DWLBC)

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

- status and trends of water quality and quantity
- identification of existing and future risks of damage to, or degradation of, water resources
- evaluation of living resource habitats
- ensuring the EWR of water-dependent ecosystems.

SA Water

SA Water is responsible for the storage, treatment and distribution of bulk water; the provision of reticulated, potable and public water supplies; and the collection, treatment and disposal of sewage.

SA Water's water quality monitoring program provides key information to assist the management of water supply systems and to ensure that performance standards are met. It comprises both routine and event-based monitoring programs. The key objectives of the monitoring program 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 the effective operation of treatment systems

- provide key information to facilitate the effective operation of drinking water supply systems and distribution
- identify emerging issues with the total water system.

Bureau of Meteorology (BoM)

BoM is one of the major water resource data collection agencies in South Australia. Since 1988 it has been responsible 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 purposes.

BoM 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.

Natural Resources Management Board (NRMB)

The NYNRM Integrated Natural Resources Management Plan (NYAD INRMC 2003) lists three goals in relation to water management, all of which require monitoring programs to provide baseline data and enable evaluation of the condition of water resources and progress towards these goals.

The three goals are:

- Water use in balance with the requirements of natural ecosystems while also sustaining primary production and domestic and urban use.
- Surface and groundwater quality protected and enhanced to ensure suitability for natural ecosystems and beneficial use where appropriate.
- No further increase in the area affected by secondary groundwater driven salinity on natural and human-made resources. Areas subject to salinity contributing significantly to profitable production, biodiversity conservation and/or landscape amenity. Surface water salinity at levels that do not impact significantly on natural biodiversity within those water systems.

3.2 SYSTEMIC MONITORING MODEL

Table 1 gives the systemic model for water monitoring in South Australia. This model is based on that developed for Northern Adelaide and Barossa (NAB) catchment area by Johnston (2002), which was based on the work of Kneebone (2000). This model indicates the roles, responsibilities and information needs of the various agencies with an interest in water-related monitoring data.

Table 1. Systemic model for water monitoring in South Australia (source: Wen 2005).

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

Classification	Parameter	Purposes	Lead agency[1]	Collaborative agency[2]	Interested agency[3]
Water availability (continued)	Effluent	Additional water supplies Receiving water body ecosystem health assessment Water quality assessment	SA Water	EPA, NRMB, local councils, DWLBC	DEH
	Soil moisture	Catchment hydrological model	PIRSA	DWLBC, NRMB	EPA, DEH
	Groundwater level	Water allocation Environmental flows Groundwater dependent ecosystem health assessment Water quality assessment Dryland salinity management Surface to groundwater relationships	DWLBC	EPA, NRMB, PIRSA, SA Water	DEH
	Climate change	All aspects of natural resources management	BoM	PIRSA, DWLBC, DEH, EPA, NRMB, SA Water	
Water withdrawal	Extraction	Water allocation Environmental flows Catchment water budget	DWLBC	SA Water, NRMB	EPA, DEH
	Water use	Water allocation Environmental flows Efficient use of water resources Catchment water budget	NRMB	DWLBC, SA Water	EPA, DEH
	Farm dam	Catchment hydrological model Environmental flows	DWLBC	NRMB, PIRSA, EPA	SA Water, DEH
Return flow	Irrigation drainage	Catchment hydrological model Environmental flows Salinity management	PIRSA	DWLBC, NRMB, SA water, EPA	DEH

Classification	Parameter	Purposes	Lead agency[1]	Collaborative agency[2]	Interested agency[3]
Water Quality	Deep drainage	Dryland salinity management Groundwater quality assessment	PIRSA	DWLBC, NRMB	EPA
	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 Evaluation salt interception schemes Dryland salinity management	DWLBC	EPA, NRMB, PIRSA, SA Water	DEH
Aquatic ecosystems (inland)	Water regime Water quality Biological integrity	Environmental value assessment Ecosystem health assessment Environmental flows Surface and groundwater interaction	DWLBC	EPA, NRMB, DEH	PIRSA
Aquatic ecosystems (marine)	Water quality Biological integrity	Ecosystem health assessment Environmental value assessment Aquaculture based monitoring	DEH, PIRSA	DWLBC, EPA, NRMB	PIRSA, DWLBC, EPA

Note

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

4. CURRENT MONITORING SCHEMES — BACKGROUND

4.1 OVERVIEW OF WATER MONITORING

The ultimate source of all fresh water available for human use in the NYNRM region is precipitation, except that sourced through water purification processes. Fresh water is used for agriculture, harvested as runoff or streamflow, and stored in dams or aquifers from which it is pumped or redirected to areas of need.

Different information needs will affect the design of monitoring networks, with differing spatial and temporal scales of data collection required. It is vital that information needs are considered during the design and review of monitoring programs to ensure the suitability of data collected. A suitable regional monitoring strategy would synthesise the needs of the users of resource information across scales of time and space to ensure that appropriate information is available when required.

4.1.1 NETWORK DESIGN PRINCIPLES

As discussed above, information requirements dictate monitoring network design considerations. Networks are dynamic arrangements, responding to emerging understanding or potential issues requiring investigation. DWLBC has determined a range of differing station types, which are provided in Appendix B. Data will rarely fulfil only one purpose and hence many stations can be placed under more than one station category. Placing stations into categories helps to provide a conceptual basis for understanding the overall monitoring approach and where individual stations may fit within a strategy.

Station types are matched to major information requirements and this in turn provides a reference to consider issues such as location of site, parameters sampled, lifespan of station and cost-sharing possibilities during both the program design and review processes.

It is important to consider the information needs of resource managers to formulate responsible policy when designing monitoring networks. Hydrometric monitoring is only one element of an integrated surface water information system (Saunders 1985) capable of providing such information. Other aspects of an information system, beyond that of the physical monitoring network, include the following (adapted from Saunders 1985):

- Data editing — preparation of raw data for entry into databases or for analyses.
- Data verification — ensuring that data looks ‘reasonable’ based on what is known about the system.
- Data storage, security and accessibility — ensuring effective storage of data in a secure, maintained database, available to researchers or the public.
- Evaluation — analysis of the data to produce information.
- Regular review — adequacy of the water information system (including but not limited to the monitoring network).

- Assessment of the adequacy of information being provided in relation to foreseeable needs.
- Assessment of any existing gaps or emerging redundancies.

Information requirements change considerably over time as new issues or needs arise and as greater understanding is gained. The roles and responsibilities of authorities are also subject to change, potentially disconnecting end-users from the data collection process. It is therefore essential for monitoring networks to be adaptable to change to ensure that the current and future needs of resource managers are met (Saunders 1985; Greenwood 2001).

Regular reviews of water information systems, including monitoring networks, are advisable to ensure their adequacy. This need not be an onerous task provided that programs are designed with clearly articulated goals and have coordinators who maintain a good understanding of the process of collecting, editing and analysing data. It is suggested that at least a cursory review occurs with each annual budget cycle, with a full review every five years during catchment planning processes.

4.1.2 OPERATIONAL LIFE

As the monitoring record builds up, a higher degree of certainty can be developed that hydrological parameters, such as mean flow determined from monitoring data, will approach the true value. Statistical sampling theory shows that the standard error in the mean (as a proportion of the mean) is inversely proportional to the square root of the number of years of monitoring record and directly proportional to the coefficient of variance. Hence, highly variable systems require longer monitoring records to reduce the error in the mean (see Saunders 1985 for a more detailed discussion). Put simply, to halve the error in the mean for a given variability, four times the length of monitoring record is required.

An implication of the spatial and temporal variability in rainfall patterns in the NYNRM region is that very long monitoring records are required to discern any measurable change due to shifts in climatic patterns. There is also a risk that a project station commissioned for a short period of time may produce limited results within the predicted period of record required.

4.2 DEFINITIONS OF WATER RESOURCE MONITORING

It is not possible, practical or appropriate to monitor every single aspect of all natural resources to the utmost level of scrutiny possible with existing technology. At some point in time during the program design process compromises will inevitably be made between appropriate spatial and temporal coverage and the available resources for monitoring.

Although critical, monitoring exists to support management and is only one component of the process of managing natural resources. Adaptive management is generally considered to be best practice, particularly where technical understanding is incomplete, as is often the case with natural resources. As one part of a management cycle, monitoring data neither exists, nor is of any value, by itself. The aim of monitoring data in the first instance is to clarify issues most relevant to natural resources management. This can only occur through regular technical evaluation of the raw data.

It is therefore vital that the aims of monitoring data collection, including the specific management questions that are to be addressed, are made explicit when designing a monitoring program. This is to ensure that issues such as the scale and precision of data collected are appropriate for the intended use. Part of a review process for monitoring programs then entails ensuring that data being collected are matched to information or knowledge requirements. Monitoring program design would ideally also consider the program review and evaluation process.

Monitoring station categories have been developed by DWLBC to assist in the design of programs (these appear in App. B).

4.3 MONITORING METHODS EMPLOYED

This section contains descriptions and background information on monitoring programs for groundwater, surface water and ecological condition, with site information provided later in this report.

4.3.1 SURFACE WATER QUANTITY

DWLBC is the state agency responsible for collecting and storing surface water quantity data. The South Australian Surface Water Archive contains data collected at surface water and other water-related monitoring sites across the state. Data collected by DWLBC and any other organisation is available through this archive. The data are stored in the HYDSYS data management and reporting system, which can be queried to provide subsets of the data.

Site information such as location, equipment and monitoring parameters can be stored on HYDSYS, as well as information on measured values for rainfall stream or reservoir water level, flow volume or rate, and salinity.

In addition to current ongoing monitoring sites, a lot of data are collected as part of specific projects. Such data are likely to be particular to short-term objectives and may require contextual information regarding the project in order to be interpreted effectively.

Prepared HYDSYS-generated reports are available from the DWLBC website <http://www.dwlbc.sa.gov.au/water/rivers/swa.html>. For more detailed information or for information not available online, requests can be directed to the Knowledge and Information Division of DWLBC (contact details at the front of this report).

4.3.2 SURFACE WATER QUALITY

The EPA conducts ambient water quality testing for a range of analytes including nutrients and heavy metals at various sites and frequencies. Macro-invertebrate sampling assessed using the AusRivAS model (described in further detail in Section 4.3.4) is also undertaken at some sites. Bacteriological and algal cell count monitoring may be undertaken where this is considered to be a catchment risk. Information is recorded in a database at the Australian Water Quality Centre (AWQC) where the analysis is undertaken. It is planned that the data will be made available via the Internet in the future. The location of ambient water quality monitoring sites is provided in another section of this report.

4.3.3 GROUNDWATER MONITORING

Observation monitoring wells have been established to monitor trends in groundwater levels and/or salinity for all areas of the state by a variety of organisations. 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 SAGeodata database.

Where observation wells are to be used for monitoring purposes, they are grouped together into 'networks' that delineate a region in the state, a particular organisation doing the monitoring, or a specific aquifer. Any group that maintains and reads monitoring wells would ideally provide the information to DWLBC for entry into SAGeodata.

In some instances monitoring is undertaken for only a short period of time, for example during project work. In such circumstances the onus currently lies with the organisation undertaking the project to provide the data for inclusion in the database. There is, however, no requirement or incentive for this to occur. Resourcing and communication problems mean that some data have inevitably not been recorded.

The timeframes for forwarding information to DWLBC head office for entry into the database vary. For example, some groups may forward the information immediately after wells are actually read, whilst other groups may collate results and forward periodically, for example 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 searchable Obswell interface is linked to SAGeodata and provides access to monitoring well information. Wells are read periodically at intervals specific to the well or network. 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. Information on the networks and individual wells associated with each of these networks is available on the DWLBC website <http://www.dwlbc.sa.gov.au/water/publications /obswell.html>.

4.3.4 AQUATIC ECOSYSTEMS

AusRivAS

The only ongoing ecosystem monitoring program in the state is the EPA Ambient Program, which uses the National Australian River Assessment System (AusRivAS) model. The AusRivAS program has been operating since 1994. The model requires data obtained by the sampling of macro-invertebrate communities from the basic habitat types (riffles and edge). Representative samples are identified to species level where possible, and physico-chemical characteristics of the site are also measured.

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

Waterwatch

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

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

Frog Census

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

5. CURRENT MONITORING — SURFACE WATER QUANTITY

5.1 *WILLOCHRA CREEK CATCHMENT*

The current surface water monitoring sites within the Willochra Creek Catchment are shown in Figure 6. Details of site operation such as periods of record and parameters monitored are provided in Appendix A. Below is a discussion of the current monitoring for surface water quantity, perceived inadequacies (or gaps) in this network and suggestions for improvement. Unless noted otherwise, suggestions presented are taken from Risby et al. (2003).

5.1.1 METEOROLOGICAL MONITORING

Risby et al. (2003) stated that most of the rainfall gauging stations in the Willochra Creek Catchment are located in the low-lying areas and very few have been established in the ranges. To gain a better understanding of the rainfall–runoff relationship and thus improve on rainfall–runoff modelling, recommendations made in that report to expand rainfall monitoring into the ranges, as well as upstream of any newly established streamflow gauging stations, are supported.

DWLBC recently established a new meteorological station in the Spring Creek sub-catchment 'Spring Creek Pluvio @ Willowie Forest' (A5091003). At least one further monitoring site is suggested in higher elevation country. The catchment divide between Campbell and Yellowman Creek sub-catchments or Horrocks Pass Road in Beautiful Valley sub-catchment would provide ideal locations for an expanded pluviometer network.

No monitoring of evaporation is currently carried out for the Willochra Creek Catchment. Appropriate meteorological monitoring stations could be used to fill this gap.

5.1.2 STREAMFLOW MONITORING

A discussion of where each existing station fits within DWLBC hydrological monitoring network station categories is provided below.

Base Stations

The role of a base station (see App. B or Greenwood 2001 for an explanation) is to monitor outflow from the major yielding section(s) of the catchment. It is a high priority monitoring station category and the minimum monitoring parameters generally include rainfall, level or flow, and salinity. One base station is currently operating in the catchment, namely 'Willochra Creek @ Partacoona' (AW509502). Consideration could be given to installing a pluviometer at this site to record rainfall, although Risby et al. (2003) indicated that understanding rainfall generated within the ranges is a higher priority.

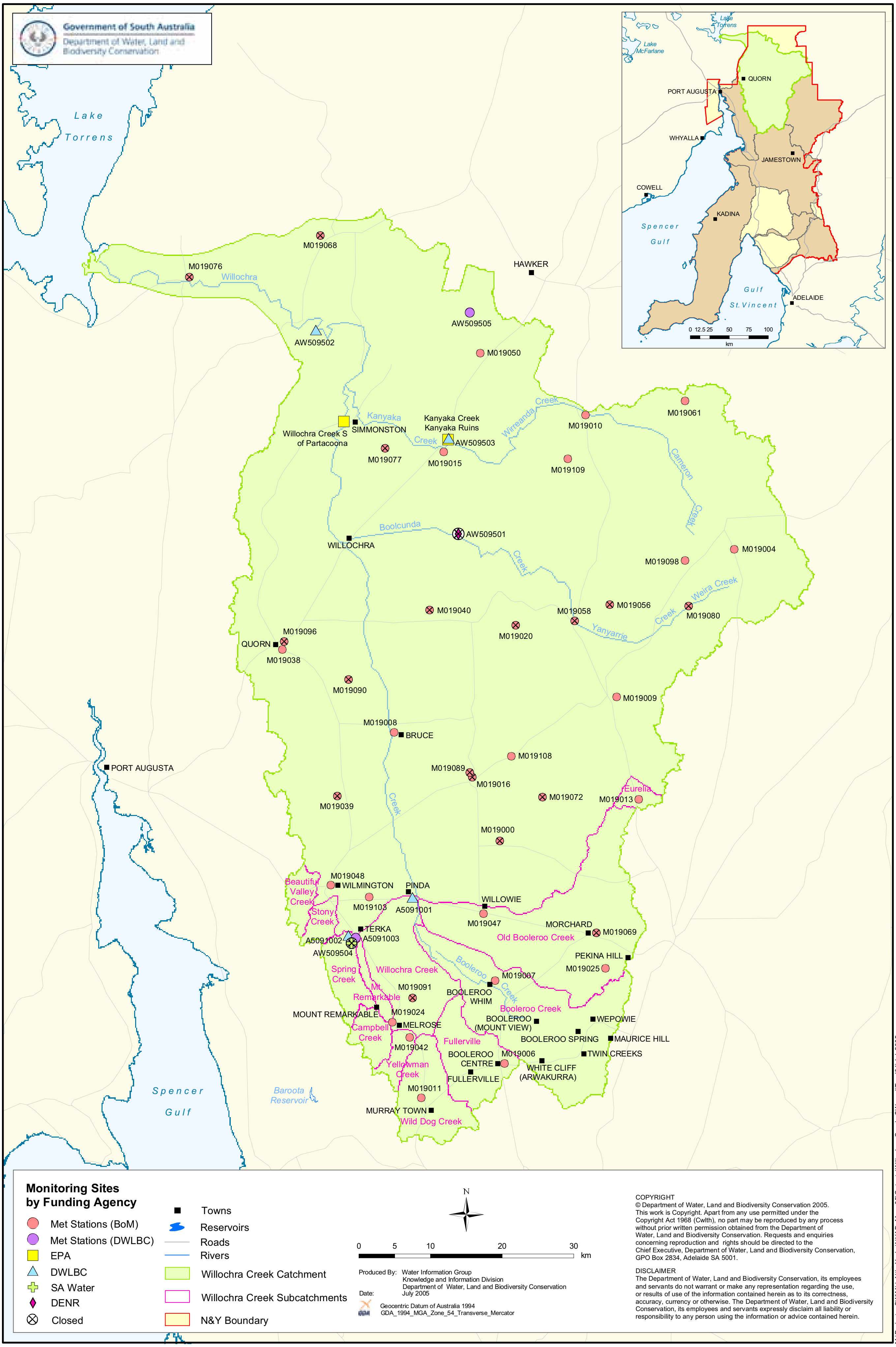

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Figure 6. Surface Water Monitoring Sites (Current and Historic) in the Willochra Creek Catchment

The new site 'Spring Creek @ upstream Willowie Forest' (A5091002) could serve as a base station for the southern section of the catchment, as this site has been established to monitor flow and salinity. Having an adjacent site 'Spring Creek Pluvio @ Willowie Forest' (A5091003) that will monitor rainfall will meet the minimum requirements of a base station.

Streamflow is currently being monitored at 'Willochra Creek @ Partacoona' (AW509502), 'Kanyaka Creek @ Old Kanyaka Ruins' (AW509503) in the northern catchment area, 'Willochra Creek @ Pinda Bridge' (A5091001) and 'Spring Creek @ upstream Willowie Forest' (A5091002) in the southern area of the catchment (Fig. 7).

Figure 7. 'Spring Creek @ upstream Willowie Forest' (A5091002). This site has replaced 'Spring Creek @ Terka' (AW509504) (source: DWLBC).

A velocity transducer has been installed to monitor flow velocity at the Pinda Bridge site (Fig. 8) as there is no permanent controlling feature (weir). A cross-sectional area is derived and is multiplied by the measured velocity to produce discharge and volume measurements.

Streamflow monitoring for the southern portion of the catchment will ideally be expanded to become more representative of the various catchment characteristics, in conjunction with rainfall monitoring. The northern catchment region has less development than the southern and suggestions for an expansion of streamflow monitoring made in this report are therefore considered to be a higher priority for the southern region.

It is suggested that a site be located in the Willochra Creek sub-catchment immediately downstream of Melrose to measure the volume of water entering the Willochra Plain. In addition, two sites could be located on Old Booleroo Creek downstream of the confluence of Stokes and Morchard Creeks off the Orroroo Road to provide a greater understanding of the volume of water generated from the eastern Willochra catchment. Another site south of Willowie and upstream of the overflow could be used in conjunction with previously described locations to determine stream transmission losses.

Figure 8. 'Willochra Creek @ Pinda Bridge' (A5091001) (source: DWLBC).

These sites would ideally monitor level, flow, EC and temperature, but could potentially be replaced by low-cost water level monitoring sites at suitable locations (see below).

Environmental Water Level Stations

There are currently insufficient data to ascertain what water regimes are needed to sustain the ecological values of aquatic ecosystems. New monitoring sites are essential to address this information gap. Water level monitoring sites provide additional data, adding value to quantitative continuous streamflow monitoring sites.

Three water level monitoring sites are suggested to address the above requirement and the three proposed streamflow sites in the above section could potentially be replaced by water level sites.

Three sites are proposed for Willochra Creek to provide an indication of longitudinal flow duration patterns:

- upstream of the township of Bruce
- upstream of the township of Willochra (at the same location as the current EPA ambient and macro-invertebrate monitoring site 'Willochra Creek South of Partacoona')
- downstream of the confluence with Kanyaka Creek.

Just upstream of the township of Willochra along Boolcunda Creek at Langwarren there is an old DEH site, namely 'Boolcunda Creek @ Langwarren' (AW509501), where flow was monitored from 1972 until 1992. This site could be reopened to monitor EWR. Data obtained over the course of 20 years from the old site may be a useful addition to any future monitoring at this location.

5.1.3 RELATED ISSUES

Flood Irrigation

Flow monitoring for the Willochra Creek and Wild Dog Creek sub-catchments is advisable in relation to the impact of flood irrigation on environmental flows. Suggested locations are — Willochra Creek upstream of confluence with Booleroo Creek to determine the volume of water used for flood irrigation to compare to the ’Willochra Creek @ Pinda Bridge’ data; a second site could be located in the northern section of Wild Dog Creek sub-catchment. For the remaining sub-catchments, flood irrigation is either unsuitable due to terrain or has not been identified.

Farm Dams

Where on-stream farm dams occur in high densities, a delay may be caused in the onset of streamflow downstream. Off-stream farm dams capture surface water runoff before it enters a watercourse, which again may delay the onset of streamflow events and may also reduce peak flows. These impacts could be detrimental to parts of the environment that depend on early seasonal streamflow, particularly in areas where rainfall is generally low. Farm dams across the catchment have not yet been mapped and it is suggested that this be done. Later in the future, after a good rainfall season and while dams are still at capacity, aerial photographs of the catchment will improve the accuracy of volumetric calculations of dam capacity.

Wild Dog Creek, Beautiful Valley and Willochra sub-catchments have been identified as close to, or possibly exceeding, the sustainable development limit. Wild Dog Creek has the greatest level of development and a high density of farm dams. It is therefore suggested that dam development be monitored for these sub-catchments in the lower reaches of relevant watercourses.

Table 4 provides details of suggestions developed during this review for the improvement of surface water quantity monitoring in this catchment.

5.2 BROUGHTON RIVER CATCHMENT

5.2.1 METEOROLOGICAL MONITORING

Rainfall monitoring is occurring in all sub-catchments in the Broughton River Catchment (Table 2). Evaporation is being monitored by BoM at the ’Beetaloo Reservoir Port Germein’ (M021124) meteorological site in the Crystal Brook sub-catchment and the ’Spalding (Bundaleer Reservoir)’ (M021009) site in the Bundaleer and Never Never Creeks sub-catchment. SA Water is monitoring evaporation at the ’Bundaleer Reservoir’ (AW507504) site. It is suggested that investigation into expanding the evaporation monitoring program be carried out.

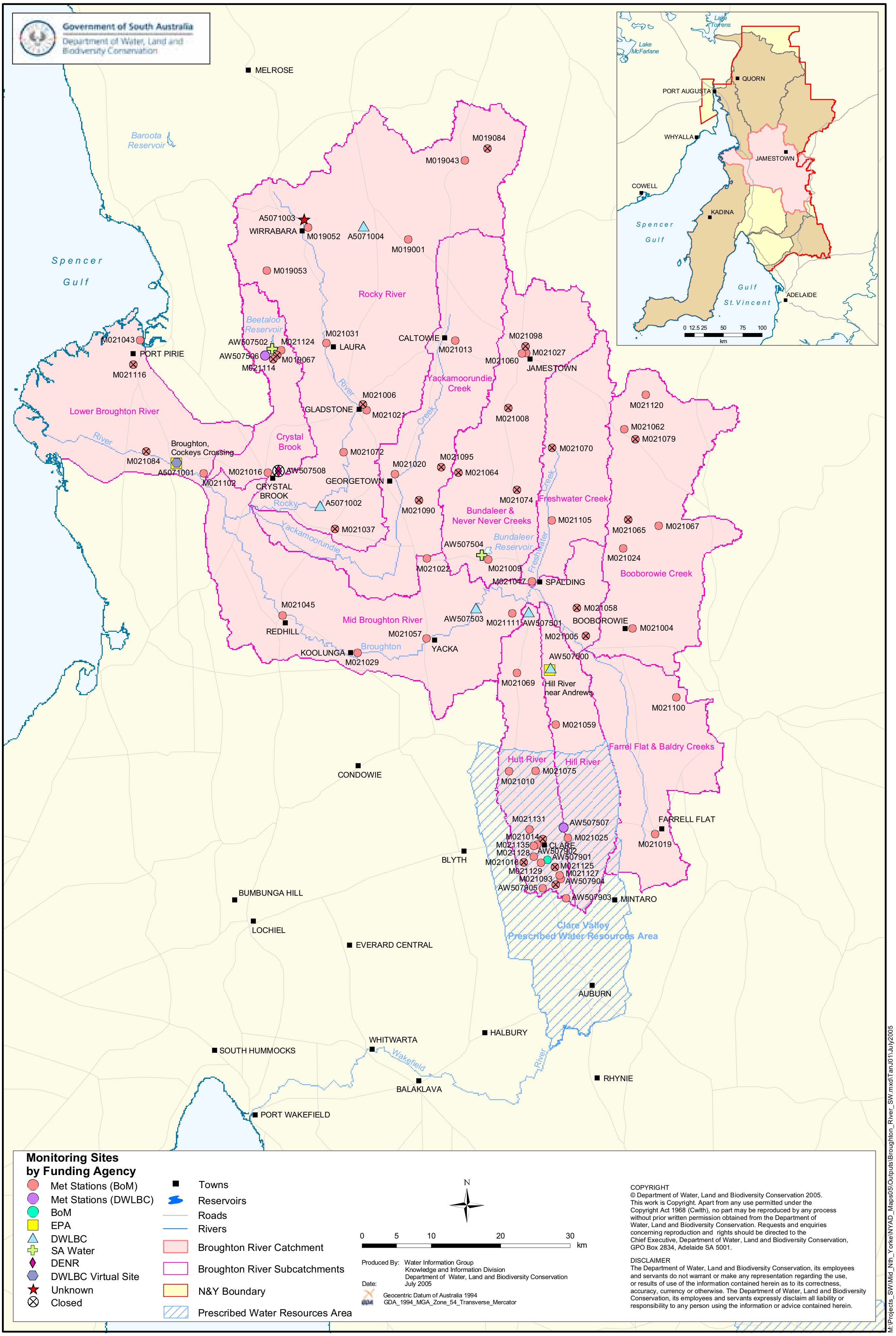

Figure 9. Surface Water Monitoring Sites (Current and Historic) in the Broughton River Catchment

Table 2. Surface water quantity monitoring — Broughton River Catchment.

Sub-catchment	Current ongoing monitoring	
Lower Broughton River	Rainfall	BoM
	Ambient and macro-invertebrate	EPA
Crystal Brook	Rainfall and evaporation	BoM
	Rainfall	DWLBC
	Reservoir level and yield	SA Water
Yackamoorundie Creek	Rainfall	BoM
Bundaleer and Never Never Creeks	Rainfall and evaporation	BoM
	Reservoir yield	SA Water
Freshwater Creek	Rainfall	BoM
Booborowie Creek	Rainfall	BoM
Farrel Flat and Baldry Creeks	Rainfall	BoM
Lake View	Rainfall	BoM
Lake Bumbunga	Rainfall	BoM
South Hummocks	Rainfall	BoM
Diamond Lake	Rainfall	BoM

5.2.2 STREAMFLOW MONITORING

Streamflow is currently being monitored by DWLBC at base station ’Broughton River @ Mooroola’ (AW507503) in the Mid Broughton sub-catchment, by DWLBC at ’Hutt River @ near Spalding’ (AW507501), by BoM at ’Hutt River @ Clare Caravan Park’ (AW507901) in the Hutt River sub-catchment, by DWLBC at ’Hill River @ near Andrews’ (AW507500) in the Hill River sub-catchment, by DWLBC at ‘Rocky River downstream of Thredgolds Crossing’ (A5071002), at ‘Rocky River @ upstream of Wirrabara’ (A5071003) and at ‘Pine Creek upstream of Appila Creek’ (A5071004).

Base station AW507503 does not meet the minimum requirements of this kind of monitoring station as it does not include salinity monitoring.

Three new sites have recently been established in the Rocky River sub-catchment ’Rocky River downstream Thredgolds Crossing‘ (A5071002), ’Rocky River @ upstream Wirrabara‘ (A5071003) and ’Pine Creek @ upstream Appila Creek‘ (A5071004). Flows and salinity are monitored at these sites for the Rocky River sub-catchment.

It is suggested that:

- An additional basin outflow station monitoring flow and salinity be established in the Lower Broughton River sub-catchment at the highway. This station will measure the total runoff from the catchment, allow loss rates to be determined and monitor salinity trends.
- A site be established on Yackamoorundie Creek to provide information on runoff and salinity relationships in drier areas of the catchment.

The hydrology of watercourses in the catchment is not well understood and needs further research. There is little recorded flow data available for the Broughton River downstream of Mooroola and along major tributaries such as Rocky River and Crystal Brook.

Overall, there is still a need for an expansion of the flow monitoring network to include those sub-catchments representative of various catchment characteristics within the Broughton River Catchment. A discussion of other stations defined within the DWLBC hydrological monitoring network station categories follows (Appendix B).

System Inflow–Outflow Stations

Beetaloo Reservoir

Beetaloo Reservoir provides on-stream storage for domestic water supply and is situated on Crystal Brook. The reservoir has altered the natural flow regime downstream, reducing low, medium and high flows. Monitoring upstream and downstream of this reservoir would ascertain its impact on streamflows.

Bundaleer Reservoir

Bundaleer Reservoir provides off-stream storage for domestic supply in the Yakilo Creek sub-catchment, which is supplied via an aqueduct system from the Bundaleer and Baderloo Creeks. Being an off-stream reservoir, it does not have a direct effect on flows in the Bundaleer Creek but does take good quality water out of the system which may indirectly affect flows. In addition, weirs constructed as part of the aqueduct system will affect flow downstream as well as transport of sediment. This water is used in conjunction with River Murray water. SA Water currently monitors water levels in the reservoir.

Weirs were constructed as part of the aqueduct system for this reservoir and it is suggested that flows downstream of these be monitored.

Environmental Water Level Stations

As in the Willochra Creek Catchment, there are currently insufficient data to ascertain what water regimes are needed to sustain the ecological values of aquatic ecosystems in the Broughton River Catchment. New monitoring sites are essential to address this information gap. Water level monitoring sites provide additional data, adding value to quantitative continuous streamflow monitoring sites.

Five environmental monitoring stations are suggested for the Broughton River to give an indication of flow downstream of the Mooroola base station, and salinity monitoring could be established on at least two of these sites:

- Yacka
- Koolunga
- Redhill
- Cockeys Crossing
- downstream Hutt River.

Two water level sites are suggested for Rocky River near Laura and Gladstone. These will provide additional information on flow in support of the new Rocky River gauging stations.

5.2.3 RELATED ISSUES

Farm Dams

Farm dams are common in the Hutt and Hill River sub-catchments and also within the Rocky River Catchment. These dams alter flow downstream in terms of volume and timing of flows. There are insufficient data to determine whether farm dams are presenting an unacceptable impact on flows in these sub-catchments or the Broughton River. Monitoring and research in this area is therefore suggested to address this knowledge gap.

Water use in general needs to be further investigated, for example with regard to the expanding viticulture industry.

Table 9 details suggestions developed during this review for the improvement of surface water quantity monitoring for this catchment.

5.3 WAKEFIELD RIVER CATCHMENT

5.3.1 METEOROLOGICAL MONITORING

Rainfall monitoring is occurring in all sub-catchments (except the Pine Creek sub-catchment) of the Wakefield River Catchment. At meteorological site 'Koonowla' (M023350), BoM was monitoring rainfall from 1899 until 1907 in the Pine Creek sub-catchment. It is suggested that rainfall monitoring be re-established within this sub-catchment. Evaporation monitoring is also suggested in this catchment as none is currently being carried out.

5.3.2 STREAMFLOW MONITORING

Streamflow is currently being monitored by DWLBC in the Eyre Creek sub-catchment at 'Eyre Creek @ Watervale' (AW506501) and 'Eyre Creek @ Auburn' (AW506502), as well as in the Woolshed Creek sub-catchment at the DWLBC base station 'Wakefield River @ near Rhynie' (AW506500).

No streamflow monitoring is currently being conducted for the sub-catchments listed in Table 3. Where any of these sub-catchments feature unique catchment characteristics, it is suggested that ongoing flow monitoring be established and that such monitoring be located so it may be used in conjunction with any existing rainfall monitoring.

A discussion of where each existing station fits within DWLBC hydrological monitoring network station categories follows.

Base Stations

One base station is currently operating in the catchment, namely 'Wakefield River @ near Rhynie' (AW506500), monitoring rainfall and streamflow. This station does not currently meet the minimum requirements of a base station as it does not monitor salinity.

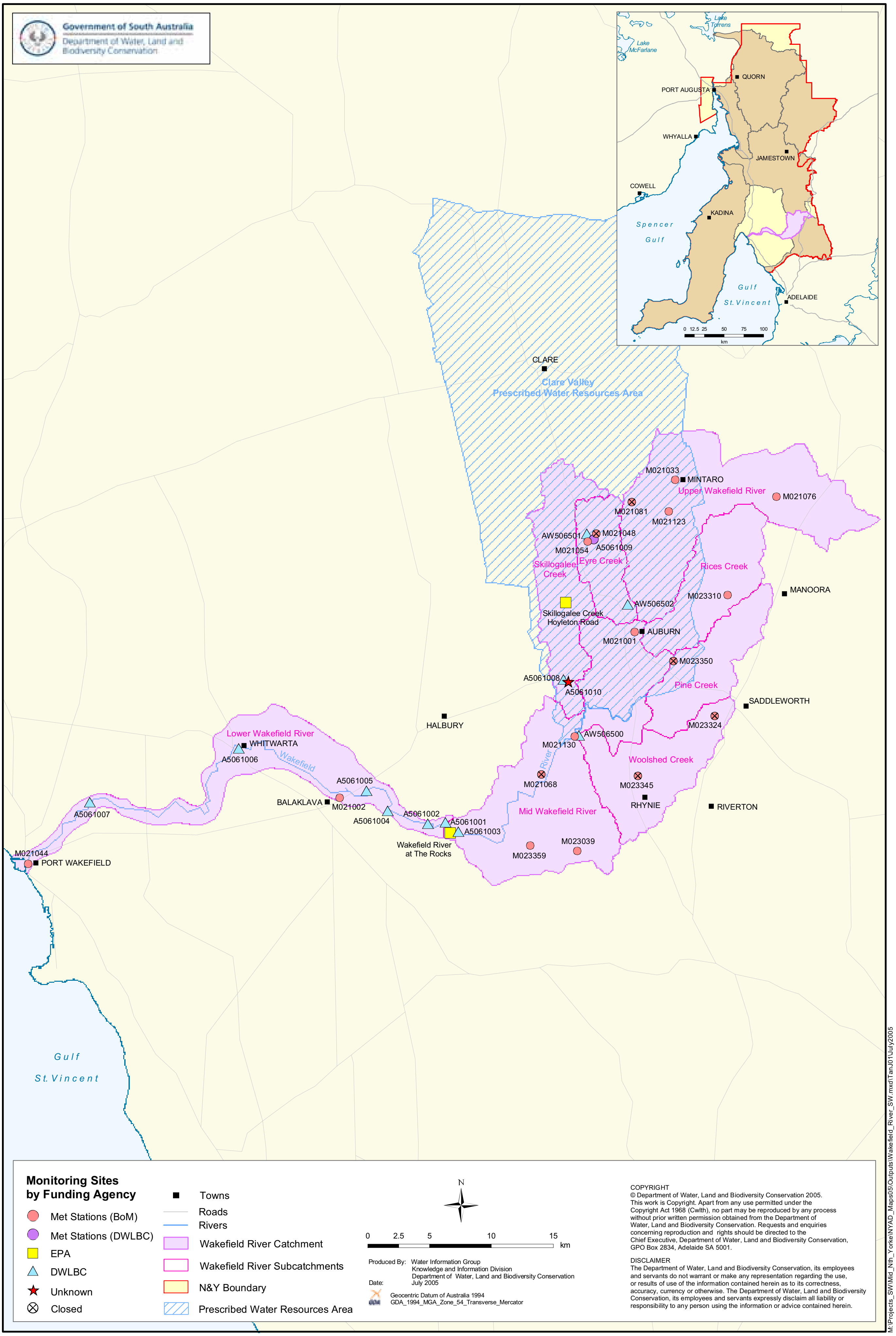

Figure 10. Surface Water Monitoring Sites (Current and Historic) in the Wakefield River Catchment

Table 3. Surface water quantity monitoring — Wakefield River Catchment.

Sub-catchment	Current ongoing monitoring	
Upper Wakefield River	Rainfall	BoM
Skillogalee Creek	Ambient and macro-invertebrate Rainfall, levels and salinity	EPA DWLBC
Rices Creek	Rainfall	BoM
Pine Creek	None	None
Mid Wakefield River	Rainfall Levels Ambient and macro-invertebrate	BoM DWLBC EPA
Lower Wakefield River	Levels Rainfall	DWLBC BoM

Basin Outflow Station

In the Lower Wakefield River sub-catchment, a DWLBC station is monitoring water levels at 'Wakefield River @ Port Wakefield' (A5061007) to fulfil the purpose of an environmental flow monitoring site. It is suggested that this station also serve as a basin outflow station to monitor levels or flow and salinity (and ideally other water quality parameters) of water entering Gulf St Vincent.

Environmental Water Level Stations

Five environmental water level monitoring sites have been established on the Wakefield River. It would be beneficial to establish two further stations for environmental water level monitoring on the river, located near to Whitwarta and Port Wakefield. These stations would also include salinity monitoring to investigate any affect of Diamond Lake on water quality in the river.

5.3.3 RELATED ISSUES

Farm Dams

The number of farm dams and associated volumes of water have not been quantified accurately for the Wakefield River Catchment. It is essential that this information gap is addressed through further assessment of farm dam surface water capture and its impact on downstream users.

Table 15 details suggestions developed during this review for the improvement of surface water quantity monitoring for this catchment.

5.4 LIGHT RIVER CATCHMENT

5.4.1 METEOROLOGICAL MONITORING

Rainfall monitoring is carried out in all sub-catchments of the Light River Catchment except the Pine Creek sub-catchment.

Evaporation is not being monitored at all in the Light River Catchment. It is suggested that appropriate sites be selected for the establishment of evaporation monitoring in the catchment, as it is essential to address this data gap.

5.4.2 STREAMFLOW MONITORING

There is currently only one gauging station monitoring levels (and flow) in the Light catchment. This is the 'Light River @ Mingays Waterhole' (AW505532) site, located in the Mid Light sub-catchment. In order to determine flow characteristics and assess EWR of aquatic ecosystems in this catchment, it is suggested that the streamflow monitoring network be expanded. In ecologically important areas, determining flow characteristics would aid in assessing whether EWR are being met.

DWLBC recently reviewed the Light River Catchment monitoring requirements to meet state reporting requirements. Following consideration of two key reports (VanLaarhoven et al. 2004; Murdoch 2003) the following 12 monitoring suggestions were developed by hydrologists from DWLBC in order to implement an ideal monitoring network.

1. 'Light River Mingays Waterhole' AW505532 — existing monitoring site.

   Currently measuring continuous water level, flow and rainfall. Telemetered.

   Station categories: long-term, base station and EWR.

   Upgrade requirements:
   - new weir to increase low to mid-flow sensitivity, needed for trend analysis on baseflow
   - continuous salinity, requiring EC and temperature probe
   - 100% backup of continuous water level — self-contained water level recorder
   - 100% backup of rainfall logging recorder. General data use: long-term assessment of the catchment; flood warning site.

2. Gilbert River upstream of Light River — new monitoring site.

   Location: just upstream of the Light River junction and before any significant contributing catchment.

   Station categories: long-term, representative station and EWR.

   Requirements:
   - weir with good low to mid-flow sensitivity
   - continuous water level and flow
   - continuous salinity, requiring EC and temperature probe
   - rainfall (pluviometer) — Rimco
   - telemetry
   - 100% backup of continuous water level — self-contained water level recorder.

General data use: long-term assessment of the catchment; flood warning site (subject to BoM requirements); quality of recharge water; altitudinal effects on rainfall and better isohyet definition.

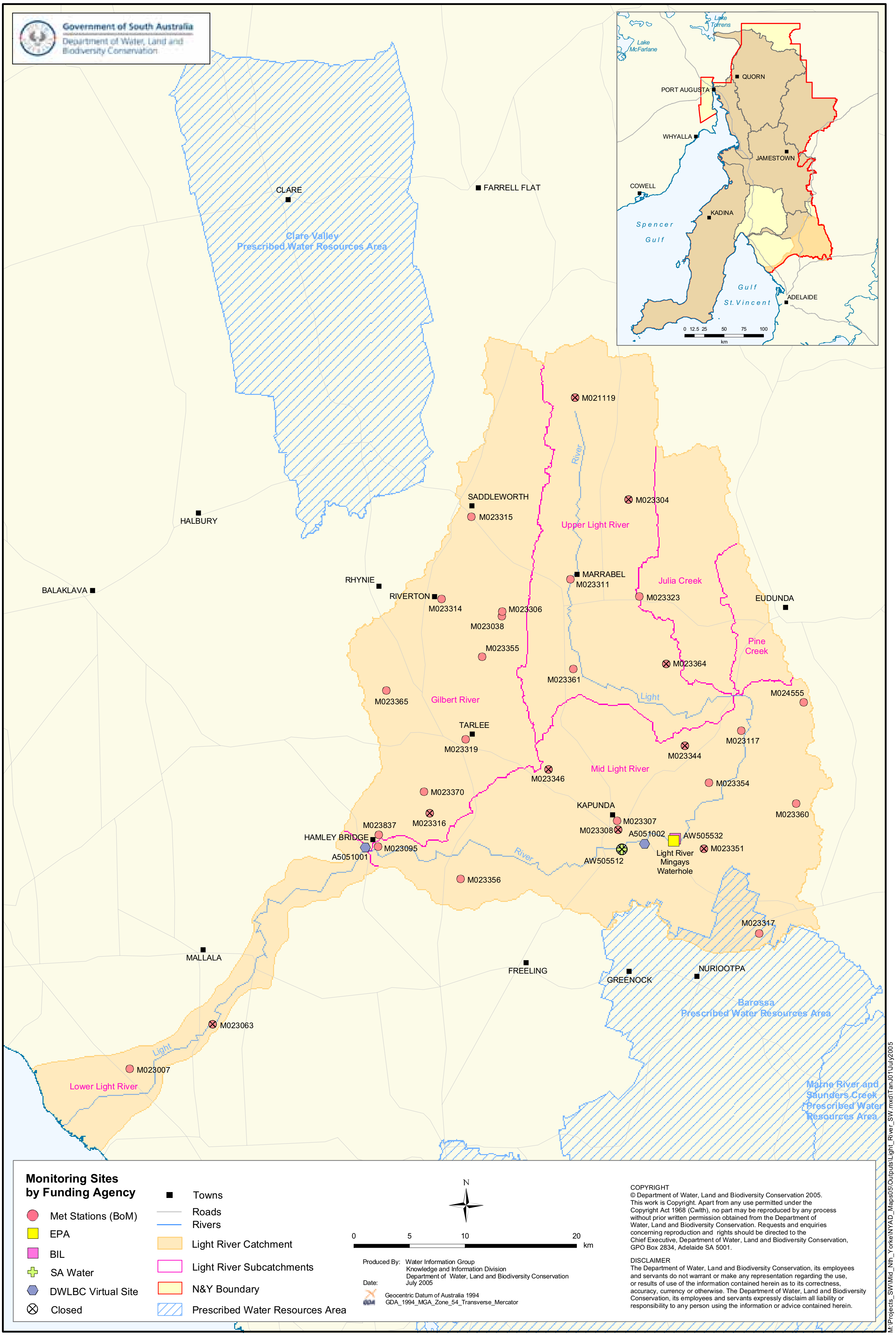

Figure 11. Surface Water Monitoring Sites (Current and Historic) in the Light River Catchment

3. Light River, Lower Light — new monitoring site.

   Location: downstream of Port Wakefield Road and as near as practical to the coast.

   Station categories: long-term, basin outflow station, surface–groundwater interaction and EWR.

   Requirements:
   - weir with good low to mid-flow sensitivity
   - continuous water level high resolution and flow
   - continuous salinity, requiring EC and temperature probe
   - telemetry
   - 100% backup of continuous water level — self-contained water level recorder.

   Potential development site requirements:
   - continuous velocity probes (two or three)
   - two self-contained water level recorders away from the influence of the weir, in a straight reach and a minimum distance apart of 100 m
   - development site to assist in assessing new technologies and alternative methods for estimating flow (the two self-contained water level recorders will be used to estimate the stream's water surface slope — then applied to the slope/area method).

   General data use: long-term assessment of the catchment; estimation of groundwater recharge; frequency and duration of connectivity to the coast of the system; flood warning site (subject to BoM requirements); salt loads; and water quality surface – groundwater interaction.

4. Light River upstream of Redbanks — new monitoring site.

   Location: between the Redbanks to Mallala Road and an area including the edge of the escarpment (at the downstream end of the permanent pools).

   Station categories: short-term, surface–groundwater interaction and EWR.

   Requirements:
   - weir with good low flow sensitivity (cheaper low profile weir)
   - continuous water level — high resolution at low ranges and flow
   - continuous salinity, requiring EC and temperature probe
   - rainfall (pluviometer)
   - 100% backup of continuous water level — self-contained water level recorder.

   General data use: estimation of groundwater recharge; frequency and duration of connectivity of permanent pools to the coast; quality of recharge water; altitudinal effects on rainfall; and better isohyet definition.

5. St Kitts upstream of Light River — new monitoring site.

   Location: just upstream of the Light River junction.

   Station categories: short-term, representative station, potential 'hot spot' sub-catchment and EWR.

   Requirements:
   - weir with good low flow sensitivity (cheaper low profile weir)

- continuous water level — high resolution at low ranges and flow
- continuous salinity, requiring EC and temperature probe
- 100% backup of continuous water level — self-contained water level recorder.

General data use: check on effects of ongoing development and assist in modelling.

6. Light River downstream of Julia Creek — new monitoring site.

   Location: just downstream of Julia Creek and upstream of next creek.

   Station categories: short-term, representative station and EWR.

   Requirements:
   - weir with good low flow sensitivity (cheaper low profile weir)
   - continuous water level — high resolution at low ranges and flow
   - continuous salinity, requiring EC and temperature probe
   - 100% backup of continuous water level — self-contained water level recorder
   - rainfall (pluviometer).

   General data use: characteristics of the Upper Light sub-catchment; assist in modelling; in conjunction with Mingays Waterhole and St Kitts sites assist in better modelling of a wetter sub-catchment; altitudinal effects on rainfall and better isohyet definition.

7. Light River Catchment pluvio, east of Hansborough — new stand-alone pluvio monitoring site (BoM is also interested in a site in this area).

   Location: coordinates — latitude 34°15.140’ south; longitude 139°05.297’ east, on an elevated ridge at the edge of the catchment.

   Station categories: short-term.

   Requirements: rainfall monitoring (pluviometer).

   General data use: assist in modelling; altitudinal effects on rainfall and better isohyet definition.

8. Light River Catchment pluviometer, east of St Kitts — new stand-alone pluviometer monitoring site.

   Location: to be finalised in an approximate line between the site selected above and an existing pluviometer at Penrice gauging station, and on the ridgeline of the St Kitts catchment.

   Station categories: short-term.

   Requirements: rainfall (pluviometer).

   General data use: assist in modelling; altitudinal effects on rainfall and better isohyet definition.

9. Light River Peters Road crossing — new monitoring site.

   Location: in consultation with the EPA.

   Station categories: EWR (five years; subject to determining relationship with a long-term monitoring site).

Requirements:
- no control, cheaper continuous water level recorder
- continuous salinity, requiring EC and temperature probe.

General data use: EWR to determine the water level and EC relationships; frequencies and durations with a long-term monitoring site (Mingays Waterhole).

10. Light River, Hamilton — new monitoring site.

Location: in consultation with the EPA.

Station categories: EWR (five years, subject to determining relationship with a long-term monitoring site).

Requirements:
- no control, cheaper continuous water level recorder
- continuous salinity, requiring EC and temperature probe.

General data use: EWR to determine the water level and EC relationships; frequencies and durations with a long-term monitoring site (Mingays Waterhole). If there is not a good relationship with Mingays Waterhole, then an alternative site may be located at Light River, downstream of Julia Creek. If there is a good relationship with this site then this site may become a long-term site.

11. Light River upstream of Hamley Bridge — new monitoring site.

Location: in consultation with the EPA.

Station categories: EWR (five years, subject to determining relationship with a long-term monitoring site).

Requirements:
- no control, cheaper continuous water level recorder
- continuous salinity, requiring EC and temperature probe.

General data use: EWR to determine the water level and EC relationships; frequencies and durations with a long-term monitoring site (Mingays Waterhole). If there is not a good relationship with Mingays Waterhole, then an alternative site may be located at Light River, Redbanks. If there is a good relationship with this site then this site may become a long-term site.

12. Light River downstream of Redbanks — new monitoring site.

Location: in consultation with the EPA, approximately mid-way between Light River near the coast and Light River upstream of Redbanks.

Station categories: EWR and groundwater to surface water interaction (five years, subject to determining relationship with a long-term monitoring site).

Requirements:
- no control, cheaper continuous water level recorder
- continuous salinity, requiring EC and temperature probe.

General data use: EWR to determine the water level and EC relationships; frequencies and durations with a long-term monitoring site (Light River near the coast); estimation of groundwater recharge; frequency and duration of connectivity of permanent pools to the coast.

The above suggestions are considered ideal for meeting reporting requirements. A first priority for improvements would involve implementation of suggestions 1, 2, 3, 9, 10 and 11. Broader regional priorities are relevant to water monitoring and the design of monitoring programs, and implementation of any and all of the above suggestions should consider these.

5.4.3 RELATED ISSUES

Surface Water – Groundwater Interactions

Little is understood about the interactions between surface water and groundwater for the Light River Catchment, or any other catchment in the Mid-North. For effective resource management, this knowledge gap must be addressed. It is therefore suggested that levels monitoring be carried out to aid in further investigations into identifying and quantifying surface – groundwater interactions, as follows:

- Lower Light sub-catchment, just upstream of Redbanks at the downstream end of the permanent pools, to measure frequency and duration of the height component of flow.
- Lower Light sub-catchment, just downstream of Redbanks, to include investigations into connectivity to the coast.

Weirs

Weirs can have a significant impact on the flow regimes of natural watercourses. The effects on the hydrology of controlling features can be felt both up and downstream. Two major weirs have been built in the catchment — one is on the Gilbert River at Riverton and is used to create a recreational lake within the town; the other is on the Light River at Hamley Bridge and has resulted in an accumulation of sediment upstream. The impact of Riverton and Hamley Bridge weirs on flows downstream is not presently understood, hence it is suggested that flow monitoring be carried out.

Farm Dams

Only a small number of dams exist in the catchment, most of which are in the upper areas and are used for stock and domestic purposes. However, dams will still impact on the streams on which they are located in terms of flow downstream. It is therefore suggested that an investigation into the impact of farm dams on catchment yield be carried out.

Table 21 details suggestions developed during this review to improve surface water quantity monitoring in this catchment.

5.5 MAMBRAY COAST

5.5.1 METEOROLOGICAL MONITORING

There are five BoM stations on the Mambray Coast measuring daily rainfall, as well as a DWLBC pluviometer. This provides a reasonable indication of latitudinal variations in rainfall patterns. The effects of the ranges could in future be further examined by evaluating the change in rainfall with elevation. It is considered that there are currently higher priorities in the region as a whole.

5.5.2 STREAMFLOW MONITORING

The most likely requirement for surface water data in the catchment relates to irrigation water use from the Baroota Creek (including the reservoir itself) and groundwater resources downstream.

Surface water quantity at Baroota Reservoir is currently monitored only through measurement of water levels. Owing to the fact that the reservoir wall is a rated structure (D. Cresswell, DWLBC, pers. comm., 2005), and evaporation and rainfall are also monitored at this site, sufficient information may be available to develop a reservoir water balance model. Provided that data on any transfers or diversions of water to and from the reservoir were available and vertical leakage could be estimated, this would then allow for knowledge of catchment streamflow volumes to be derived.

The catchment in general features only very irregular flows reaching the mid to lower sub-catchments. Creeks flow to the gulf in only one out of 10 or more years.

Surface flows were historically monitored at Saltia Creek gauging station, operational from 1979 to 1991, when it was closed following storm damage. These data are stored by DWLBC in the Surface Water Archive.

Loss characteristics of the streams as these enter the foothills and coastal plains, and the manner in which these interact with groundwater resources, presents a knowledge gap. Investigations to determine these would likely involve costly drilling programs. Given the low levels of current development, this could be considered a low priority at regional level. Technical investigations of a scale suited to determining the sustainable yield of the future Baroota PWA will provide some indication of the surface – groundwater interactions of streams in the region. The results of these investigations will enable wider predictions to be made.

5.6 YORKE PENINSULA

5.6.1 METEOROLOGICAL MONITORING

BoM rainfall stations are distributed throughout Yorke Peninsula, providing an adequate coverage.

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Figure 12. Surface Water Monitoring Sites (Current and Historic) in the Mambray Coast Catchment

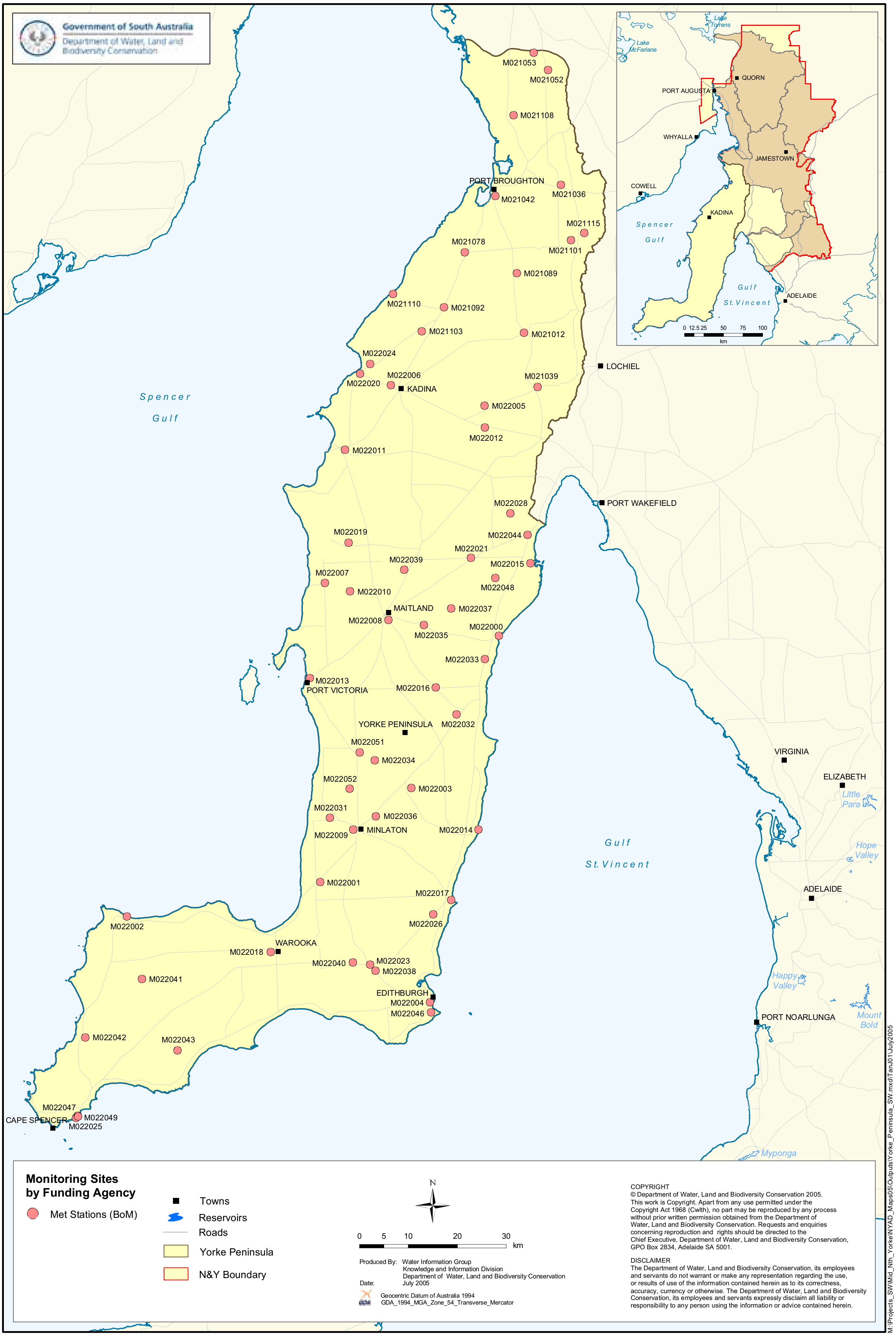

Figure 13. Surface Water Monitoring Sites (Current and Historic) on the Yorke Peninsula

5.6.2 STREAMFLOW MONITORING

As there is no defined surface water drainage there has been no prior surface water flow monitoring.

5.7 SOUTHERN LAKE FROME BASIN

5.7.1 METEOROLOGICAL MONITORING

There is a reasonable coverage of daily-read rainfall stations throughout the southern Lake Frome Basin, given the semi-arid climate and low water resource development potential. Information on rainfall intensity and evaporation is measured at Beetaloo and Bundaleer Reservoirs, and that data could possibly be adapted for this area if required in future. Owing to the lack of streamflow gauging or continuous groundwater level monitoring, it would appear to be of limited value to collect data on these parameters in the southern Lake Frome Basin unless as part of a specific project, e.g. to develop a water balance for the Walloway Groundwater Basin.

5.7.2 STREAMFLOW MONITORING

Streamflow monitoring in the southern Lake Frome Basin has not been the focus of significant work in the past due to the episodic nature of surface flows. A monitoring station was proposed to monitor levels at Pekina Reservoir, but this was not implemented. Siltation and abandonment of the reservoir has made this consideration irrelevant at present.

Flow gauging data from Pekina Creek could be of use in undertaking water balance studies to evaluate recharge volumes from this source to the Walloway Basin groundwater resource (Magarey & Deane 2004).

5.7.3 RELATED ISSUES

Farm dams

Dam development appears significant on topographic maps, but the impact of this on local surface flows and hence aquatic ecosystems is unknown. Significant investigations are required to evaluate whether existing levels of dam development are of concern.

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Figure 14. Surface Water Monitoring Sites (Current and Historic) in the Southern Lake Frome Region

6. CURRENT MONITORING — SURFACE WATER QUALITY

6.1 WILLOCHRA CREEK CATCHMENT

6.1.1 SALINITY

In the southern section of the catchment, DWLBC is currently monitoring salinity continuously in the Willochra Creek sub-catchment at 'Willochra Creek @ Pinda Bridge' (A5091001) and in the Spring Creek sub-catchment at 'Spring Creek @ upstream of Willowie Forest' (A5091002).

In the northern section of the catchment, DWLBC is monitoring salinity continuously at 'Willochra Creek @ Partacoona' (AW509502), and the EPA currently monitors salinity as part of their ambient and macro-invertebrate grab sampling monitoring program at 'Willochra Creek South of Partacoona' and 'Kanyaka Creek @ Old Kanyaka Ruins'. Salinity is very high in the downstream reaches (northern section) of the Willochra Creek Catchment. There are no long-term records of salinity trends available to determine whether the salt balance has changed over time.

Development in both the southern and northern sections of the Willochra Creek Catchment has impacts on water quality and environmental water requirements. At present however, most of the catchment is not monitored for salinity and it is suggested that this knowledge gap is addressed through the expansion of such monitoring throughout the catchment. Salinity monitoring could be carried out in conjunction with already established flow monitoring.

It is suggested that salinity monitoring be established at all new flow monitoring stations, in particular — along Willochra Creek immediately downstream of the township of Melrose; along Willochra Creek upstream of confluence with Booleroo Creek; along Old Booleroo Creek downstream of confluence of Stokes and Morchard Creeks of the Orroroo Road; and south of Willowie upstream of the overflow. Data obtained from such monitoring can then be used to gain a better understanding of runoff–salinity relationships, observe salinity trends and understand spatial changes in salinity.

6.1.2 OTHER WATER QUALITY ISSUES

Pesticides contribute significantly to both point source pollution as a result of waste being dumped instream, including dumping of pesticide drums and diffuse pollution from chemical pesticide spray. Other forms of pollution include that from septic tanks, water treatment, stock and wildlife that impact upon water quality.

Water quality monitoring for the Willochra Creek Catchment (including point source and diffuse pollution) is currently insufficient, hence it is suggested that this be established throughout the catchment. The EPA's sites in the northern section of the catchment are the only existing forms of ongoing monitoring of water quality for parameters other than salinity.

At 'Willochra Creek South of Partacoona' and 'Kanyaka Creek @ Old Kanyaka Ruins', N and P, DOC, turbidity, DO, EC, pH and water temperature are sampled quarterly, and macro-invertebrates and alkalinity are sampled biannually.

It is therefore suggested that composite water quality monitoring be established, and ambient and macro-invertebrate sampling be expanded at strategic locations throughout the catchment.

Table 5 details the suggestions for surface water quality monitoring developed during this review for the Willochra Creek Catchment.

6.2 BROUGHTON RIVER CATCHMENT

There are currently little long-term data available on the water quality of watercourses in the Broughton River Catchment.

6.2.1 SALINITY

Currently there is no continuous salinity monitoring being carried out in the Broughton River Catchment.

In the Lower Broughton River sub-catchment, the EPA is carrying out grab sampling as part of their ambient and macro-invertebrate monitoring program at the 'Broughton Cockeys Crossing' site. Levels of N and P, DOC, turbidity, DO, EC, pH, and temperature are monitored monthly, while macro-invertebrates and alkalinity are monitored biannually. In the Hill River sub-catchment, the EPA is carrying out the same form of monitoring at the 'Hill River near Andrews' site, which is co-located with DWLBC's site 'Hill River @ near Andrews' (AW507500).

These two sites are the only ongoing salinity monitoring sites in the Broughton River Catchment. It is therefore suggested that salinity monitoring be established at strategic locations as a matter of priority, as well as at all current and future flow monitoring sites. The EPA is planning on adding an ambient and macro-invertebrate monitoring site to its Broughton River Catchment program on the Broughton River downstream of the confluence with Crystal Brook.

6.2.2 POLLUTION

In Hutt River Zone 2, the nutrient levels downstream of the Clare Valley Waste Water Treatment Plant (WWTP) are significantly elevated and silt deposits widespread. Landholders have also expressed concern about pollution from farm chemicals and septic overflow (Favier et al. 2004). Pollution levels therefore need to be investigated.

Table 10 details the suggestions for surface water quality monitoring in this catchment developed as part of this review.

6.3 WAKEFIELD RIVER CATCHMENT

Surface water quality in the Wakefield River Catchment has been monitored infrequently. It is suggested that the current monitoring program in the region be expanded to include frequent and ongoing surface water quality monitoring.

6.3.1 SALINITY

Currently, salinity is continuously monitored by DWLBC at 'Eyre Creek @ Watervale' (AW506501), 'Eyre Creek @ Auburn' (AW506502) in the Eyre Creek sub-catchment, and at 'Skillogalee Creek @ Goodonga' (A5061008) in the Skillogalee Creek sub-catchment. The EPA is currently monitoring salinity at its ambient and macro-invertebrate monitoring sites 'Skillogalee Creek, Hoyleton Road' in the Skillogalee Creek sub-catchment and 'Wakefield River @ The Rocks' in the Mid Wakefield River sub-catchment, where N and P, DOC, turbidity, DO, EC, pH and temperature are monitored on a monthly basis, and macro-invertebrates and alkalinity biannually.

It is suggested that continuous salinity monitoring be expanded within the Wakefield River Catchment. Possible locations for such monitoring are at the DWLBC environmental flow monitoring sites 'Wakefield River @ Balaklava' (A5061005) and 'Wakefield River @ Whitwarta' (A5061006) in the Lower Wakefield River sub-catchment.

As stated earlier in this report (Section 5.3.2), it is suggested that salinity be monitored at the base station 'Wakefield River @ near Rhynie' (AW506500) in the Woolshed Creek sub-catchment, and at 'Wakefield River @ Port Wakefield' (A5061007) in the Lower Wakefield River sub-catchment in relation to that monitoring station serving as a basin outflow station.

6.3.2 AMBIENT WATER QUALITY PROGRAM

Species composition of macro-invertebrates is affected by flow rate, timing of flows, water temperature, oxygen levels and salinity. These fauna are commonly used as a measure of water quality.

The EPA is carrying out macro-invertebrate sampling at its 'Wakefield River @ The Rocks' site in the lower reaches of the Mid Wakefield River sub-catchment and its 'Skillogalee Creek @ Hoyleton Road' site in the Skillogalee Creek sub-catchment.

While this scale of investigation is appropriate for state reporting, building on these protocols could also be used to help characterise ecosystem condition at reach to catchment scale. This would require an expanded program, employing more intensive spatial and temporal distribution of monitoring efforts to understand underlying patterns of natural variation.

The program could also be expanded for various habitat types, e.g. ones with low flow zones like pools, and ones with high stream gradients and turbulence, within sub-catchments representative of the various catchment characteristics. This expansion of monitoring programs could also include long-term studies of macro-invertebrate populations, including their migration patterns and reproductive biology.

6.3.3 COAST AND MARINE

As contamination from land-based human activities can have an impact on the water quality of marine waters and associated biodiversity, it is suggested that water quality monitoring be established for Gulf St Vincent where the Wakefield River discharges to the sea.

Table 16 details suggestions for surface water quality monitoring for the Wakefield River Catchment developed during this review.

6.4 LIGHT RIVER CATCHMENT

Information on surface water quality is very limited for the Light River Catchment, and the only ongoing water quality data that are gathered is from the Mingays Waterhole gauging station.

6.4.1 SALINITY

There is a lack of salinity monitoring for streams in the Light River Catchment. DWLBC only collect data for ongoing salinity monitoring in relation to the Barossa Infrastructure Ltd scheme from the Mingays Waterhole gauging station. As in other catchments in the Northern and Yorke region, it is suggested that salinity monitoring be included at all new flow gauging stations in the Light River Catchment.

Tothill Creek in the Upper Light sub-catchment, in particular, has recorded significant salinity levels. It is therefore suggested that ongoing salinity monitoring be undertaken for this waterway as a matter of priority. Salinity monitoring could also be established at the suggested levels monitoring site just upstream of Redbanks at the downstream end of the permanent pools (in the Lower Light sub-catchment) to assist in investigations of surface water – groundwater interactions in this area.

6.4.2 AMBIENT WATER QUALITY

At the Mingays Waterhole gauging station, monthly data are collected by EPA as part of its ambient water quality monitoring program for parameters including nutrients, turbidity, DO, pH and salinity.

6.4.3 POINT SOURCE AND DIFFUSE POLLUTION

Storm water and wastewater are potential sources of point source pollution that are generated from townships in the catchment. Pollution from sources such as sediments, pesticides and nutrients are forms of diffuse pollution that occur within the catchment. It is suggested that identification of potential point source and diffuse pollution takes place for the catchment.

6.4.4 COAST AND MARINE

As contamination from land-based human activities can have an impact on the water quality of marine waters and associated biodiversity, it is suggested that water quality monitoring be established for Gulf St Vincent where the Light River discharges to the sea.

Table 22 details all suggestions for surface water quality monitoring for the Light River Catchment developed during this review.

6.5 MAMBRAY COAST CATCHMENT

6.5.1 SALINITY

Currently there is no continuous salinity monitoring being carried out anywhere in the catchment. The only salinity monitoring for surface water is undertaken at the Baroota Reservoir, where fortnightly measurements are made.

6.5.2 AMBIENT WATER QUALITY PROGRAM

The EPA has a site at the Mambray Creek National Park campground, which is sampled quarterly for macro-invertebrates.

6.6 YORKE PENINSULA

There are no significant water supplies or surface streams warranting regular water quality assessment on Yorke Peninsula.

6.7 SOUTHERN LAKE FROME BASIN

There are no significant water supplies or surface streams warranting regular water quality assessment in these regions.

7. CURRENT MONITORING — GROUNDWATER QUANTITY

The following information has largely been derived from Magarey and Deane (2004). The Clare Valley and Baroota Prescribed Resources Areas have not been included as monitoring in these areas is regularly reviewed as part of the administration of prescribed resources areas. These reviews are available from DWLBC.

7.1 WILLOCHRA CREEK CATCHMENT

The Willochra Basin network (Fig. 15) monitors water level and salinity, with most observation wells located in the sedimentary aquifers. The network is focused on areas with the highest water quality, largely within the hundreds of Willochra and Gregory, where groundwater is used for the irrigation of pasture and vines as well as providing the Melrose town water supply (TWS). The network is currently maintained by DWLBC and is monitored every six months in the autumn and spring. Most of the current monitoring wells have a period of record from 1985 to the present (Magarey & Deane 2004).

7.1.1 DATA AND INFORMATION GAPS — WILLOCHRA CREEK CATCHMENT GROUNDWATER

The current monitoring network sufficiently covers the important areas, including major extractive pressure on the Willochra Plain. However, Spring Creek receives recharge from seasonal surface water flow, emphasising the need for conjunctive management of surface and groundwater resources. Reductions in surface water runoff are likely to have an impact on replenishment of the resource and further understanding of this is required. As a first priority, it is suggested that an expanded monitoring network be installed in the vicinity of Spring Creek (D. Clarke, consultant, pers. comm., 2004).

According to anecdotal evidence, there has been a decline in groundwater levels, both in the middle and deep aquifer systems. There are no data available on groundwater extraction rates from the basin to determine whether the overall decline of groundwater is a result of current climatic conditions, current extraction, or a combination of the two. This lack of information to determine the cause of groundwater decline potentially places groundwater resources under risk of long-term decline.

Table 6 contains specific suggestions for groundwater monitoring in the Willochra Creek Catchment (reproduced from Magarey & Deane 2004).

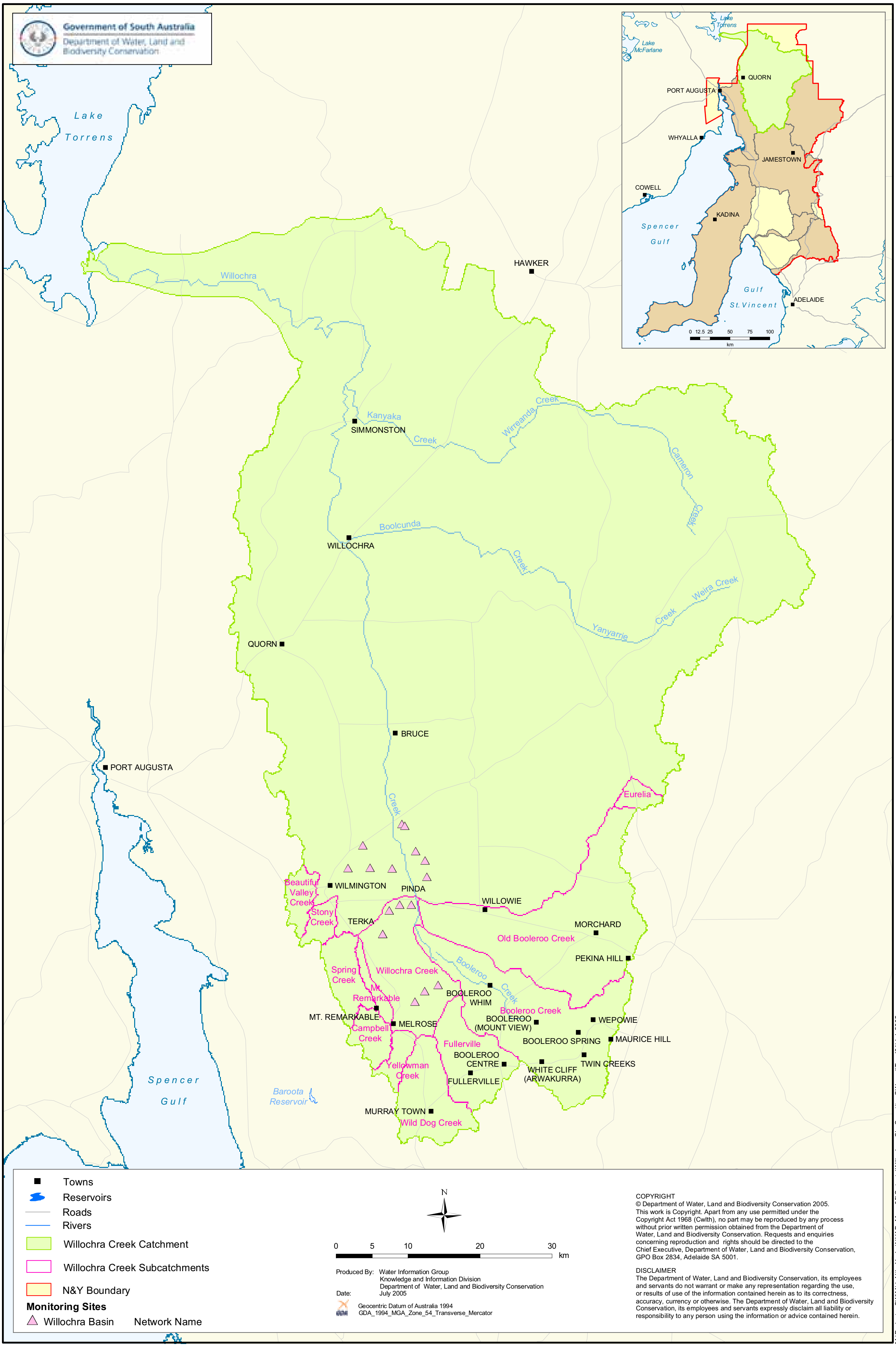

Figure 15. Current Groundwater Quantity Monitoring Sites in the Willochra Creek Catchment

7.2 BROUGHTON RIVER CATCHMENT

The Broughton River system is highly dependent on groundwater, most of which is stored in the low capacity FRA. The higher capacity sedimentary aquifers occur in the Booborowie Valley and at Stanley Flat in the Clare Valley. Areas where permanent groundwater-driven baseflow occur are in the Broughton River just downstream of Spalding to just downstream of Cockeys Crossing, as well as along the lower reaches of the Rocky and Hutt Rivers, and Bundaleer, Freshwater and Yakilo Creeks, and along sections of Belalie and Farrell Creeks.

There are several networks of observation wells monitoring groundwater levels in the Broughton River Catchment (Fig. 20):

- one observation well is monitoring levels in the northwest section of the Rocky River sub-catchment which is part of the Willochra Basin network
- the Jamestown network is monitoring levels in the northern sections of the Yackamoorundie Creek, Bundaleer and Never Never Creeks and Freshwater Creek sub-catchments
- the Georgetown network in the mid-section of the Yackamoorundie Creek sub-catchment
- the Booborowie network in the Booborowie Creek and northern section of the Farrell Flat and Baldry Creeks sub-catchment
- one from the Mid-North Rivers network in the western portion of the Mid-Broughton River sub-catchment
- the Lochiel network in the Lake View, Lake Bumbunga and Diamond Lake sub-catchments
- the Kybunga network in an eastern portion of the Diamond Lake sub-catchment
- the Clare-Auburn network near the Kybunga network and southern sections of the Hutt and Hill River sub-catchments
- a small number of wells from the Balaklava network are monitoring levels in the southern portion of the Diamond Lake sub-catchment.

7.2.1 DATA AND INFORMATION GAPS — BROUGHTON RIVER CATCHMENT GROUNDWATER

The majority of the Broughton River Catchment is underlain by fractured Adelaidean rocks. As with all groundwater in fractured rock aquifers, the natural variability makes assessment of the resource technically difficult and costly. Generally, the available quality and quantity limits most users in these areas to stock and domestic purposes, although isolated good supplies do occur, and in places these support higher water use activities.

Outside of the Clare Valley, groundwater resources are not well understood and water managers at all levels operate without the benefit of technical understanding, appreciations of current condition or estimates of sustainable use levels. This situation is further complicated by the almost complete lack of current and historical groundwater monitoring in the catchment outside of prescribed areas.

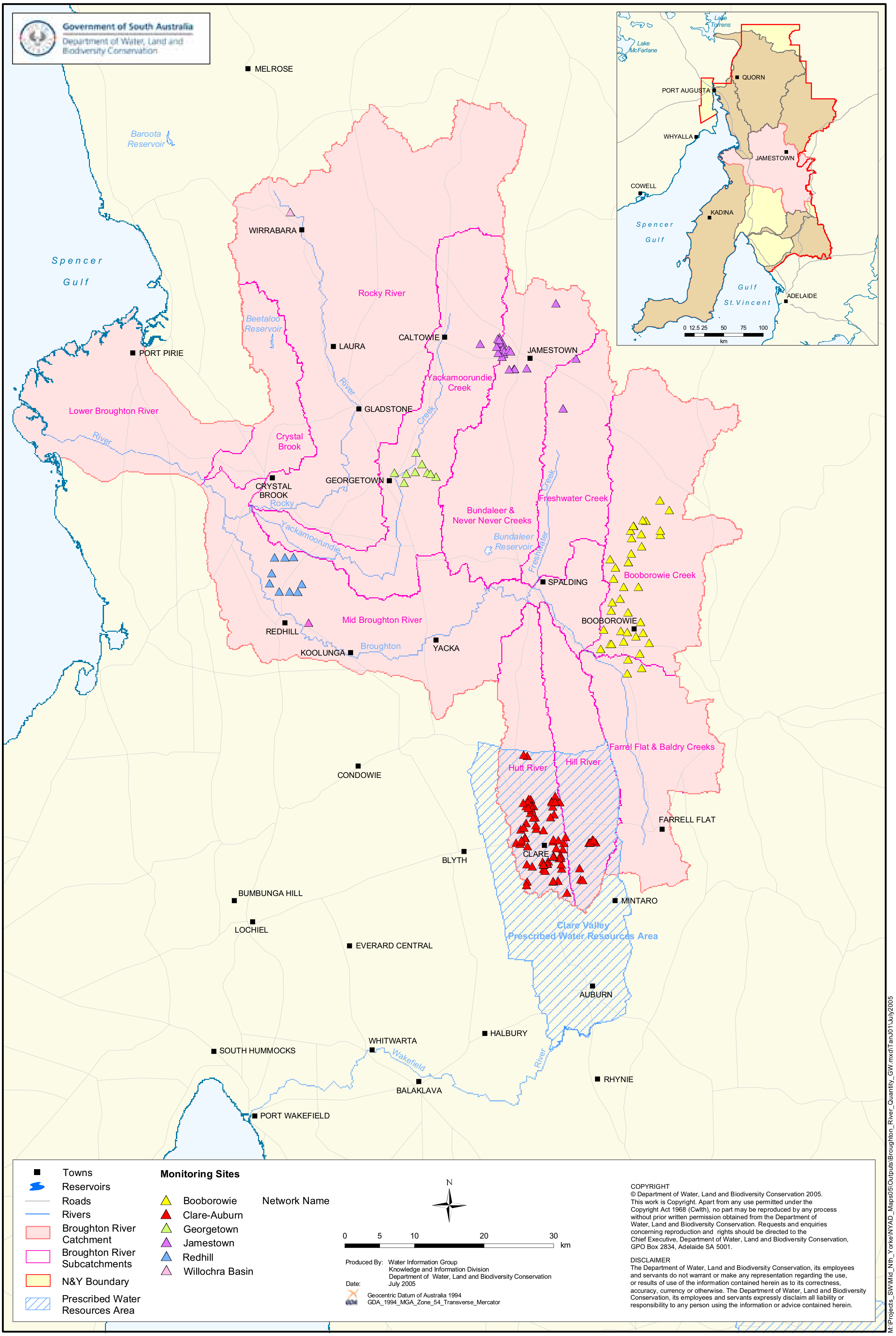

Figure 16. Current Groundwater Quantity Monitoring Sites in the Broughton River Catchment

Establishment of a regional groundwater monitoring network in the FRA would provide data that could be analysed to improve the current understanding. Such a network could measure water level and salinity twice yearly, with sampling occurring at the end of the recharge period, and again at the end of the summer irrigation season. Implementation of such a network would ideally be preceded by a technical investigation to refine the monitoring program objectives and determine the optimal sites and sampling densities for the network. Table 11 contains more detailed and specific suggestions for groundwater monitoring in the Broughton River Catchment.

The interaction between surface and groundwater resources is also a key gap in understanding throughout the region. In areas of significant groundwater extraction, there may be impacts on surface water resources through reductions in baseflow volumes or drying of permanent pools. Based on the level of water being extracted, priority areas within the Broughton River Catchment where it is suggested there is the potential for this to occur are downstream of Booborowie Valley lucerne irrigation area and the Hutt and Hill River sub-catchments.

7.3 WAKEFIELD RIVER CATCHMENT

The major groundwater flows influencing the Wakefield River system are provided by aquifers associated with the Skillogalee Creek sub-catchment, and the upper section of the Eyre Creek sub-catchment.

Groundwater levels in the Skillogalee Creek, Eyre Creek and Upper Wakefield River sub-catchment areas are being monitored by the Clare–Auburn observation wells network. The Mintaro network also monitors levels in the northern section of the Upper Wakefield River sub-catchment area. The Balaklava network monitors groundwater levels in the Lower Wakefield River sub-catchment area.

7.3.1 DATA AND INFORMATION GAPS — WAKEFIELD RIVER CATCHMENT GROUNDWATER

There is a lack of understanding about the groundwater systems in the Wakefield River Catchment, including the relationship between rainfall, aquifer discharge and baseflow levels. It is therefore suggested that investigations into these relationships be carried out.

Groundwater usage of the Balaklava Basin with regard to current application rates needs to be better understood, and sustainable yields and aquifer connectivity needs further investigation.

Table 17 contains specific suggestions for groundwater monitoring in the Wakefield River Catchment.

7.4 LIGHT RIVER CATCHMENT

The Barossa and Lyndoch Valleys network is monitoring groundwater levels in the southern section of the Mid Light River sub-catchment as part of the Barossa PWRA.

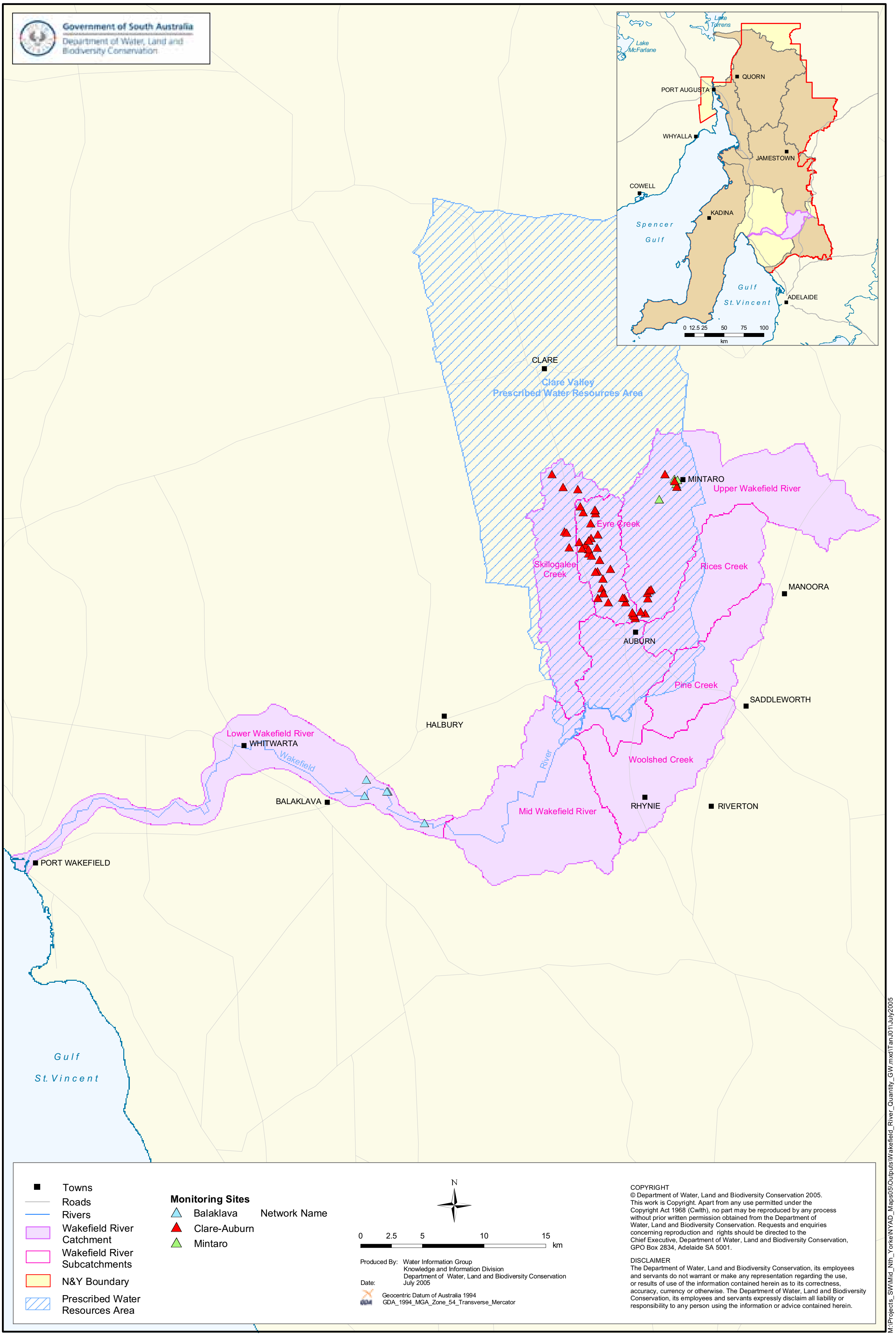

Figure 17. Current Groundwater Quantity Monitoring Sites in the Wakefield River Catchment

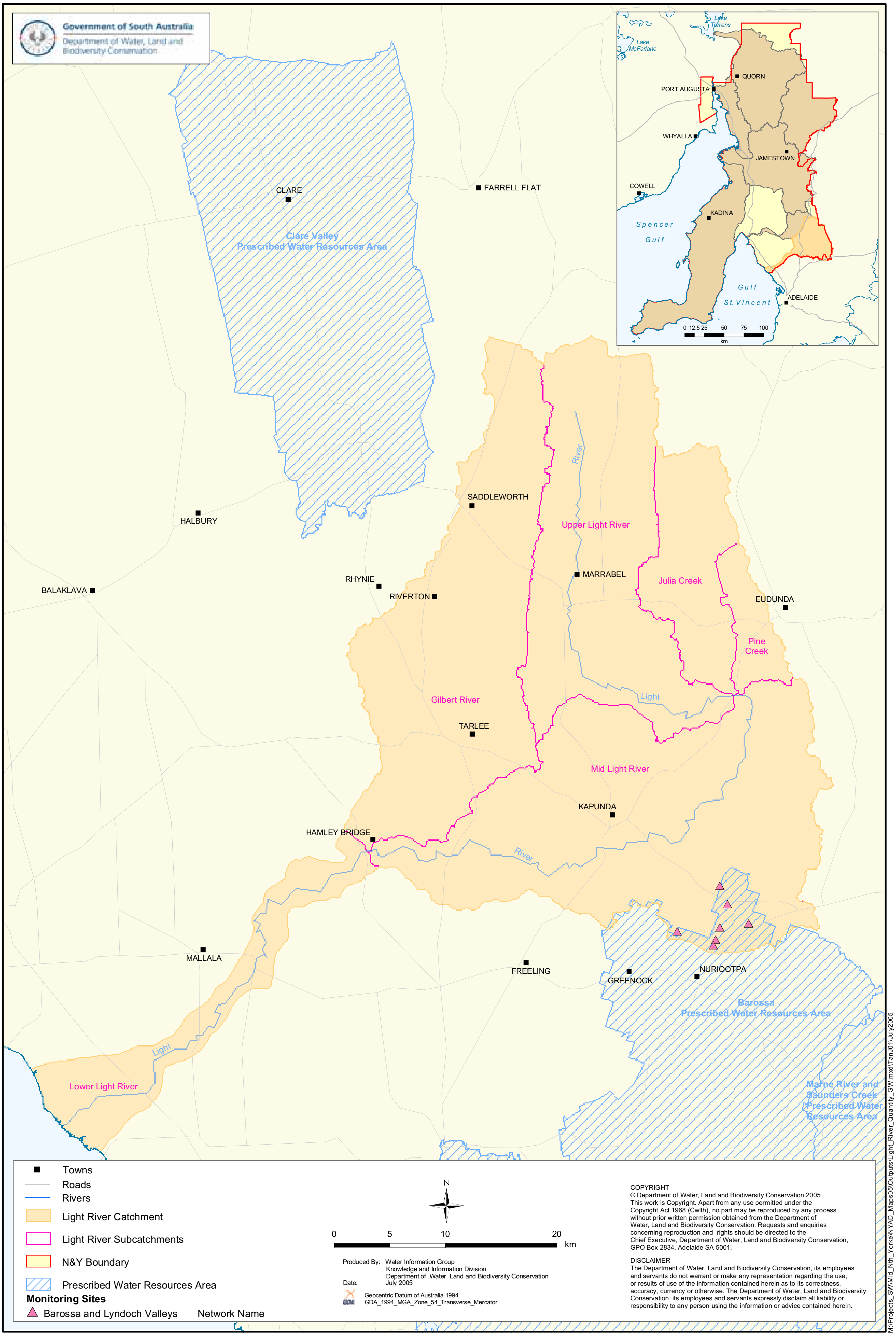

Figure 18. Current Groundwater Quantity Monitoring Sites in the Light River Catchment

There is little groundwater extraction in the catchment, as salinity levels are too high for irrigating crops. Although it appears that groundwater-driven baseflow is relatively secure in the Light River Catchment, if significant groundwater extraction occurred in the baseflow source areas, this may threaten supplies for baseflow. There is still much to understand about the hydrogeology of the catchment and it is suggested that this be further investigated, including the groundwater systems supporting permanent pools and baseflow.

7.4.1 DATA AND INFORMATION GAPS — LIGHT RIVER CATCHMENT GROUNDWATER

Further investigation into groundwater systems is required to gain an understanding of groundwater interactions with surface water. Hydrogeological processes generally need to be better understood, including the location of groundwater recharge and discharge zones that influence baseflows.

The impact of practices designed to reduce groundwater recharge (to overcome dryland salinity problems) on baseflows and permanent pools also need further investigation.

Table 23 contains specific suggestions for groundwater monitoring in the Light River Catchment.

7.5 MAMBRAY COAST CATCHMENT

The Pirie Basin observation network monitors the major use areas in the Mambray Coast area. This focuses on the high water use area of Baroota, where a recent expansion and assessment of the monitoring network was undertaken. Wells are monitored quarterly by DWLBC.

Whilst the network coverage is generally considered to be adequate, there are issues associated with the data generated due to multiple completion of wells and frequency of data collection (S. Evans, DWLBC, pers. comm., 2005). Some observation and production wells in the region have multiple completions, meaning that they draw water from more than one aquifer simultaneously. Problems arise for both management and monitoring of a resource under these circumstances.

From a management perspective, there is potential for cross-contamination and pollution of higher quality water through the artificial connection provided by multiple-completion wells. Under ideal circumstances, these wells would be rehabilitated and single completion wells drilled to replace them. When monitoring water levels in such wells, observed levels represent the combined response of all aquifers. Data generated need careful evaluation and provide greatly reduced information on aquifer response.

Monitoring data have shown some of the upper aquifers to be highly responsive to seasonal patterns. In order to improve understanding of the behaviour of the aquifers in response to climatic patterns and pumping, it is suggested that consideration be given to increasing the frequency of monitoring in such wells (to monthly). Use of data loggers to continuously monitor selected wells could avoid the necessity for more frequent visits by monitoring staff but still deliver more data.

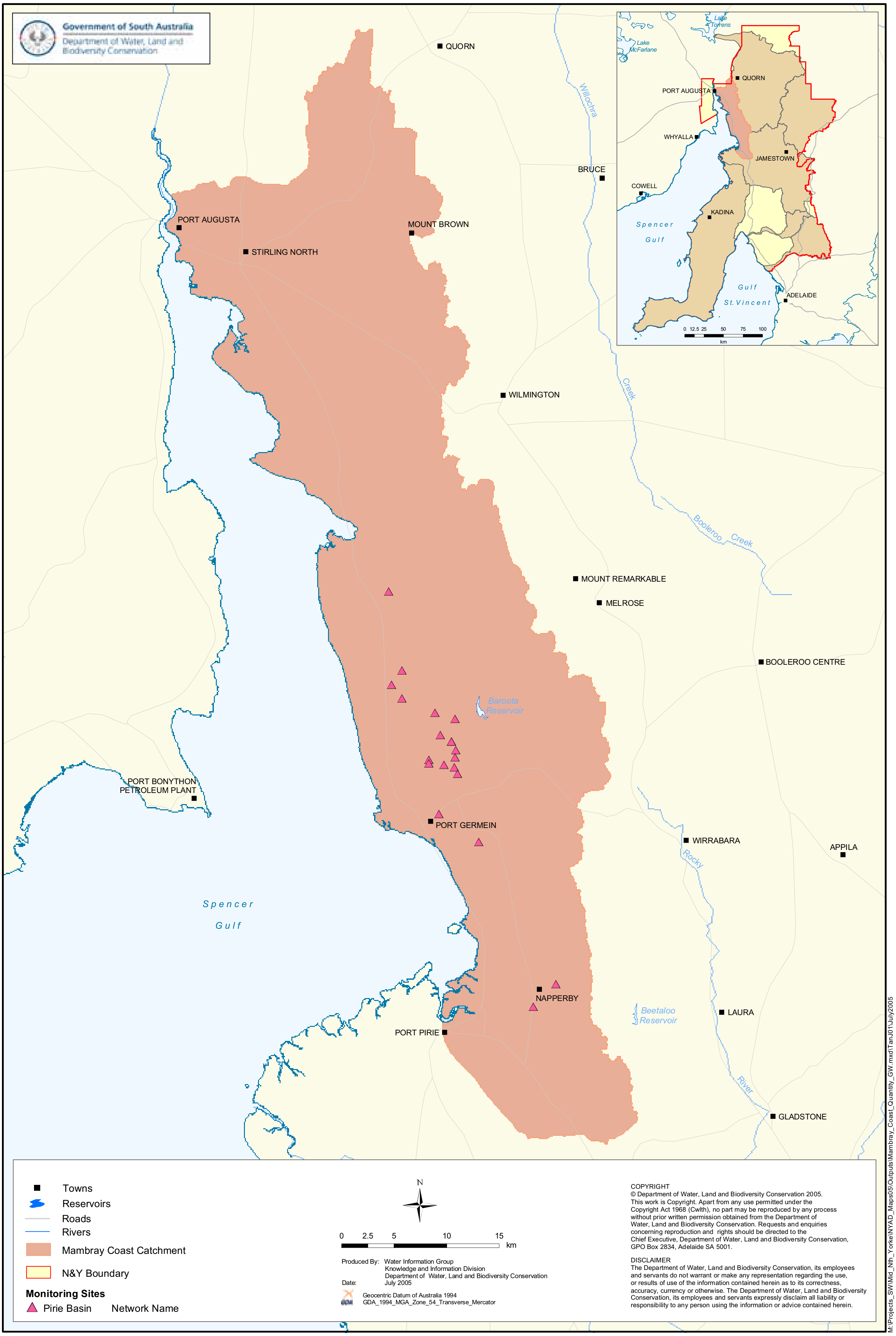

Figure 19. Current Groundwater Quantity Monitoring Sites in the Mambray Coast Catchment

7.5.1 DATA AND INFORMATION GAPS — MAMBRAY COAST CATCHMENT GROUNDWATER

- Continue to monitor the existing network.
- Consider increasing the frequency of monitoring to monthly in targeted wells in more seasonally responsive aquifers.

7.6 YORKE PENINSULA

DWLBC monitors the major groundwater resources in the Para-Wurlie and Carribie Basins on Yorke Peninsula (Fig. 19). Other networks, such as that around Minlaton, have also been established in the region. These networks monitor groundwater levels for dryland salinity.

The following information and suggestions regarding the major monitoring networks is summarised from Magarey and Deane (2004). More detailed information is provided in that reference.

7.6.1 PARA-WURLIE

The Para-Wurlie network currently has six observation wells monitored by DWLBC staff. These include four government observation wells, one operating town water supply (TWS) (PWL 13) well, and a private windmill (PWL 14). The network covers the deepest section of the basin and is centred on the Warooka extraction wells.

The current observation network adequately monitors the sensitive parts of the basin where major extraction takes place. Wells are located to the north, west and south of the town water supply well field, and monitor any intrusion of poorer quality groundwater. The network is currently monitored every six months.

7.6.2 CARRIBIE

The network consists of a number of 150–250 mm diameter holes in the upper unconfined aquifer, mostly unequipped and located on roadsides. The remaining observation wells are on private land, with the majority being windmills or shallow hand-dug wells.

The current monitoring network is evenly spaced throughout the basin and comprises a mixture of government observation wells and private windmills. The age and condition of some wells is of some concern and these may require rehabilitation in the near future.

7.6.3 DATA AND INFORMATION GAPS — YORKE PENINSULA GROUNDWATER

- Continue groundwater monitoring at major networks at six-monthly intervals.
- Undertake regular evaluation of groundwater monitoring data to determine trends in groundwater levels and quality. It is suggested that an evaluation of monitoring data trends for Para-Wurlie be undertaken as soon as possible and biannually thereafter.

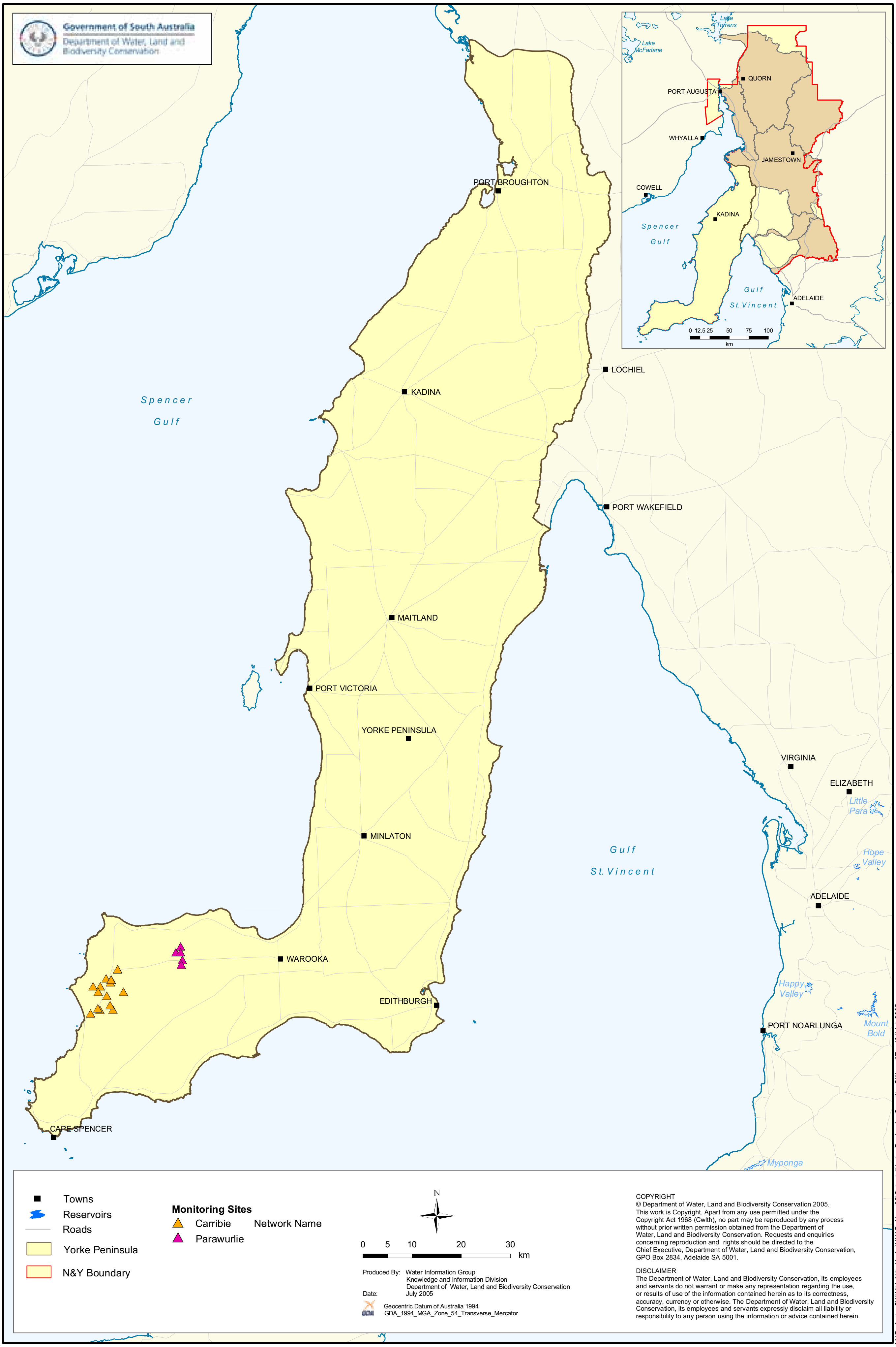

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Figure 20. Current Groundwater Quantity Monitoring Sites on the Yorke Peninsula

7.7 SOUTHERN LAKE FROME BASIN

The only monitoring undertaken in these regions is the DWLBC observation network, monitoring the Walloway Basin resource. Figure 21 shows that the current observation network is focused on the mid- to mid-western section of the basin. This is in the region of better quality groundwater in the Tertiary (artesian) and Quaternary aquifers (Magarey & Deane 2004).

7.7.1 DATA AND INFORMATION GAPS — SOUTHERN LAKE FROME BASIN

The suggestions below come from Magarey and Deane (2004):

- The present network is spatially adequate. It is advisable to add the new TWS well (6632-01140) to the observation network.
- At present, the groundwater monitoring network is monitored at six-monthly intervals. It is advisable for this to continue.

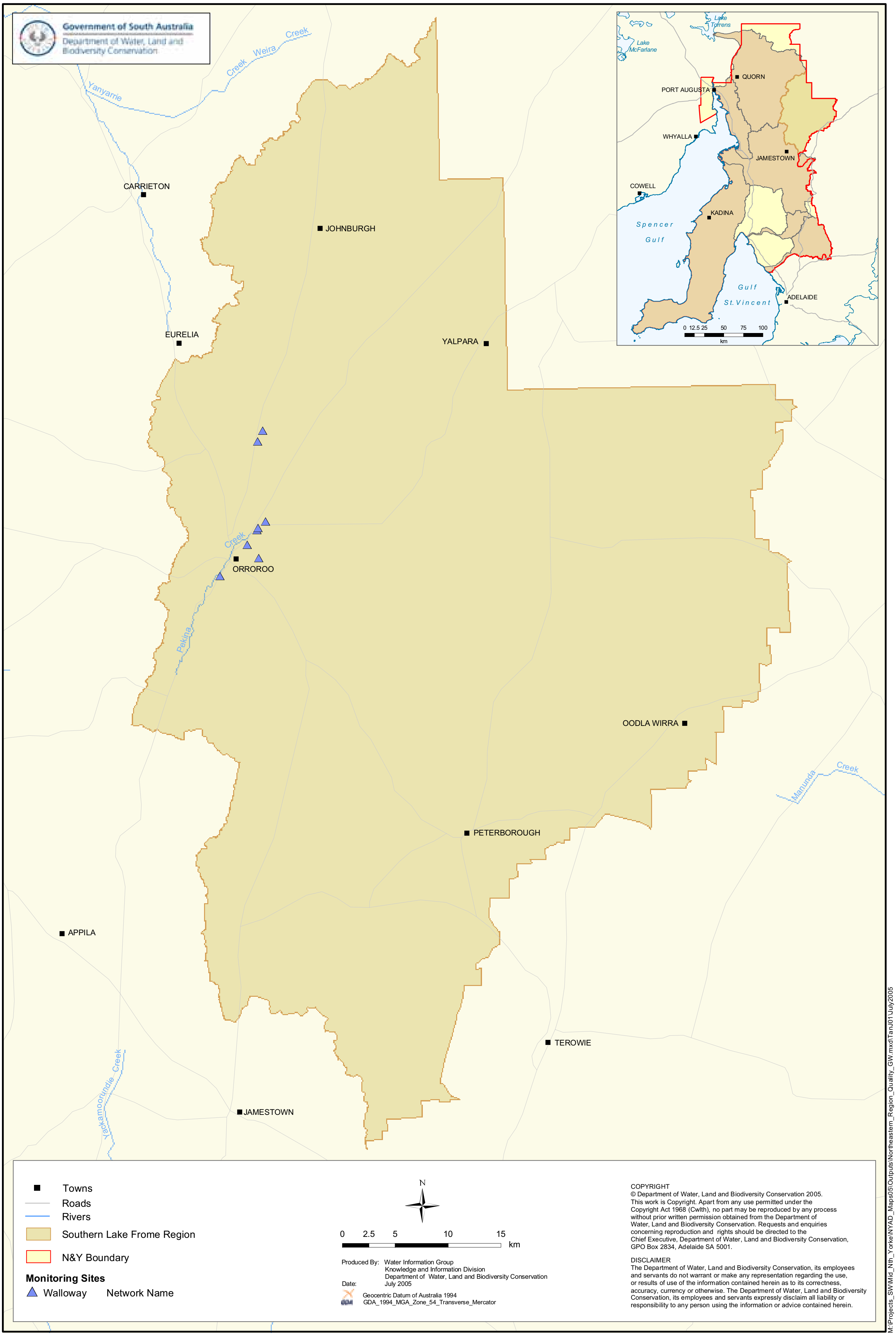

Figure 21. Current Groundwater Quantity Monitoring Sites in the Southern Lake Frome Region

8. CURRENT MONITORING — GROUNDWATER QUALITY

8.1 WILLOCHRA CREEK CATCHMENT

DWLBC currently maintains an observation network that monitors both quantity and quality of groundwater in the southern portion of the Willochra Basin (Fig. 22). Observation wells are located northeast of Wilmington and in the Willochra Creek sub-catchment. There are no observation wells within the FRA system of the Southern Flinders Ranges to monitor salinity.

Magarey and Deane (2004) provided details of the monitoring network in the Northern and Yorke region. The following paragraph and suggestions provided in this section are reproduced from that report.

The Willochra network is monitored every six months in the autumn and spring and is focused on the areas of good quality groundwater in the hundreds of Willochra and Gregory. These areas correspond to the current irrigation areas on the Willochra Plain that use groundwater for irrigation of pasture and vines as well as the Melrose TWS. Most of the current monitoring wells have a half-yearly dataset from 1985 to present.

8.1.1 DATA AND INFORMATION GAPS — GROUNDWATER QUALITY MONITORING

It is suggested that the current groundwater salinity monitoring network be expanded for the Willochra Creek Catchment. Salinity monitoring needs to be included in monitoring near Melrose to determine impacts of the decline of groundwater levels on salinity levels. It is apparent from consultation with landholders that many of the old wells were only partially cased. Partially cased wells and old eroding well casing can lead to leakage of higher salinity water into aquifers with water of a lower salinity. Further investigations are suggested.

Table 7 contains specific suggestions for groundwater quality monitoring in the Willochra Creek Catchment.

8.2 BROUGHTON RIVER CATCHMENT

In the Rocky River sub-catchment area, the Willochra, Walloway and Mid-North Rivers networks monitor salinity with a good coverage of the area. The Mid-North Rivers network also monitors salinity in the Crystal Brook, lower Broughton River, mid Broughton River; in the southern portion of Bundaleer and Never Never Creeks sub-catchment; and in the north of the Hutt River sub-catchment. Jamestown and Georgetown networks monitor at one site each in the north and mid-sections, respectively, of the Yackamoorundie sub-catchment area. The Jamestown network monitors salinity in the northern sections of the Bundaleer and Never Never Creeks and Freshwater Creek sub-catchments. The Booborowie network

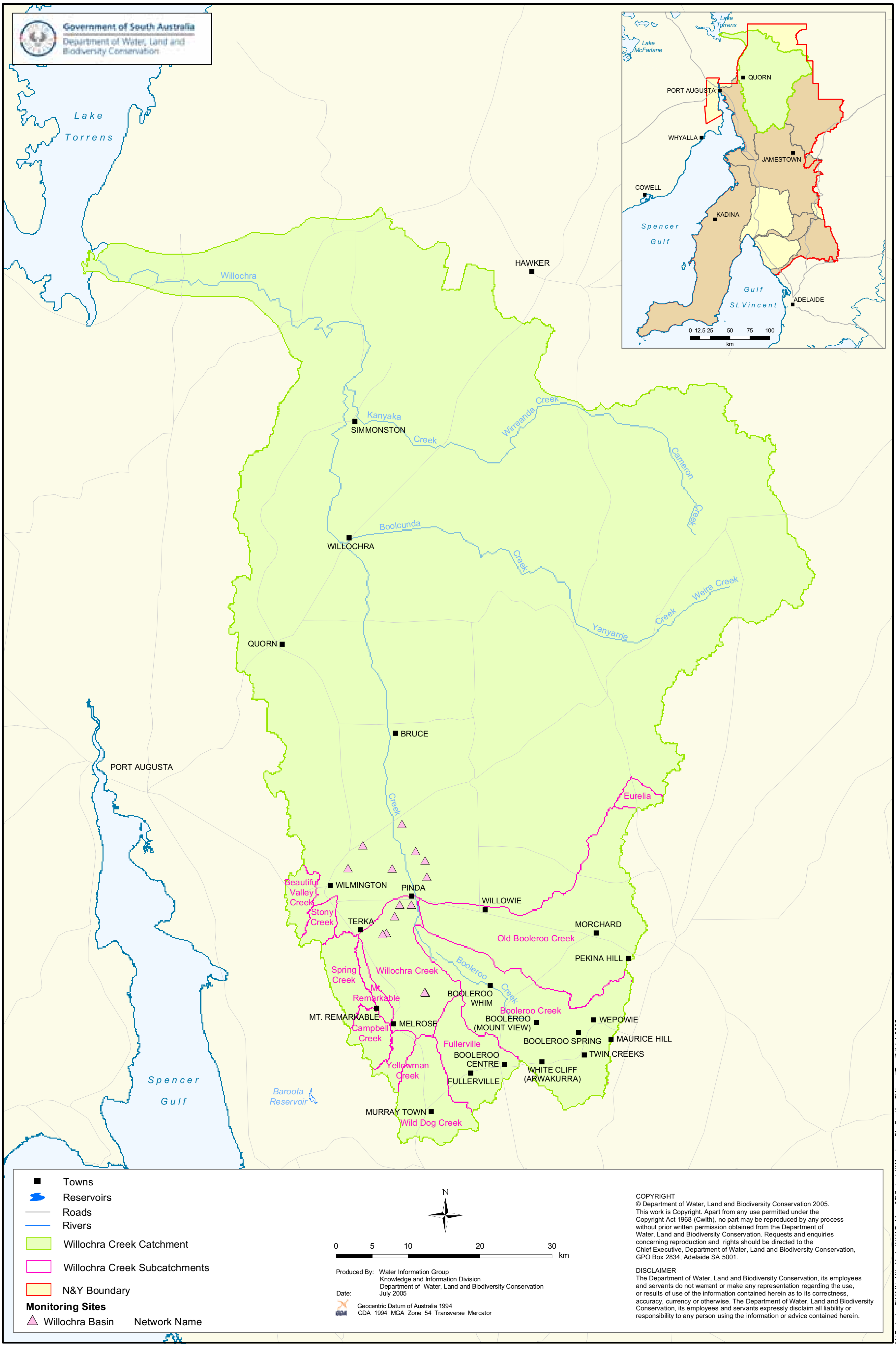

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Figure 22. Current Groundwater Quality Monitoring Sites in the Willochra Creek Catchment

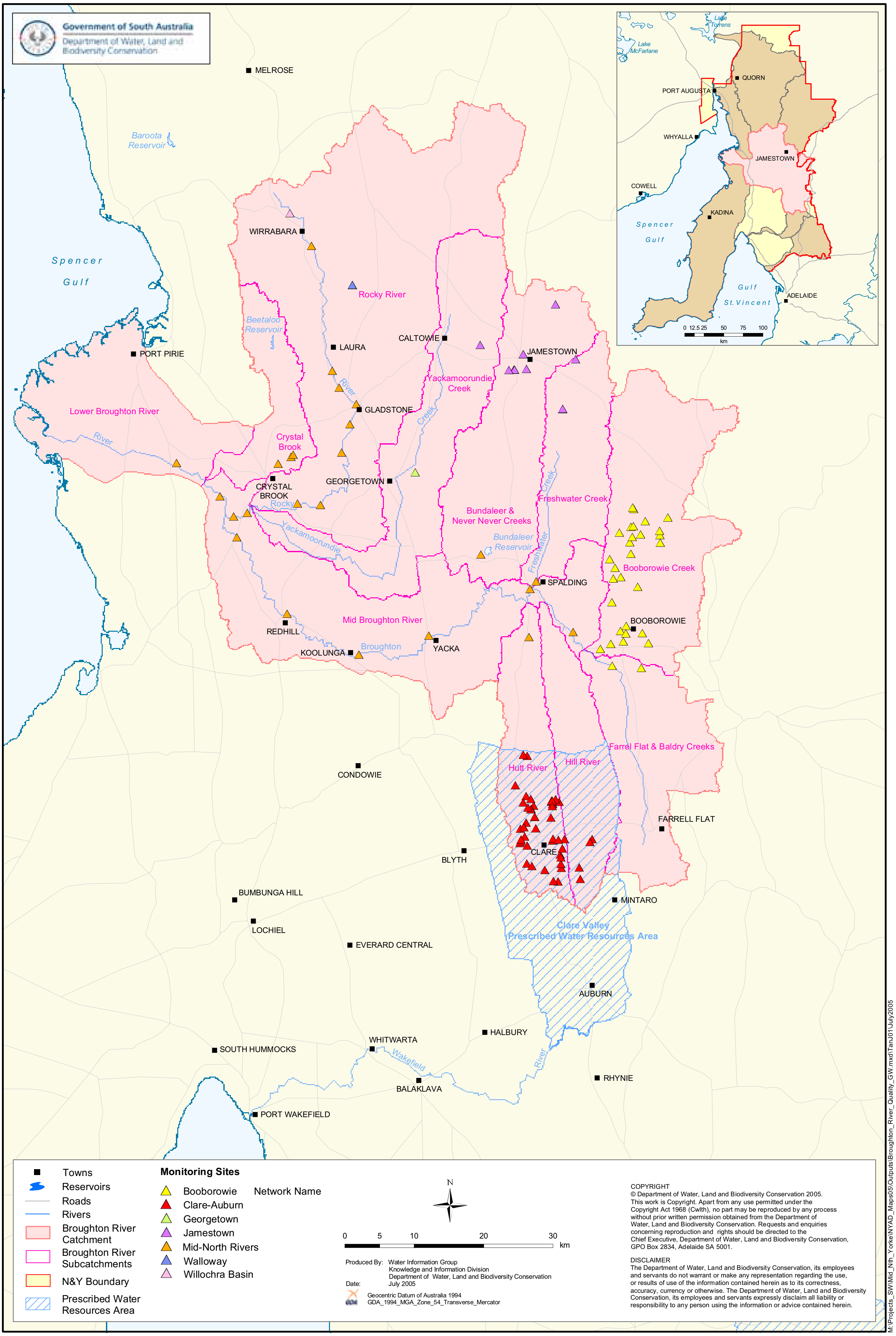

Figure 23. Current Groundwater Quality Monitoring Sites in the Broughton River Catchment

monitors salinity in the Booborowie Creek sub-catchment, and just into the northern portion of the Farrel Flat and Baldry Creeks sub-catchment. The Lochiel network is monitoring salinity in the Lake View sub-catchment, and the Kybunga network monitors salinity in the Diamond Lake sub-catchment area. The Clare–Auburn network monitors salinity in the eastern portion of the Diamond Lake sub-catchment, as well as in the southern sections of the Hutt and Hill River sub-catchments. The Balaklava network monitors salinity in a small southern portion of the Diamond Lake sub-catchment.

8.2.1 DATA AND INFORMATION GAPS — GROUNDWATER QUALITY MONITORING

It is suggested that groundwater salinity be monitored at a minimum of two sites in the Lake Bumbunga sub-catchment, and one site in the Diamond Lake sub-catchment. This can be done at wells that form part of the existing Lochiel observation well groundwater monitoring network in those sub-catchments.

Table 12 contains specific suggestions for groundwater quality monitoring in the Broughton River Catchment.

8.3 WAKEFIELD RIVER CATCHMENT

Groundwater salinity in the Skillogalee, Eyre Creek and Upper Wakefield River sub-catchment areas is being monitored by the Clare–Auburn observation wells network. The Mintaro network also monitors salinity in the northern section of the Upper Wakefield River sub-catchment. The Balaklava network monitors groundwater salinity in the Lower Wakefield River sub-catchment.

Table 18 contains specific suggestions for groundwater quality monitoring in the Wakefield River Catchment.

8.4 LIGHT RIVER CATCHMENT

There is limited salinity monitoring of groundwater in the Light River Catchment. The Barossa and Lyndoch Valleys network is monitoring groundwater salinity in the southern section of the Mid Light River sub-catchment as part of the Barossa PWRA. Although little groundwater extraction takes place due to high salinity levels, it is suggested that research into groundwater use be carried out as any increases may affect groundwater quality, and thus have an impact on groundwater dependent ecosystems.

Table 24 contains specific suggestions for groundwater quality monitoring in the Light River Catchment.

8.5 MAMBRAY COAST CATCHMENT

Addressed under Section 7.5.

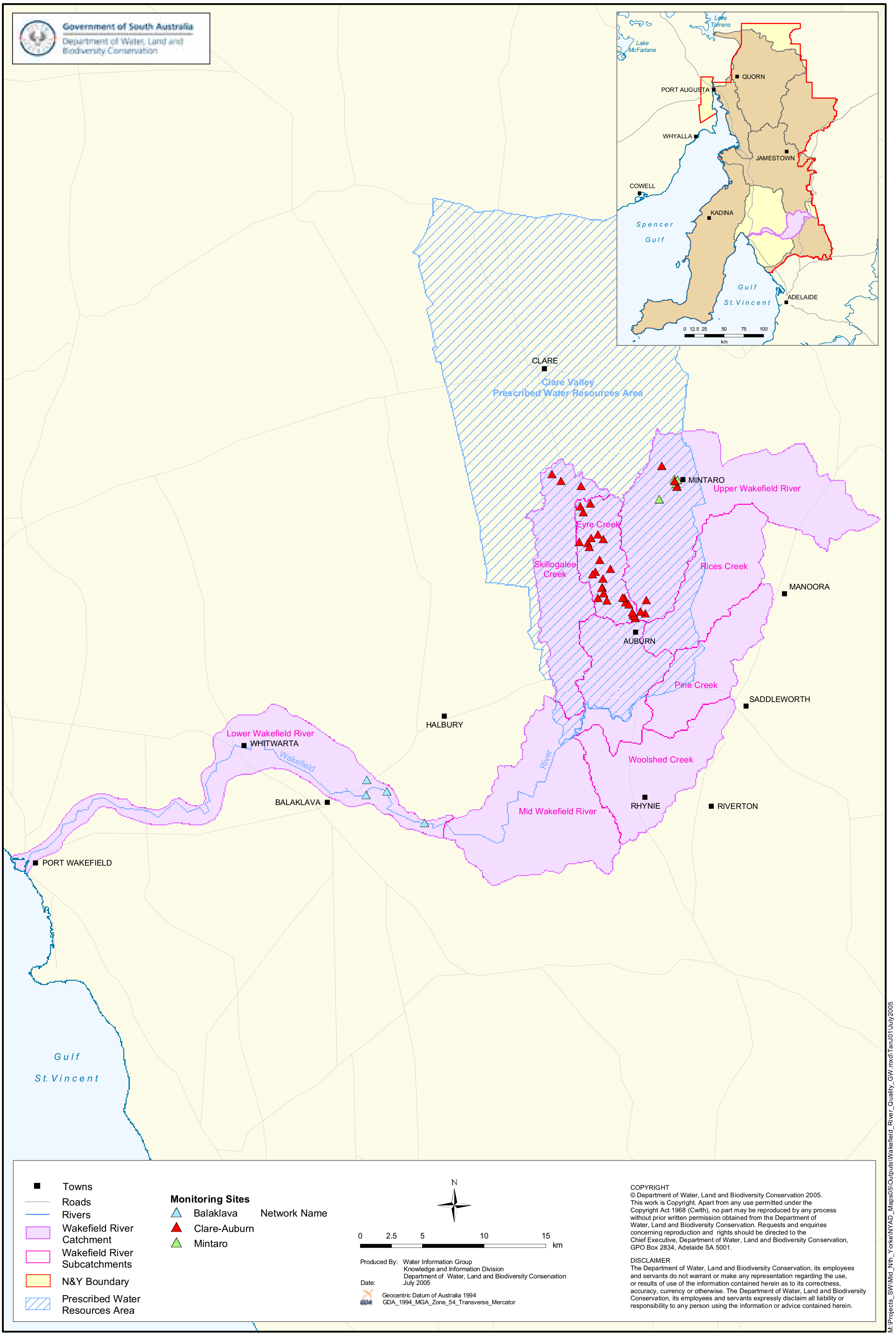

Figure 24. Current Groundwater Quality Monitoring Sites in the Wakefield River Catchment

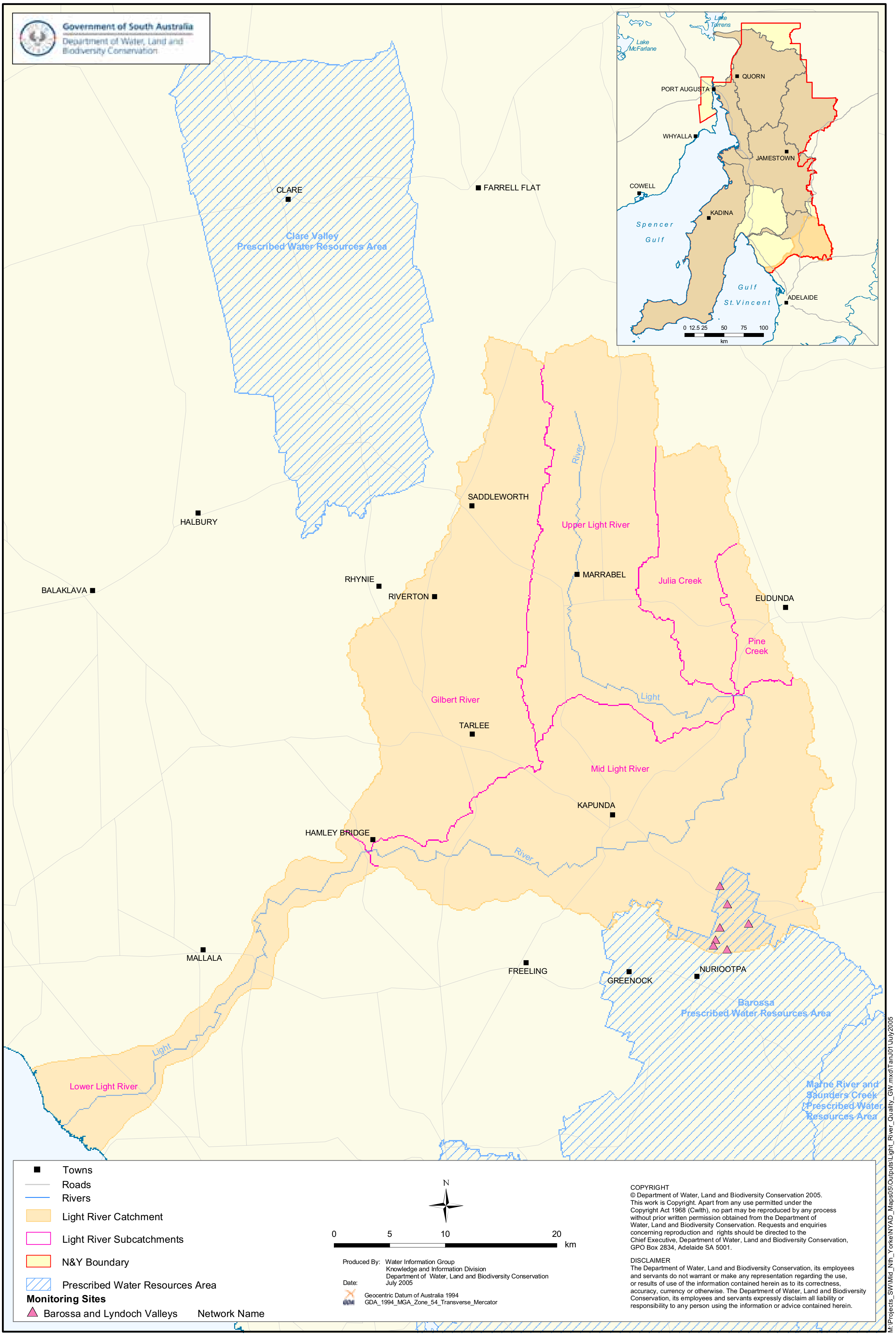

Figure 25. Current Groundwater Quality Monitoring Sites in the Light River Catchment

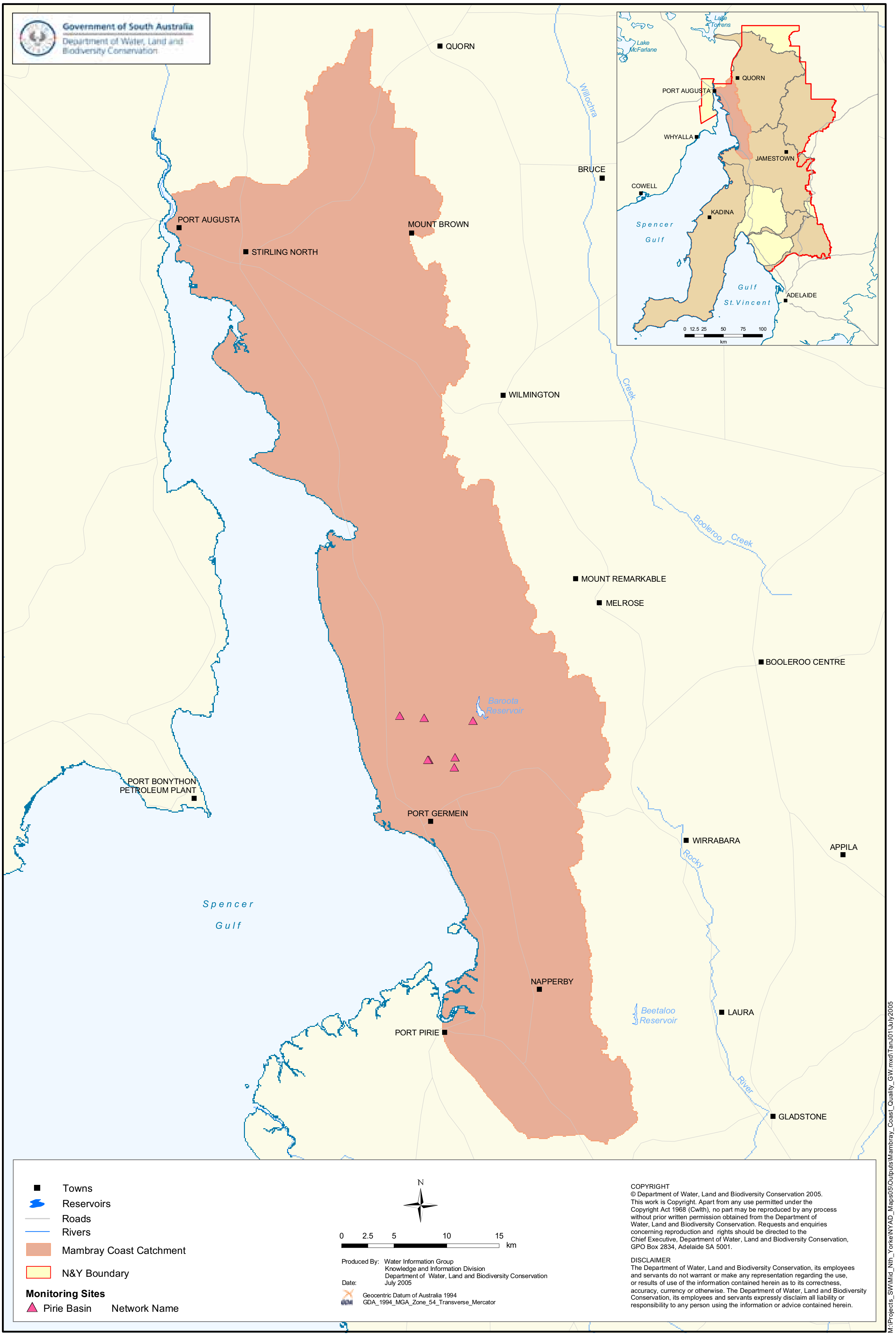

Figure 26. Current Groundwater Quality Monitoring Sites in the Mambray Coast Catchment

8.6 YORKE PENINSULA

Addressed under Section 7.6.

8.7 SOUTHERN LAKE FROME BASIN

Addressed under Section 7.7.

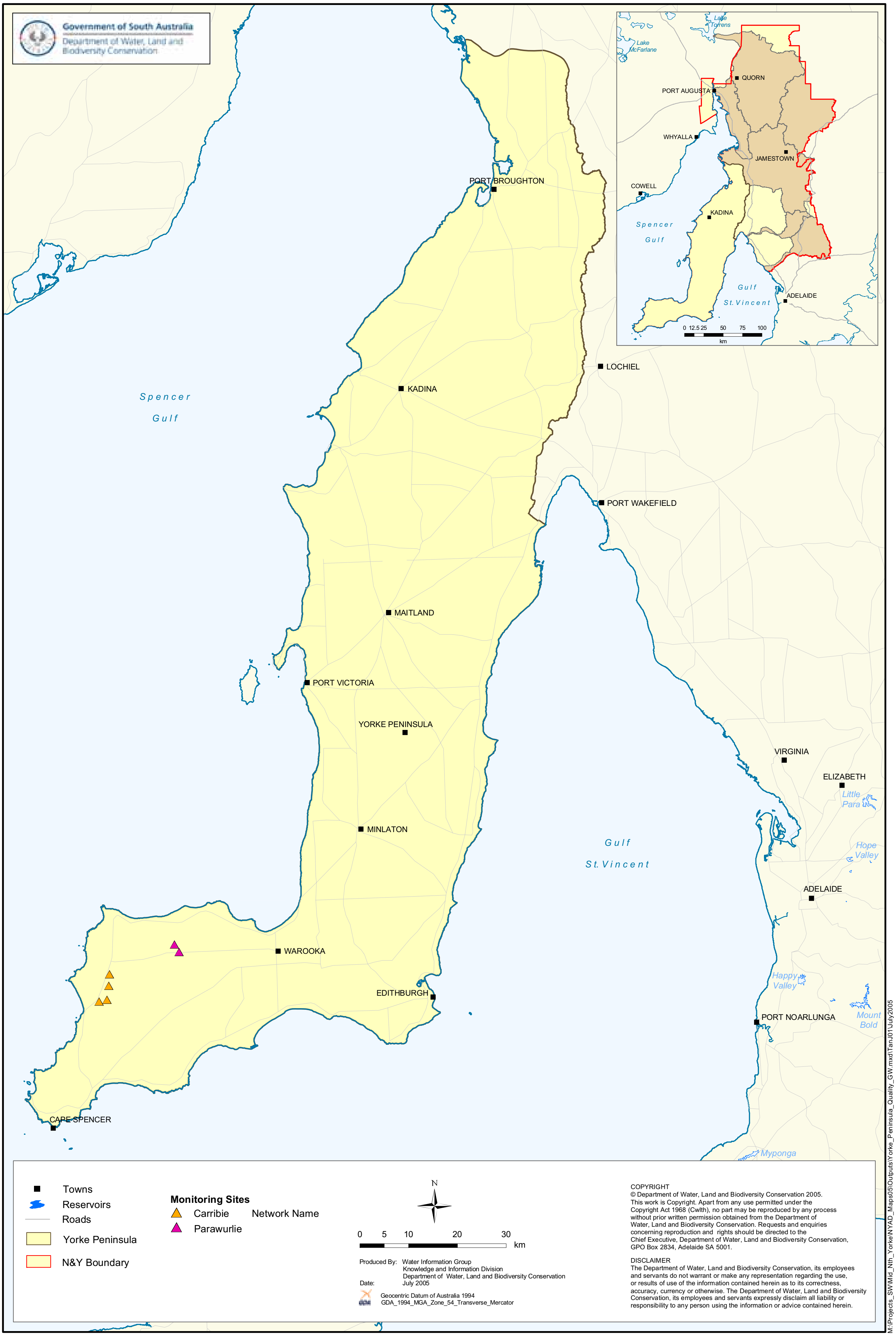

Figure 27. Current Groundwater Quality Monitoring Sites on the Yorke Peninsula

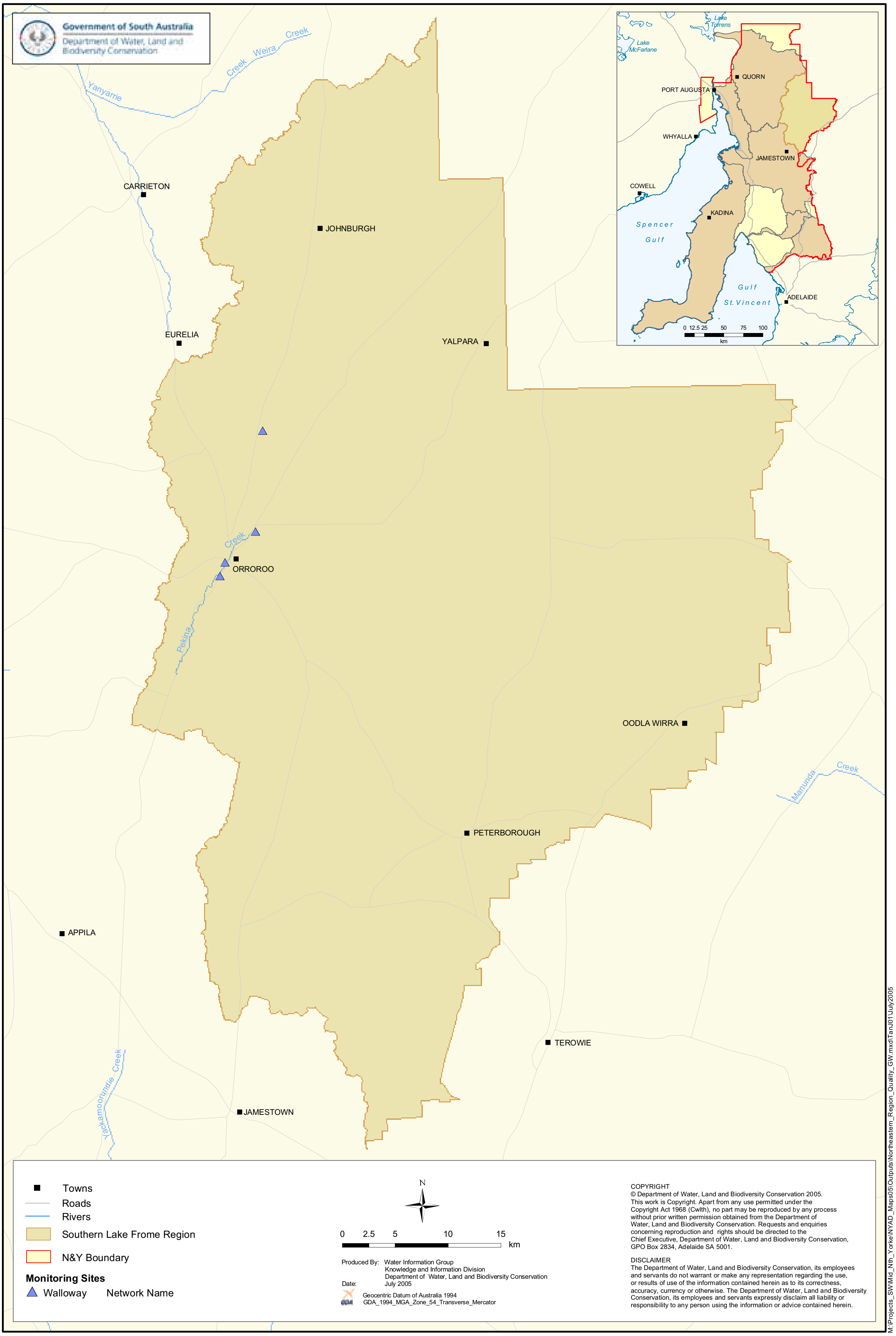

Figure 28. Current Groundwater Quality Monitoring Sites in the Southern Lake Frome Region

9. CURRENT MONITORING — AQUATIC ECOSYSTEMS

9.1 INTRODUCTION

There are currently no quantitative aquatic ecosystem monitoring programs in place within the Northern and Yorke NRM Region. Macro-invertebrate monitoring commissioned by the EPA occurs at a number of sites, but this is qualitative in nature and focused on a whole-of-state spatial scale of reporting.

The role of Waterwatch has been significant in raising awareness and involving the community in aquatic ecosystem monitoring. The data collected in community monitoring programs can add great value to considered scientific monitoring programs. However, such programs cannot be relied upon as the sole source of data for ecosystem monitoring.

9.2 DISCUSSION — AQUATIC ECOSYSTEM MONITORING

Monitoring of aquatic ecosystems is problematic in many respects and has been the subject of a wealth of research and evaluation in recent years. Despite this, no clearly defined, universal approach exists that can currently inform a gap analysis from the perspective of program-level spatial and temporal requirements. Additionally, much of the work completed to date has focused on permanent aquatic systems and is unproven in monitoring the ephemeral streams typical of South Australian conditions.

This situation may change rapidly for South Australian NRM Regions in the near future, with a range of research projects focusing on ephemeral system monitoring methodologies nearing completion. The most notable of these is the National Rivers Consortium (Land and Water Australia) project entitled 'Quantifying the Health of Ephemeral Rivers'. This project is developing and trialling a monitoring methodology tailored to Australian ephemeral river systems. Additionally, the National Monitoring and Evaluation Framework will be an important resource to inform future monitoring programs.

In reviewing recent literature relating to monitoring program design for environmental flows, King et al. (2003) summarised the commonly observed steps into three themes:

1. Initial development: defining objectives, constructing conceptual models and developing predictions and hypotheses about how the system will respond to environmental flows.
2. Choice of response variables or indicators: selection of appropriate indicators based on the understanding acquired in stage one.
3. Design considerations: analytical and statistical design, formal target setting, evaluation processes.

Whilst aimed at environmental flow assessments, which typically have specific reporting requirements, this provides a useful framework. Many program design principles remain applicable to broader aquatic ecosystem monitoring. The stages outlined above by King et al. (2003) are further discussed below.

9.2.1 INITIAL DEVELOPMENT

Program Aims

A key step in designing an effective monitoring program is to determine and clearly state the objectives of monitoring. This enables a more structured approach to the development of program details (ANZECC–ARMCANZ 2000; King et al. 2003; Downes et al. 2002). In some cases this will be decided by reporting requirements.

It is preferable to state program aims explicitly, rather than making a general statement about improved 'health', which is highly open to interpretation. A tightly defined series of objectives assists in the design of monitoring programs to measure progress towards these goals (ANZECC–ARMCANZ 2000; Downes et al. 2002).

Literature and Research Review

Any prior work undertaken in a region is a valuable asset. Historical biological data may be a particularly useful source of baseline information for an un-impacted ecosystem.

Methodologies of previous studies can provide guidance in planning any new investigations, as can reviews or case studies of prior monitoring program implementation experience (e.g. NRC 1995; Growns et al. 2003).

Scientific panels can provide critical input to program design, particularly in cases where little or no published research is available. Ideally, scientific input will be maintained throughout the design–implement–evaluate–review cycle of effective monitoring.

Conceptual Models

The complexity of ecological systems requires that the conceptual understanding of ecosystem function, upon which monitoring programs are founded, is clearly articulated. Conceptual models provide a sound framework to base decisions on monitoring and management (Gross 2003), and facilitate multi-disciplinary input through scientific panels. They also provide an interpretive aid for evaluating monitoring data and a forum for the integration of new knowledge of ecosystem function, as this is developed (Kurtz et al. 2001; NRC 1995).

The final form of the models will be a subject for clarification during the development process, and these may feature alternative representations to suit a range of audiences. For example, simple models supported by clear diagrams will enable communication of key concepts with stakeholders irrespective of experience or training.

Ideally it will be appropriate to develop at least control (explaining system dynamics) as well as stressor (detailing interactions between stressors, ecosystem function and indicators) models for the system (Gross 2003). Such models are required in order to integrate understanding of ecosystem function and to justify monitoring program decisions, such as indicators, respectively.

9.2.2 CHOICE OF RESPONSE VARIABLES OR INDICATORS

There is abundant literature on the topic of suitable indicators for use in monitoring programs. Typically, a mixture of measurements covering ecosystem structure and function are used, and physical–chemical monitoring helps to interpret the results obtained.

Monitoring program objectives and understanding or knowledge acquired through previous studies or relevant literature are vital contributions toward selecting specific indicators to be monitored. The expected responses of each indicator to conditions can be framed as hypotheses, allowing for appropriate analysis of results, refinement of conceptual models and ongoing improvements to the monitoring program.

9.2.3 DESIGN CONSIDERATIONS

Inference of Beneficial Ecological Impact

Monitoring programs to evaluate and link ecological responses directly to management actions are a form of impact monitoring. To achieve the best statistical inference of change due to human activities, variations on the Before-After-Control-Impact (BACI) design are most suitable (Downes et al. 2002).

In our highly modified contemporary landscapes, it is often not possible to achieve a BACI design due to the lack of an available control site. A control site is one of (relatively) pristine condition, and is used for comparison to the monitored site in statistical analysis. Appropriate selection of both control and monitoring sites is vital to the success of monitoring programs. Essential criteria include similar ecological characteristics and non-anthropogenic influence (such as climate). It is also vital that management intervention will not have a negative effect on the chosen location.

In the absence of a suitable control, it is necessary to incorporate a 'levels of evidence' approach to verify that changes identified through any monitoring program are due to management action (Downes et al. 2002). Such approaches apply 'causal criteria' (Downes et al. 2002) to develop what is effectively circumstantial evidence of impact.

Where there is no control site, the requirement for baseline information is a higher priority. A good understanding of the natural variations found in the system needs to be developed in order to establish that beneficial changes are due to on-ground actions.

Data Storage

Appropriate data storage is an essential consideration during any monitoring program design phase. Ideally, all data will reside on a state-maintained database and be made freely available to researchers and the general public.

The following actions are suggested when developing monitoring programs for aquatic ecosystems:

- Obtain the input of a scientific advisory panel to capture the perceptions of current and un-impacted ecosystem function. This panel would also be charged with ongoing monitoring program development (including conceptual models) and review.

- Develop, regularly review, and improve conceptual models explaining current understanding of ecosystem function and responses to stresses.
- Ensure that all ecological information gathered under monitoring programs is entered onto a suitable state database and made freely available for researchers and the general public.

9.2.4 PROGRESSING ECOSYSTEM MONITORING IN THE REGION

Consideration of EWR is mandated in state legislation and defined in the State Water Plan 2000 as:

> "The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk".

NRM Boards will have the lead role in ensuring that the water-dependent ecosystems found within catchment areas are identified and EWR are being met. Where this is not the case, appropriate environmental water provisions must be made and protected. Hence, the identification of appropriate water regimes, including volumes, timing, duration and quality (see for example McCosker 1998; Davis et al. 2001) and the degree to which they are being met is essential background information for the boards.

As a starting point, it is useful to characterise or estimate the natural (pre-European) water regime in order to identify important flow characteristics. These can then be related to their significance in maintaining ecological pattern and process. Flow volumes required to achieve these can then be determined and used to benchmark the level of hydrological stress on a system. In turn, it is vital that policy development is based on ensuring, or returning, these flows as required under the State NRM Plan.

Aquatic ecosystems function in varying states of three-dimensional connectivity with the surrounding landscape, and ensuring that EWR are met will largely address these connectivity issues. Providing adequate water is a major step in assuring that ecosystem patterns and processes are maintained. Critical habitats must also be protected or restored if ecosystems are to return to pre-European patterns.

To date, work undertaken in the region has consisted only of mapping ecological assets and completing snapshot assessments of baseline condition (Seaman 2002; Risby et al. 2003; Vanlaarhoven et al. 2004; Favier et al. 2000, 2004). These studies have been completed virtually throughout the NYNRM region to varying levels of detail. The value of snapshot surveys is limited because they fail to account for the natural variations present within normal ecosystem function. This is critical information for the design of quantitative monitoring programs, helping to inform the selection of appropriate indicators, and the level of replication required to account for natural variations when determining trends in natural patterns or processes.

Whilst not sufficient to base future programs on, these studies have considerably improved the position of resource managers to tailor programs for the region. The 'Quantifying the Health of Ephemeral Rivers' project aims to develop a methodology for use in undertaking such monitoring work. This methodology constitutes a strong base from which to tailor future monitoring programs.

Much can be done immediately to initiate a culture of monitoring in the region. Following is a summary of the key findings of the baseline assessments undertaken to date; and a discussion of the assets identified. These are likely to be future monitoring sites.

Given the range of natural variations present in aquatic ecosystems, it is important that considered and scientifically robust monitoring programs be implemented as a matter of some priority. Monitoring suggestions made below will not suffice in this regard, but are intended to improve the baseline information available and allow some rudimentary tracking of resource condition.

9.2.5 INITIATING MONITORING

Where good habitat and high-risk features have been identified in the references reviewed below, it is suggested that immediate monitoring be instigated to observe any changes.

Until more rigorous scientific methodologies can be developed, it is further suggested that simple monitoring based around photo points be established immediately, possibly undertaken by contracted NRM Officers, to develop a permanent visual record.

Biannual visits in spring and autumn will help to show any seasonal changes in vegetation cover. The location of erosion features or the extent of encroaching reeds could be noted at each visit against permanent or semi-permanent landmarks (such as roads, fence lines, power lines, intentionally-placed star pickets) to provide simple data.

Additional information that can be collected, subject to resources and skill levels, includes:

- Bird surveys.
- Vegetation assessment using the Rapid Appraisal of Riparian Condition method (Land and Water Australia (LWA) see <http://www.lwa.gov.au/downloads/publications_pdf /PR040656.pdf>.
- Noting any regeneration of pest or endangered plant species.
- Fish surveys (using fyke nets or bait traps).
- Frog surveys (using the Frog Census methodology).
- Qualitative macro-invertebrate sampling using Waterwatch protocols.
- Simple water quality parameters: salinity, pH, nutrients (using the Waterwatch sampling kits).
- Cross-sections of stream bed and bank profile.
- Water levels where permanent structures exist to reference this against (e.g. bridges).

9.3 WILLOCHRA CREEK CATCHMENT

DWLBC carried out a preliminary assessment of aquatic ecosystems in 2003 for the Willochra Creek Catchment (Risby et al. 2003). This identified types of aquatic ecosystems occurring in the catchment and potential threats to those ecosystems. It was found that most of the significant aquatic ecosystems are located in the valleys and gorges of the western section of the catchment. Saline riparian wetlands also occur in the lower catchment and represent important aquatic habitat.

The following environmental changes have been reported by landholders:

- Stress on Eucalypts with little to no regeneration that would normally occur following high flows.
- A reduction in permanent pools and soaks and hence of the refuge areas these provide for aquatic flora and fauna when there is no streamflow.
- A reduction in the distribution of fish species as a result of the reduced connectivity between the northern and southern sections of the catchment, as well as a reduction of refuge areas in the southern section.

Macro-invertebrates

The tributary streams in the upper catchment area were found to be in good condition in terms of diverse macro-invertebrate communities (EPA–AWQC 2003). However, once flow reaches the Willochra Plain the diversity of macro-invertebrate species was significantly reduced. This was attributed to high salinity in these lower reaches.

9.3.1 DATA AND INFORMATION GAPS — AQUATIC ECOSYSTEM MONITORING

- Determine and map riparian vegetation condition and link this to salinity trends.
- Map watercourse condition parameters to determine risk levels (i.e. bed and bank stability, channel disturbance, sedimentation, cultivation, location of dams and levee banks).
- Assess areas in the southern section of the catchment where River Red Gum occurs (which relies on flooding to regenerate), to determine whether populations are self-sustaining.
- Carry out more detailed fish surveys including catchment distribution following a major flood event, and on unsurveyed streams in the catchment.
- Map significant geomorphic habitat types including hyporheic (zone below streams) habitat.
- Expand macro-invertebrate monitoring throughout the catchment to improve the calibration of the AusRivAS model.

These and other suggestions are outlined in more detail in Table 8.

9.4 BROUGHTON RIVER CATCHMENT

There is currently no dedicated environmental monitoring undertaken in the Broughton River Catchment. The following issues were identified as being of particular concern for the catchment by Favier et al. (2004):

- Lack of native vegetation. Dominant annual exotic grasses and an absence of, or very sparse, overstorey.
- Increased reed distribution, with concentrations of Common Reed (Phragmites sp.) and Bulrush (Typha sp.) along the Broughton River in the eastern Mid Broughton River sub-catchment.

- Potential loss of good areas of native vegetation through degrading processes such as weed invasion and/or stock grazing. Such areas were found along the Broughton River and tributaries from just downstream of Yacka, as well as where the Broughton passes through the Yackamoorundie Hills. These areas typically featured good in-stream vegetation but a lack of native vegetation on the banks and floodplain; or they had a good cover of native overstorey but understorey layers of shrubs and grasses were absent.
- Monitoring of aquatic ecosystems that have habitat considered to be in good condition is vital. In these areas it is suggested that weed removal and revegetation (or natural regeneration) be carried out, followed by ongoing monitoring to evaluate the success of rehabilitation and to carry out further rehabilitation if threatening processes are still impacting upon the native vegetation.

9.4.1 SUGGESTED SITES FOR IMMEDIATE PHOTOPOINT MONITORING

- Areas of remnant vegetation found along the lower Rocky River where it joins with the Broughton River.
- Significant riverine habitat for fish, birds, frogs and macro-invertebrates in the Lower Broughton River sub-catchment (downstream of Cockeys Crossing), and at Mooroola gauging station in the Mid Broughton River sub-catchment, where a range of native vegetation and in-stream physical habitats and permanent or semi-permanent aquatic habitat occurs.
- Within the Rocky River, Yackamoorundie Creek, Crystal Brook and Broughton River sub-catchments a unique habitat occurs that comprises permanent springs and macrophyte beds where these streams turn westward. Lignum swamps in these sub-catchments are considered to be a high priority for management and protection, particularly with regard to the maintenance of the required flooding regime.
- The Hill River chain of ponds pools.
- Lower and middle reaches of the Hutt River chain of ponds pools.
- Areas identified as active or potential erosion sites.

9.4.2 INVESTIGATIONS

In addition to the preliminary monitoring suggested above, a number of technical and scientific investigations have been proposed by Favier et al. (2004). This section outlines the priority investigations included in that report.

- Impact of groundwater extraction upon pools and baseflow extraction in the Hutt River and Hill River sub-catchments.
- Information about fish populations and distribution throughout the catchment, and causes of low numbers and diversity of native fish. It is suggested that further fish surveys be carried out for:
  - middle reaches of the Hutt River sub-catchment
  - Hill River
  - Yakilo Creek sub-catchment.
- The impacts of trout distribution on native fish, fish migration processes and the impacts of impediments such as weirs upon fish migration are not well understood for the Mid

Broughton River sub-catchment (upstream of Yacka to the confluence of the Hill River and Yakilo Creek (upstream of delta)).

- The largest numbers of introduced macro-invertebrates were found in the Broughton and Hutt Rivers, south of Spalding and in Crystal Brook at Bowman Park. Investigations are suggested to provide greater understanding of the impact of introduced macro-invertebrates on native species.
- There is an inadequate understanding of the relationship between flow and the opportunistic nature of some species of plants and animals. It is suggested that this relationship be further researched to provide a better understanding of the reproductive and migratory habits of such species.
- Spalding Blown Grass (*Agrostis limitanea*) grows along sections of Yakilo Creek. It is threatened by grazing and resulting weed invasion, herbicide drift and alterations to flow due to water extraction for irrigation. Weed control and the re-introduction of new populations of Spalding Blown Grass followed by ongoing monitoring are advisable.
- The Krefft's Tiger Snake (*Notehcis ater*), found along the Broughton and Rocky Rivers, is threatened by modification of watercourse vegetation as a result of agricultural activities as well as impacts on water quality. It is important that nutrient levels are reduced and that riparian vegetation is protected to maintain suitable habitat.
- Currently there is no information on the location of hyporheic fauna in the Broughton River Catchment. It is therefore suggested that research into the location and biota of such environments be carried out.
- Investigations are advised to provide an understanding of whether the Yabby parasite Thelohania has an adverse impact on other fauna, in particular those animals that use yabbies as a food source (e.g. fish, birds and mammals).
- In the vicinity of Yacka, the Broughton River is different to the rest of this section of the Mid Broughton River sub-catchment. Investigations to determine the chronology of change and its causes, including natural hydraulic factors and human impacts, is advised.
- It is suggested that water quality monitoring for the Spencer Gulf where the Broughton River discharges to the sea be established and potential impacts on near shore marine ecosystems be determined.

These and other suggestions are outlined in more detail in Table 13.

9.4.3 COMMUNITY MONITORING

As part of the Waterwatch program, community groups monitor mainly creeks and rivers in the Broughton River Catchment with the occasional group monitoring a well. It is advisable for data collected by Waterwatch to be incorporated into water quality monitoring assessments (Table 14). Data would ideally be stored in a secure and freely available database (with appropriate data quality statements).

9.4.4 GEOMORPHOLOGICAL ZONES

Favier et al. (2004) divided the catchment into geomorphological zones that have unique physical and hydrological characteristics that determine each zone's ecological processes. These can be used as a basis to structure a monitoring program, with an appropriate number of sites included from each zone. Zones identified were:

- Lower meandering zone — Wakefield River main channel from the town of Balaklava to the estuary.
- Upper meandering zone — Wakefield River main channel from downstream of The Rocks to Balaklava.
- Mobile zone — approximately 2 km downstream of Hermitage Creek to 1 km downstream of The Rocks.
- Transition zone — upstream of Robin's Ford to the confluence with Skillogalee Creek.
- Constrained zone — Skillogalee Creek.
- Incised zone — Wakefield River main channel from Skillogalee Creek to Wookie Creek; and Eyre, Pine, Rices, Hermitage and Woolshed Flat Creeks.
- Chain of ponds zone — Wakefield River main channel upstream of Wookie Creek.

9.5 WAKEFIELD RIVER CATCHMENT

The ecology of the Wakefield River Catchment is highly dependent on groundwater fed baseflows and resulting permanent pools and hyporheic environments. These areas of permanent surface water are of great importance as refugia to aquatic flora and fauna in dry periods. The following monitoring site suggestions and research investigations were taken from Favier et al. (2000).

9.5.1 SUGGESTED SITES FOR IMMEDIATE PHOTOPOINT MONITORING

- The Lower Wakefield sub-catchment ephemeral floodplain swamps that have been cut off from the main channel.
- Areas of significant riparian habitat, in particular:
    - the main channel from The Rocks to Undalya
    - sections of the main channel above Mintaro Creek
    - Skillogalee Creek below Port Road bridge
    - Long Gully
    - Wakefield River from 2 km upstream of Robins Ford to ~5 km downstream of The Rocks
    - the water reserve at Riley Road.
- Permanent pools above the confluence of the Wakefield River and Wookie Creek (diverse in-stream vegetation, indicative of pre-European pools in Rices and Eyre Creek sub-catchments).
- Estuarine mangrove environment around Port Wakefield.
- Areas of good native vegetation at:
    - the main channel from The Rocks to Whitwarta
    - sections of Skillogalee Creek
    - along Pine Creek (small patch of degraded remnant riparian vegetation featuring native shrub and grass species).

- Potentially active erosion heads:
  - within the Lower Wakefield sub-catchment
  - within the Port Wakefield town common ~300 m downstream of Highway One
  - about 5 km upstream of the previous location
  - along tributaries of Hermitage Creek
  - within the Skillogalee Creek sub-catchment
  - on Rices Creek and a tributary of Pine Creek
  - on Honey Suckle Creek and a small tributary of the upper Wakefield River.

9.5.2 INVESTIGATIONS

- Further research into aquatic ecosystems in the catchment needs to be carried out and the results applied to a revision of environmental water requirements. In particular:
  - the estuarine mangrove environment around Port Wakefield
  - low-lying salt marshes on the coastal floodplain of the Wakefield River.
- No native fish were present in Skillogalee Creek. It is suggested that this be investigated further to find an explanation.

These and other suggestions are outlined in more detail in Table 19.

9.5.3 COMMUNITY MONITORING

Community groups as part of Waterwatch monitor mainly creeks and rivers in the Wakefield River Catchment, with the occasional group monitoring a bore. It is advisable for data collected by Waterwatch to be incorporated into water quality monitoring assessments (Table 20). Data would ideally be stored in a secure and freely available database (with appropriate data quality statements).

9.5.4 GEOMORPHOLOGICAL ZONES

Favier et al. (2004) divided the catchment into geomorphological zones having unique physical and hydrological characteristics that determine each zone's ecological processes. These can be used as a basis to structure a monitoring program, with an appropriate number of sites included from each zone. Zones identified were:

- Lower meandering zone — Wakefield River main channel from the town of Balaklava to the estuary.
- Upper meandering zone — Wakefield River main channel from downstream of The Rocks to Balaklava.
- Mobile zone — ~2 km downstream of Hermitage Creek to 1 km downstream of The Rocks.
- Transition zone — upstream of Robin’s Ford to the confluence with Skillogalee Creek.
- Constrained zone — Skillogalee Creek.
- Incised zone — Wakefield River main channel from Skillogalee Creek to Wookie Creek; and Eyre, Pine, Rices, Hermitage and Woolshed Flat Creeks.
- Chain of ponds zone — Wakefield River main channel upstream of Wookie Creek.

9.6 LIGHT RIVER CATCHMENT

The ecology of the Wakefield River Catchment is highly dependent on groundwater fed baseflows and resulting permanent pools and hyporheic (zone below streams) environments. These areas of permanent surface water are of great importance as refugia to aquatic flora and fauna in dry periods. The following monitoring site and research suggestions were taken from Vanlaarhoven et al. (2004).

9.6.1 SUGGESTED SITES FOR IMMEDIATE PHOTOPOINT MONITORING

- Mangrove and samphire estuary environments at the Light River estuary.
- Permanent pools in The Rockies areas and upstream of Hamley Bridge.
- Light River downstream of the junction with Ross Creek.
- Gorge area downstream of Peters Road Crossing.
- Light River 3 km upstream of Hamley Bridge.
- Areas of remnant vegetation at:
  - lower reaches of Gilbert River, between Tarlee and Hamley Bridge (Short Leaf Honey Myrtle)
  - headwaters of St Kitts Creek (open woodland with a good cover of native grasses)
  - Light River, downstream of Ross Creek (open forest River Red Gum and Lignum, plus sedgelands)
  - southern tributary of Allen Creek (SA Blue Gum and Peppermint Box woodland and a good cover of native grasses)
  - middle reaches of the upper Light River between Hamilton and the junction with St Kitts Creek (Short Leaf Honey Myrtle).
- The extensive River Red Gum stand between the Light River estuary and just downstream of The Rockies (high ecological value as a wildlife corridor between the two areas of significant riparian habitat).
- Areas of potentially active erosion heads:
  - upper reaches of Fannel Creek
  - a tributary south of Kapunda
  - the most southerly of the Eastern Hill tributaries.
- Areas of potentially active gully erosion at:
  - a tributary south of Kapunda
  - St Kitts Creek
  - the tributary of St Kitts Creek in the Upper Light sub-catchment.

9.6.2 INVESTIGATIONS

- Due to the very limited flow monitoring currently being carried out in the catchment, environmental water requirements are poorly understood. Further investigation is required after sufficient data are provided by the establishment of additional flow gauging stations.

- There is little information available on the groundwater systems that support permanent pools and baseflow within the catchment. It is suggested that further research be carried out to gain a good understanding of the groundwater dependence of these ecosystems, and assess the impacts of extraction.
- Sediment transport processes.
- Investigations of increases in reed populations and their causes are advised.
- Investigations into the low abundance and diversity of native fish outside of the Light River estuary are suggested.
- The natural history of fish populations, particularly with regard to frequency of migration to the estuary and the breeding biology of landlocked fish, such as the Common Jollytail.
- A survey of fish populations for Allen Creek upstream and downstream of the weir are suggested to investigate the impact of the weirs at Hamley Bridge and Allen Creek as fish migration barriers.
- An assessment of the distribution of European Carp is advised to assess its impact on native fish.
- Only a small number of frogs have been recorded. It is not clear whether this is due to a low number of surveys.
- Major variations in macro-invertebrate diversity have been observed. As a precursor to ongoing macro-invertebrate monitoring, further investigations are advisable to improve the calibration of the AusRivAS model for the catchment.
- Mapping and basic assessment of hyporheic environments for the Light River Catchment, including basic faunal biology and their role as a refuge in dry periods.

These and other suggestions are outlined in more detail in Table 25.

9.6.3 COMMUNITY MONITORING

Community groups as part of Waterwatch have recently received training for monitoring water quality in the Light River Catchment. They will be monitoring mainly creeks and rivers, with the occasional group monitoring a well. It is advisable for data collected by Waterwatch to be incorporated into water quality monitoring assessments (Table 26). Data would ideally be stored in a secure and freely available database (with appropriate data quality statements).

9.7 MAMBRAY COAST CATCHMENT

No significant studies in aquatic ecosystems have been previously undertaken in this region. It is understood that this knowledge gap is currently being addressed. This work will provide an indication of suitable ecological assets for consideration in future monitoring programs in the catchment.

Isolated and groundwater dependent springs and pools of surface water of varying permanence occur in the Flinders Ranges. Permanent waters are found upstream of the Baroota Reservoir and in the Mambray Creek National Park.

Pools in the national park are already monitored for macro-invertebrates by the EPA. As this is only a recent inclusion in the program, no data have yet been released on the ecological condition. As much of the higher rainfall catchments in upland areas are under protection in the parks system, these are under only limited stress.

Key coastal areas of ecological significance including samphire and mangroves are also found in this region and will need consideration. Streamflow events that reach Spencer Gulf are extremely rare, averaging perhaps one year in 10; surface water is therefore not likely to have any ecological significance in the gulf waters.

Suggestions for monitoring are included in Table 28.

9.8 YORKE PENINSULA

The key aquatic ecological assets on Yorke Peninsula are the saline wetlands associated with topographic lows in the landscape. Seaman (2002), in a regional inventory and assessment of Mid-North wetlands, identified three wetlands of significance warranting monitoring — Gum Flat, Native Hen Lagoon and Chain of Lakes. Suggested monitoring parameters were water chemistry (conductivity, dissolved oxygen, temperature, turbidity and pH) and macro-invertebrates (including zooplankton and dragonfly larvae).

Recent decline in condition of the River Red Gum woodland at Gum Flat has been attributed to elevated saline groundwater levels (Moore & Ciganovic 2000). It would be appropriate to commence monitoring groundwater levels and salinity of wells in the vicinity of Gum Flat, in addition to mapping the condition of surviving River Red Gums and monitoring condition and recruitment.

Suggestions for monitoring are included in Table 27.

9.9 SOUTHERN LAKE FROME BASIN

No significant studies in aquatic ecosystems have been undertaken in this region to date. It is understood that this knowledge gap is to be addressed in projects to be undertaken in the near future. This work would provide an indication of any ecological assets present for consideration in future monitoring programs in the catchment.

Suggestions for monitoring are included in Table 29.

10. DATA AND INFORMATION MANAGEMENT

Data from many of the surface water programs conducted across the state are stored on the HYDSYS database managed by DWLBC. Much of this data is available through the Surface Water Archive which is accessible through the DWLBC Internet site. BoM has a separate HYDSYS database for its data management. Most of the rainfall data from the BoM HYDSYS database is provided to the DWLBC HYDSYS database on a regular basis. Some of this data is also available via the BoM website. The Australian Water Quality Centre (AWQC) has a separate database for management of its water quality data. Data from the SA Water quality monitoring program are stored with the AWQC and is available on request.

Data from the groundwater monitoring program are stored on SAGeodata, a database maintained by DWLBC. Groundwater data are accessible via the Obswell searchable interface through the DWLBC website. SAGeodata 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 (DES) vai the DWLBC website.

Data related to aquatic ecosystems are kept by DWLBC, DEH and the 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.

10.1 KEY FINDINGS

The review identified the datasets, databases and management arrangements for existing and historical monitoring programs. Data management processes are likely to be streamlined in accordance with new administrative arrangements under the *Natural Resources Management Act 2004* and further consultation with stakeholder agencies through the development of a comprehensive regional NRM Plan. Current data management arrangements are adequate for groundwater monitoring but require substantial improvement in the areas of surface water and aquatic ecosystem monitoring.

10.2 SUGGESTIONS

There is an urgent need to develop either a centralised system of data management, or to ensure that all data are stored on interoperable databases. Either of these systems would also require the development of standards to ensure that data collection is consistent in both format and quality. It would also be essential that, as far as is permissible, data will be readily accessible to all interested parties. An internet-based system would be the ideal method of providing data access.

The implementation of such a system would be of significant benefit to all parties as it would reduce the risk of duplication of monitoring programs; aid the establishment of communication links between organisations interested in water monitoring; enhance the ability of parties to develop information and knowledge products from the data; and ensure that management policies are based on informed conceptual models.

The use of data telemetry systems could result in cost savings over field-based downloading of data. It would also allow data to be downloaded and accessible in near real-time, which would facilitate the use of the data.

11. CONCLUSIONS

11.1 RISK FACTORS

A number of risk factors for sustainable water use and conservation of water-dependent ecosystems were identified for key catchments in the region. Some of these risk factors derive from historical activities associated with settlement such as vegetation clearance, channelisation, incision, erosion and deposition of sediment, stock grazing, and the introduction of exotic plants and animals. Ongoing risk factors vary between catchments and include the construction of farm dams, extractions of excessive amounts of groundwater for irrigation, diversion of water for flood irrigation, clearing of vegetation, channel modification, both point source and diffuse pollution, weed invasion and impacts from reeds, coastal development, and increasing population. Some actions aimed at natural resource conservation, such as construction of contour banks, may also have perverse outcomes for streamflow regimes.

Major water resources in areas of historical development are generally well monitored with a minimum network of monitoring sites. Smaller resources are usually less well understood and monitored. It is advisable that monitoring be expanded to include these resources, as they are frequently fragile and prone to over-exploitation if not managed effectively. Overcoming the lack of technical understanding of how systems function and a greater focus on resources coming under most pressure from development are key priorities for the improvement of existing monitoring systems.

11.2 CONCLUSIONS

The status of water monitoring varies considerably within the region. Depending on the theme concerned. Areas of historical use and good water quality and quantity are generally well covered from the perspective of a minimum network. The few small exceptions to this are highlighted within this report.

Areas where resources are only now coming under pressure need priority action. The recent dry conditions in the region have begun to highlight the fragility of the resources of the Mid-North, and public concern regarding over-development is growing. Even small resources require protection, but the relative size of the contribution to overall wellbeing of the region means that resources to undertake intensive technical investigations are unlikely to become available.

In many instances, the problems are due to a lack of technical understanding on how systems function. Paradoxically, much of this understanding will in part be generated through effective monitoring in a continual knowledge improvement cycle. For this to occur it is critical that monitoring is linked to the evaluation of data and the knowledge generated linked to management.

In the absence of sound technical understanding, monitoring and timely evaluation of data are essential if unsustainable use practices are to be identified and addressed before serious damage is done to the resource.

11.3 FUTURE WATER MONITORING STRATEGY

This report and suggestions contained herein can provide valuable background in developing future monitoring programs. The following tables summarise the key suggestions for each theme within each catchment, and contain section number cross-references to further information within the body of this report.

Table 4. Willochra Creek Catchment surface water quantity monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Rainfall	Understanding of rainfall spatial and intensity variations in the catchment	Five pluviometer sites: • Horrocks Pass Rd at Beautiful Valley Ck sub-catchment divide • Survey road near Rockville • Pekina Hill area • Maurice Hill area • Cook Rd near Poverty Hill.	5.1.1	High	
Evaporation	Whole catchment	Develop a monitoring program for evaporation to improve on calculations of water balances for the whole catchment.	5.1.1	High	
Streamflow	Impacts of flood irrigation on seasonality and volume of flows and how this relates to EWR	Monitor streamflow in Willochra and Wild Dog Creek sub-catchments. Monitor water usage in relation to flood irrigation to increase understanding of water usage and its potential impact upon EWR.	5.1.2	High	
Streamflow	Impact of farm dams on total catchment yield	Wild Dog, Beautiful Valley and Willochra Creek sub-catchments.	5.1.3	High	
Streamflow	Refining of initial rainfall to runoff values for much of the southern portion of the catchment	Establish streamflow gauging stations in the southern section of the catchment that are representative of the various catchment characteristics.	5.1.2	Medium	
	Understanding and quantifying longitudinal losses from streams draining the southern Flinders — input to groundwater recharge evaluations	Install at least one water level logger on Spring Creek downstream of the fault line.	Magarey and Deane (2004)	High	
Flow for EWR	Northern section of the catchment along Willochra and Boolcunda Creeks	Establish new environmenal water level monitoring sites to gain a better understanding of the duration and quality of connecting flows.	5.1.2	High	
Flow for EWR	Southern section of the catchment along Willochra and Old Booleroo Creeks	Establish new environmental water level monitoring sites to gain a better understanding of the duration and quality of connecting flows.	5.1.2		

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Farm dams	Understanding of quantities of water captured by farm dams	Research further the capture of water by farm dams to gain a better understanding of related water usage.	5.1.3	High	

Table 5. Willochra Creek Catchment surface water quality monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Salinity	Both southern and northern sections of the catchment for sub-catchments representative of various catchment characteristics	Expansion of salinity monitoring be carried out in relation to the impacts of development on water quality and EWR.	6.1.1	High	
	Any newly established flow monitoring stations	Willochra Creek and along Old Booleroo Creek to better understand runoff–salinity relationships, observe salinity trends and understand spatial changes in salinity.		High	
	Understanding of the effects of high salinity levels on vegetation	Investigate the effects of salinity in the downstream reaches of the catchment on vegetation.		High	
Pesticides	Understanding of the impact of pesticides on water quality	Monitor for pesticides following the onset of streamflow.	6.1.2	High	
Other water quality parameters. Composite and ambient and macro-invertebrate monitoring.	Comprehensive monitoring of water quality to include other parameters relevant to land-use impacts. Composite and ambient and macro-invertebrate monitoring.	Monitor water quality to assess the potential impacts of septic tanks, water treatment, stock and wildlife on watercourses, through establishing composite monitoring and expanding ambient and macro-invertebrate sampling at strategic locations	6.1.2	High	

Table 6. Willochra Creek Catchment groundwater quantity monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Recharge processes	Understanding of recharge processes throughout the catchment	Recharge processes be further investigated to gain a better understanding of surface water and groundwater interactions.		High	
Groundwater yield	Understanding of groundwater yield	Review existing estimates of groundwater yield.	7.1.1	High	
Extraction rates	Accurate measurements of extraction rates for the Willochra Basin	Monitor extraction rates of groundwater.	7.1.1	High	
Town water supply	Wilmington	Establishment of a monitoring network for the Wilmington town water supply.			DWLBC
Groundwater levels	FRA	Monitor groundwater levels for the FRA, particularly in the vicinity of the Spring Creek production well.	7.1.1		DWLBC
Sustainable use	Whole catchment	Investigate further whether groundwater resources are being used within sustainable limits.		High	

Table 7. Willochra Creek catchment groundwater quality monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Salinity	FRA	Monitor groundwater salinity for the FRA, particularly in the vicinity of the Spring Creek production well.		High	DWLBC
	Leakage of higher salinity water into aquifers with water of a lesser salinity caused by partially cased wells and old eroding well casing	Investigate further the impacts of leaky wells.	8.1.1	High	DWLBC

Table 8. Willochra Creek Catchment aquatic ecosystem monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Channel modification	Knowledge of effects of sedimentation	Monitor effects of sedimentation on aquatic ecosystems.	9.3.1	High	
Groundwater usage	Knowledge of impact of groundwater usage on permanent pools	Investigate the impact of groundwater usage on permanent pools for both Fractured rock and sedimentary aquifers.		High	
Riparian vegetation surveys	Various sections of the catchment, e.g. Boolcunda and Kanyaka Creeks	Carry out baseline on-ground riparian vegetation surveys to complete the record of such information for the whole catchment.	9.3.1	High	
Riparian vegetation health assessments	Entire catchment	Conduct an assessment of the health of riparian vegetation, including effects of salinity, impacts of water use and River Red Gum communities.	9.3.1	High	
Threatened flora and fauna	Entire catchment	Identify threatened species and determine their environmental water requirements.		High	
Fish studies	Entire catchment	Carry out fish distribution surveys, including following major flood events, and research conservation status of Lake Eyre Hardyhead.	9.3.1	High	
Macro-invertebrates	Entire catchment	Expand ongoing macro-invertebrate monitoring throughout the catchment.	9.3.1	High	EPA
Hyporheic zones	Entire catchment	Identify the location of significant hyporheic zones.	9.3.1	Medium	

Table 9. Broughton River Catchment surface water quantity monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Basin outflow station	Lower Broughton River sub-catchment	Basin outflow station be established to monitor flows leaving the catchment and entering Spencer Gulf.	5.2.2	High	DWLBC
System inflow–outflow stations	Beetaloo Reservoir	Monitoring of flows upstream and downstream of the reservoir be carried out to ascertain its impact on flows.	5.2.2	High	SA Water
	Bundaleer Reservoir	Monitor flows downstream of the weirs that were constructed as part of the aqueduct system.	5.2.2	High	SA Water
Evaporation	Most of the catchment	Investigation into the expansion of evaporation monitoring.	5.2.1	High	BoM
Flow	Most of the catchment	Expand the flow monitoring network to include those sub-catchments representative of various catchment characteristics.	5.2.2	High	DWLBC
EWR	Whole catchment	Research the physical and biological effects of flows to improve upon definitions of EWR.	5.2.2	High	DWLBC
Farm dams	Understanding of the impact of farm dams on flow downstream in the Hutt and Hill sub-catchments	Monitor and research to ascertain whether the effects of dams on flow in these sub-catchments and the consequent contribution of flow to the Broughton River are presenting a greater than acceptable impact.	5.2.3		
	Accuracy of sources of water in dams	Carry out surveys to ascertain sources of water in dams whether surface water, groundwater or both, or from off-line diversions from another stream or catchment.			
Irrigation water use	Whole catchment, but particularly in areas with an expanding viticulture industry	Further investigate irrigation water use in relation to actual, not estimated, application rates.	5.2.3		

Table 10. Broughton River Catchment surface water quality monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Base station	Salinity	Salinity to be included in monitoring at 'Broughton River @ Mooroola' (AW507503) gauging station to meet the minimum monitoring requirements of a base station.	5.2.2	High	DWLBC
System inflow–outflow stations	Bundaleer Reservoir	Monitor water quality in the reservoir.		High	SA Water
Salinity	Sufficient data to determine salinity trends	Increase salinity monitoring across the catchment. Monitor across all ranges of flow so as not to bias results.	6.2.1	High	
Farm chemicals	Understanding of the impact of farm chemicals on water quality	Investigate use of farm chemicals and their potential impact on water quality.	6.2.2		
Nutrients	Knowledge of sources of nutrients	Investigate the sources of nutrients and the potential impact of nutrients on water quality.	6.2.2		
	Clare WWTP	Monitor impacts of the Clare WWTP on water quality downstream.	6.2.2		

Table 11. Broughton River Catchment groundwater quantity monitoring suggestions (reproduced from Magarey and Deane 2004).

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Levels	Rocky River, Crystal Brook and Lower Broughton sub-catchment areas	Possibly include levels monitoring as part of the Mid-North Rivers Observation Wells network that is currently monitoring salinity in the Rocky River, Crystal Brook and Lower Broughton River sub-catchment areas.		High	DWLBC
	In relation to perennial baseflow in the Broughton River near Spalding and Yakilo, Belalie and Farrell Creeks	Establish groundwater levels monitoring where conditions are favourable for groundwater recharge and discharge.		High	DWLBC

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Sustainable use	Booborowie Valley, Balaklava (northern St Vincent Basin); ideally whole catchment area	Investigate further whether groundwater resources are being used within sustainable limits.		High	
Recharge mechanisms	Walloway Basin, Booborowie Valley; ideally whole catchment area	Investigate further recharge mechanisms and aquifer connectivity.		High	
Groundwater usage	Booborowie Valley, Balaklava (northern St Vincent Basin); ideally whole catchment area	Investigate further present land use and irrigation application rates.		High	
Impact of extractions	Hutt and Hill River sub-catchments	Further investigation of the impact of groundwater extraction on surface water flows.		Medium	

Table 12. Broughton River catchment groundwater quality monitoring suggestions.

Monitoring Category	Gaps	Suggestions for Monitoring	Refer to Section	Priority	Stakeholder/s
Salinity	In relation to perennial baseflow in the Broughton River near Spalding and Yakilo, Belalie and Farrell Creeks	Establish groundwater salinity monitoring where conditions are favourable for groundwater recharge and discharge.		High	DWLBC
	Lake Bumbunga and Diamond Lake sub-catchments	Salinity monitoring be included in the existing Lochiel Observation Wells network for at least two sites in the Lake Bumbunga sub-catchment area as well as for at least one site in the Diamond Lake sub-catchment.	8.1.2		DWLBC

Table 13. Broughton River Catchment aquatic ecosystems monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Threatened species	Krefft's Tiger Snake (*Notehcis ater*) along the Broughton and Rocky Rivers	Investigate further impact of changes in native vegetation and of nutrient input on the Krefft's Tiger Snake.	9.4.2	High	

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
	Spalding Blown Grass (*Agrostis limitanea*) along sections of Yakilo Creek	Investigate further impact of grazing and weed invasion, herbicide drift and changes in flow as a result of water extraction for irrigation.	9.4.2	High	
EWR	Good understanding of EWR	Investigate further EWR for geomorphological and ecological purposes.		High	
Groundwater extraction	Hutt River and Hill River sub-catchments	Investigate further the impact of groundwater extraction on groundwater dependent pools and baseflow.	9.4.2		
Erosion	Hutt River and Hill River sub-catchments	Establish ongoing monitoring in the Hutt River and Hill River sub-catchments for sites where erosion heads occur.		Medium	
	Knowledge of stability of channelised segments of watercourses	Monitor the stability of channelised segments of watercourses for Yakilo Creek and Hill River.			
Sedimentation	Whole catchment	Research sources of sediment causing infilling of pools and investigate whether sedimentation rates are greater than would be expected naturally. Prioritise where to monitor into the future.		Medium	
Macro-invertebrates	Yakilo Creek	Carry out a preliminary macro-invertebrate survey.			
	Whole catchment	Expand ongoing macro-invertebrate monitoring.			EPA
Introduced macro-invertebrates	Broughton and Hutt Rivers south of Spalding and in Crystal Brook at Bowman Park	Investigate the impact of introduced macro-invertebrates on native species.	9.4.2		EPA
Fish	Entire catchment	Further investigation be carried out to determine the influence of flow regime, particularly mid- and high flows, and other environmental factors on native fish populations and fish migration processes.	9.4.2	High	
	Hill River and Yakilo Creek sub-catchments	Carry out preliminary fish surveys.	9.4.2		
	Impacts of trout in relevant sections of the catchment	Investigate the impacts of trout on native fish populations.	9.4.2		

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
	Impacts of weirs in the Mid Broughton River sub-catchment (u/s of Yacka to the confluence of the Hill River and Yakilo Creek (u/s of delta))	Investigate the impacts of impediments such as weirs upon fish migration.	9.4.2		
Vegetation considered to be in good condition	Along the Broughton River and tributaries from just downstream of Yacka as well as where the Broughton River passes through the Yackamoorundie Hills.	Identify potential threats, rehabilitate and monitor for any changes to that habitat condition.	9.4.1	High	
Important remnant native vegetation	Lower Rocky River where it joins with the Broughton River	Identify potential threats and monitor for any changes to that habitat condition.	9.4.1	High	
Significant riverine habitat	Broughton River below the delta	Investigate minimum flow at which the estuary is connected to the river upstream and the frequency of this flow; the magnitude of flows required to deliver sediment to the estuary; and channel-forming processes at the upstream end of the delta.		High	
	Lower Broughton River sub-catchment (downstream of Cockeys Crossing) and Mooroola gauging station in the Mid Broughton River sub-catchment	Establish monitoring of the native vegetation, in-stream physical habitats, and permanent and semi-permanent aquatic habitats.	9.4.1	High	
	Rocky River, Yackamoorundie Creek, Crystal Brook, Broughton River sub-catchments	Establish monitoring of the permanent springs and macrophyte beds.	9.4.1	High	
Aggradation	Yacka	Investigate further the natural condition of the river in the vicinity of Yacka and the chronology and causes of change.	9.4.2		
Flora and fauna	Broughton River below the delta	Investigate further the biota in this region to improve understanding of the plants and animals.			
Opportunistic species	Whole catchment	Further research the relationship between flow and the opportunistic nature of some species of plants and animals.	9.4.2		

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Threatened species	Spalding Blown Grass (*Agrostis limitanea*) found along sections of Yakilo Creek and Krefft's Tiger Snake (*Notehcis ater*) found along the Broughton and Rocky Rivers	Rehabilitate habitats to render them suitable for the protection of these species and monitor.	9.4.2	High	
Hyporheic environments	Whole catchment	Research be carried out into the location and biota of such environments.	9.4.2		
Yabby parasite	Relevant sections of the catchment	Investigate the impact of the yabby parasite on other fauna.	9.4.2		
Increase in reeds	Common Reed (Phragmites sp.) and Bulrush (Typha sp.) along the Broughton River in the eastern Mid Broughton River sub-catchment	Investigate increases in reed populations and their causes.	9.4		
Chain of ponds morphology	Hutt River and Hill River sub-catchments	Research be undertaken to gain a better understanding of the processes that sustain the natural chain-of-ponds stream form.	9.4.1		
Permanent springs	Hutt River and Hill River sub-catchments	Monitor the impacts of flow reduction on springs.		High	
Dams and weirs	Relevant sections of the catchment	Further investigate the impact of dams and weirs on aquatic ecosystems.		High	
Marine	Coastal waters of Spencer Gulf	Establish water quality monitoring for the coastal waters of Spencer Gulf where the Broughton River discharges to the sea.	9.4.2	High	

Table 14. Broughton River Catchment community monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Waterwatch	Use of water quality data	Use be made of data collected by Waterwatch by incorporating it into water quality monitoring assessments.	9.4.3		

Table 15. Wakefield River Catchment surface water quantity monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Basin outflow station	Lower Wakefield River sub-catchment	Consideration be given for 'Wakefield River @ Port Wakefield' (A5061007) to also serve as a basin outflow station to monitor flow of water entering Gulf St Vincent.	5.3.2	High	DWLBC
Rainfall	Pine Creek sub-catchment	Establish rainfall monitoring.	5.3.1		BoM
Evaporation	Whole catchment	Establish evaporation monitoring at appropriate sites.	5.3.1		BoM
Streamflow	Skillogalee Creek and Upper, Mid and Lower Wakefield River sub-catchments	Establish streamflow monitoring at least for these waterways to help refine flow band estimates.	5.3.2	High	
Flow bands	Whole catchment	Long-term monitoring to further refine the flow bands identified by the MNRMPP study.			
Farm dams	Whole catchment	Collect data on the contribution of farm dams to the reduction of surface water runoff and streamflow.	5.3.3		
	Accuracy of sources of water in dams	Carry out surveys to ascertain sources of water in dams whether surface water, groundwater or both, or from off-line diversions from another stream or catchment.			
Water use	Whole catchment	Investigate further water use in relation to the various flow bands that have been identified by the MNRMPP.	MNRPP*	High	
Irrigation water use	Whole catchment	Further investigate irrigation water use in relation to actual, not estimated, application rates.			
Hydrological modelling	Comprehensive modelling of water balances	Carry out further hydrological modelling so that impacts of land use can be better assessed.			

*Mid-North Rivers Planning Project (see Favier et al. (2000, 2004); Vanlaarhoven et al. (2004))

Table 16. Wakefield River Catchment surface water quality monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Base station	Woolshed Creek sub-catchment	Include salinity monitoring at 'Wakefield River @ near Rhynie' (AW506500) to meet the minimum requirements of a base station.	5.3.2 and 6.3.1	High	DWLBC
Basin outflow station	Lower Wakefield River sub-catchment	Consideration be given for 'Wakefield River @ Port Wakefield' (A5061007) to also serve as a basin outflow station to monitor flow and salinity (and ideally other water quality parameters) of water entering Gulf St Vincent.	5.3.2 and 6.3.1	High	DWLBC
Salinity	Mid and Lower Wakefield River sub-catchments	Include salinity monitoring at 'Wakefield River @ u/s The Rocks' (A5061003) as well as 'Wakefield River @ Balaklava' (A5061005) and 'Wakefield River @ Whitwarta' (A5061006).	5.3.2	High	
Storm water discharge	Downstream of Watervale, Auburn and Balaklava	Investigate the impacts of storm water discharge.	MNRMPP	Medium	

Table 17. Wakefield River Catchment groundwater quantity monitoring suggestions (reproduced from Magarey and Deane 2004).

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Levels	FRA	Establish water quantity monitoring.			DWLBC
	Whitwarta area	Establish observation wells to assess rising watertables.			DWLBC
Local groundwater extraction	Upper meandering, mobile, transition, constrained, incised (Eyre Creek), and chain-of-ponds zones	Collect data on the contribution of groundwater extraction to the reduction of streamflow.			
Hydrogeology	A good understanding of the relationship between rainfall, aquifer discharge and baseflow levels	Investigate further hydrogeological systems throughout the catchment.			
Recharge zones	Whole catchment	Investigate further the location of groundwater recharge zones.			DWLBC

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Sustainable use	Whole catchment	Investigate further whether groundwater resources are being used within sustainable limits.		High	

Table 18. Wakefield River Catchment groundwater quality monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Salinity and other appropriate water quality parameters	FRA	Establish water quality monitoring.			DWLBC

Table 19. Wakefield River Catchment aquatic ecosystems monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Migration flows	Lower meandering, upper meandering, mobile, constrained, incised and chain-of-ponds zones	Monitor the impact of water use on migration flows.	MNRMPP		
Habitat connection flows	Mobile, transition and constrained zones	Monitor the impact of water use on habitat connection flows.	MNRMPP		
High flows	Transition and constrained zones	Monitor the impact of water use on high flows.	MNRMPP		
Mid flows	Incised zone	Monitor the impact of water use on mid flows.	MNRMPP		
Freshets	Transition, constrained, incised and chain-of-ponds zones	Monitor the impact of water use on freshets.	MNRMPP		
Pumping from pools	Mobile, transition and chain-of-ponds zones	Monitor the impacts of pumping water from pools.	MNRMPP		
Sediment	Mobile zone	Monitor the impacts of sediment input from the transition and incised zones.	MNRMPP		

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Erosion	Incised and chain-of-ponds zones	Monitor the potential for further erosion.			
	Lower Wakefield sub-catchment, Port Wakefield town common, along tributaries of Hermitage Creek, Skillogalee Creek sub-catchment, Rices Creek, tributary of Pine Creek, Honey Suckle Creek, tributary of the upper Wakefield River	Monitor potential to undergo active erosion.	9.5.1		
EWR	Whole catchment	Revise EWR as new data are obtained from monitoring.	9.5.2		
Fish	Whole catchment	Carry out long-term studies of fish populations including their migration patterns, reproductive biology.	9.5.2		
	Skillogalee Creek	Investigate further an explanation for the absence of native fish.	9.5.2		
Macro-invertebrates	Whole catchment	Expand macro-invertebrate sampling for different habitat types within sub-catchments representative of the various catchment characteristics.			EPA
Areas of significant riparian habitat	Main channel from The Rocks to Undalya, sections of the main channel above Mintaro Creek, Skillogalee Creek below Port Road bridge, Long Gully, Wakefield River from 2 km upstream of Robins Ford to ~5 km downstream of The Rocks, water reserve at Riley Road (chain-of-ponds zone)	Establish ongoing monitoring of these areas as part of a conservation program for these important habitats.	9.5.1	High	
	Mobile, chain-of-ponds and constrained zones	Carry out in-depth ecological studies.		Medium	
Ephemeral floodplain swamps	Lower Wakefield sub-catchment	Rehabilitate ephemeral floodplain swamps and then monitor success and for any threats.			
Low-lying salt marshes	Coastal floodplain of the Wakefield River	Establish ongoing monitoring as part of a conservation program for this important habitat.	9.5.2		
Estuarine mangrove environment	Port Wakefield	Establish ongoing monitoring as part of a conservation program for this important habitat.	9.5.3		

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Remnant native riparian vegetation	Along Pine Creek	Monitor the remnant native shrub and grass species to observe any adverse impacts.	9.5.3		
Native vegetation in good condition	Main channel from The Rocks to Whitwarta, above the main channel's confluence with Wookie Creek, a number of sections of Skillogalee Creek	Rehabilitate and monitor into the future as part of a conservation program for these important areas.	9.5.1		
Permanent pools	Comprehensive understanding of ecology	Carry out in-depth ecological studies of permanent pools, including the impacts of groundwater extraction.			
Hyporheic environments	Good understanding of hyporheic environments	Investigate the ecology of hyporheic environments, including their location, use as refuge areas in dry periods, subsurface fauna that inhabit them and related EWR.			
Reed beds	Good understanding of the role of reed beds	Investigate further the role of reed beds in waterways in light of management considerations.			
Marine	Coastal waters of Gulf St Vincent	Establish water quality monitoring for the coastal waters of Gulf St Vincent where the Wakefield River discharges to the sea.	6.3.3	High	

Table 20. Wakefield River Catchment community monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Waterwatch	Use of water quality data	Use be made of data collected by Waterwatch by incorporating it into water quality monitoring assessments.	9.5.3		

Table 21. Light River Catchment surface water quantity monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Base station	Whole catchment	Establish a monitoring station to serve the purpose of a base station in the catchment.	5.4.2 (1)	High	DWLBC
Basin outflow station	Lower Light sub-catchment	Establish a monitoring station to serve the purpose of a basin outflow station in the catchment.	5.4.2 (3)	High	DWLBC
Evaporation	Whole catchment	Establish evaporation monitoring at suitable meteorological monitoring stations.	5.4.1	High	BoM
Levels	Lower Light sub-catchment with regard to surface–groundwater interactions	Levels monitoring be established for Lower Light sub-catchment, just upstream of Redbanks at the downstream end of the permanent pools and just downstream of Redbanks.	5.4.2 (4) and (12)	High	DWLBC
Levels (cont)	Upper Light and Mid Light sub-catchments, with regard to areas of ecological importance	Levels monitoring be established for Upper Light sub-catchment at Hamilton, and Mid Light sub-catchment on the Light River 3 km upstream of Hamley Bridge and just downstream of St Peters Road Crossing.	5.4.2 (10) and (11)	High	DWLBC
Flow	Upper Light sub-catchment, Gilbert River sub-catchment, Kitts Creek in Mid Light sub-catchment, Lower Light sub-catchment, to monitor flow contributions of main waterways to the Light River system	Flow monitoring be established in the Upper Light sub-catchment, just downstream of the confluence of Julia Creek and the Light River; Gilbert River sub-catchment, close to the junction of Gilbert River and Light River; Mid Light sub-catchment, close to the junction of St Kitts Creek and the Light River; Lower Light sub-catchment, between Port Wakefield Highway and 5 km downstream.	5.4.2 (5), (2) and (3)	High	DWLBC
Hydrology	Entire catchment	Use data from expanded surface water monitoring programs to create hydrological models of each sub-catchment.		High	DWLBC
Impact of weirs on flows	Gilbert River at Riverton and Light River at Hamley Bridge	Monitor the impact of Riverton and Hamley Bridge weirs on flows downstream.	5.4.3		
Farm dams	Mostly in the upper areas of the catchment	Investigate the impacts of farm dams on flows downstream.	5.4.3		

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
	Accuracy of sources of water in dams	Carry out surveys to ascertain sources of water in dams whether surface water, groundwater or both, or from off-line diversions from another stream or catchment.			

Table 22. Light River Catchment surface water quality monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Ambient water quality	Most of the catchment	Expansion of the EPA's ambient water quality monitoring program be carried out to include one or two new sites at appropriate locations.	6.4.2		
Salinity	Most of the catchment	Where any new flow gauging stations are established, at least salinity monitoring also be included at those sites.	6.4.1		
	Tothill Creek in the Upper Light sub-catchment	Ongoing salinity monitoring be carried out for this waterway.	6.4.1		
Point source and diffuse pollution	Whole of the catchment	Identification of potential point source and diffuse pollution to be carried out.	6.4.3		

Table 23. Light River Catchment groundwater quantity monitoring suggestions (reproduced from Magarey and Deane 2004).

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Hydrogeology	Whole catchment	Further investigations into hydrogeological systems throughout the catchment, and include the use of levels and salinity data.	7.4	High	DWLBC
Groundwater interactions with surface Water	Whole catchment	Further investigation into groundwater systems to gain an understanding of groundwater interactions with surface water.	5.4.3	High	
Recharge and discharge zones	Whole catchment	Location of groundwater recharge and discharge zones that influence baseflows.		High	DWLBC
Impact of practices designed to overcome dryland salinity problems		Further investigate the impact of practices designed to reduce groundwater recharge, to overcome dryland salinity problems, on baseflows and permanent pools.	5.4.3		

Table 24. Light River catchment groundwater quality monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Salinity and other water quality parameters	Whole catchment	Further research groundwater use into the future for any increases in use that may impact on groundwater quality and thus groundwater dependent ecosystems.	8.4	High	

Table 25. Light River Catchment aquatic ecosystems monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Water resource development	Whole catchment	Investigate any water resource development into the future and monitor its impact on aquatic ecosystems.		High	DWLBC
EWR	Whole catchment	Further research EWR of aquatic ecosystems for the catchment, particularly for ephemeral streams.	9.6, 9.6.1 and 9.6.2	High	
Areas of significant riparian habitat	Whole catchment	Manage these areas for protection and monitor into the future.		High	
Remnant vegetation	Whole catchment	Manage these areas for protection and monitor into the future.		High	
Native vegetation in good condition	Throughout the catchment	Rehabilitate and monitor areas of native watercourse vegetation considered to be in good condition.		High	
	River Red Gum section that lies between the estuary and just downstream of The Rockies	As this section of vegetation has high ecological value as a wildlife corridor between the two areas of significant riparian habitat, it is essential that threats to this area are assessed and monitored into the future.	9.6.1	High	
Increase in reeds	Common Reed (Phragmites sp.) and Bulrush (Typha sp.) in the Light River Catchment	Investigate increases in reed populations and their causes.	9.6.2		
Permanent pools	Lower Light Sub-catchment, The Rockies	Monitor health of permanent pools habitat as a refuge for fish during dry summer months, including any potential threats, e.g. erosion upstream bringing sediment into the area.	9.6.2	High	
Fish surveys	Whole catchment	Further surveys of fish populations be carried out, particularly in areas with permanent baseflow.	9.6.2	High	
Impact of weirs on fish populations	In the Mid Light sub-catchment, weirs at Hamley Bridge and on Allen Creek	A survey of fish populations be carried out upstream and downstream of the weirs.	9.6.2	High	

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
European Carp	Whole catchment	An investigation into the distribution of European Carp be carried out to assess its impact on native fish.	9.6.2	High	
Fish	Influence of flow on fish populations	Carry out further investigation into the influence of flow and other environmental factors on fish populations.			
	Knowledge about the natural history of fish populations	Further studies to be carried out to improve upon understanding of the natural history of fish populations, particularly with regard to frequency of migration to the estuary and the breeding biology of landlocked fish such as the Common Jollytail.	9.6.2		
Frogs	Frog biology for the whole catchment	Additional frog surveys be carried out for summer, autumn and winter to assist in understanding their biology.	9.6.2		
Macro-invertebrates	Data for the winter season and for long time periods	Carry out ongoing macro-invertebrate monitoring, for each season.	9.6.2	High	
Erosion heads	Upper reaches of Fannel Creek and in a tributary south of Kapunda in the Mid Light Sub-catchment; and most southerly of the eastern hill tributaries in the Upper Light sub-catchment	Monitor any impacts on the river system.	9.6.1		
Gully erosion	Tributary south of Kapunda as well as in St Kitts Creek and a tributary of St Kitts Creek in the Mid Light Sub-catchment.	Monitor any impacts on the river system.	9.6.1		
In-stream structural works and channelisation	Whole catchment	Manage these aspects of land use and investigate further any impacts upon aquatic ecosystems.			
Sedimentation	Whole catchment	Sediment transport processes, as a result of erosion, also need further investigation throughout the catchment.	9.6.2	High	
Groundwater dependent ecosystems	Whole catchment	Further research be carried out to gain a good understanding of these ecosystems.	9.6.2	High	

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
	Whole catchment	Investigate the impact of groundwater extraction on groundwater dependent ecosystems.	9.6.2	High	
Hyporheic environments	Whole of catchment	Further investigate the role, location and biota of hyporheic environments.	9.6.2		
Marine	Coastal waters of Gulf St Vincent	Establish water quality monitoring for the coastal waters of Gulf St Vincent where the Light River discharges to the sea.	6.4.4	High	

Table 26. Light River Catchment community monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Waterwatch	Use of water quality data	Use be made of data collected by Waterwatch by incorporating it into water quality monitoring assessments.	9.6.3		

Table 27. Yorke Peninsula aquatic ecosystems monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Aquatic ecosystems	Comprehensive mapping of ecological assets and their values	Undertake baseline studies to map and assess all aquatic ecosystems.		High	
High value wetlands	No monitoring at identified high value wetlands	Implement monitoring at Gum Flat, Native Hen Lagoon and Chain of Lakes wetlands (Seaman 2002).	9.8	High	

Table 28. Mambray Coast monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Aquatic ecosystems	Baseline mapping of ecological assets	Use be made of data collected by Waterwatch by incorporating it into water quality monitoring assessments.			

Table 29. Southern Lake Frome Basin monitoring suggestions.

Monitoring category	Gaps	Suggestions for monitoring	Refer to Section	Priority	Stakeholder(s)
Aquatic ecosystems	Baseline mapping of ecological assets	Use be made of data collected by Waterwatch by incorporating it into water quality monitoring assessments.	9.9		

APPENDICES

A. CURRENT AND HISTORICAL SURFACE WATER QUANTITY MONITORING

Willochra Creek

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M019076	Old Kallioota Homestead	Meteorological	Closed (1909–28)	Rainfall	BoM	BoM	BoM
M019068	Neuroodla Railway Siding	Meteorological	Closed (1958–87)	Rainfall	BoM	BoM	BoM
AW509502	Willochra Creek at Partacoona	Natural Stream	Purpose National Water Resources Assessment Program: Base Station Commenced 18/07/1973 Salinity monitoring began 10/2000?	Recording 100 Water Level 450 Water Temperature 820 EC Streamflow from Rating Volume and Rate of Flow NLWRA 2000 Catchment Yield 1978–98	DWLBC	DWLBC	DWLBC
AW509505	Kanyaka Creek catchment Pluvio at The Oaks	Meteorological	Commenced 20/10/1983 Related Station W509503 Kanyaka Creek @ Old Kanyaka Ruins	Recording 10.00 Rainfall	DWLBC	DWLBC	DWLBC
M019050	Hawker (Wilson)	Meteorological	Commenced 1885	Rainfall	BoM	BoM	BoM
	Willochra Creek South of Partacoona	Natural Stream		Ambient and Macro-invertebrate	EPA	EPA	EPA
M019077	Gordon (Kanyaka Section 27)	Meteorological	Closed (1921–40)	Rainfall	BoM	BoM	BoM

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
AW509503	Kanyaka Creek @ Old Kanyaka Ruins	Natural Stream	Commenced 17/07/1973 Purpose WRMC Bench Mark	Recording 100 Water Level Streamflow from Rating Volume and Rate of Flow	DWLBC	DWLBC	DWLBC
	Kanyaka Creek @ Old Kanyaka Ruins	Natural Stream	Same location as AW509503	Ambient and Macro-invertebrate	EPA	EPA	EPA
M019015	Cradock (Kanyaka)	Meteorological	Commenced 1897	Rainfall	BoM	BoM	BoM
M019010	Cradock	Meteorological	Commenced 1888	Rainfall	BoM	BoM	BoM
M019109	Cradock (Slaty Creek)	Meteorological	Commenced 1989	Rainfall	BoM	BoM	BoM
M019061	Cradock (Yednalue)	Meteorological	Commenced 1916	Rainfall	BoM	BoM	BoM
AW509501	Boolcunda Creek @ Langwarren	Natural Steam	Closed Commenced 13/06/1972 Ceased 11/06/1992	Recording 100 Water Level Streamflow from Rating Volume and Rate of Flow	DENR (DEH)		DWLBC
M019098	Carrieton (Glenroy Estate)	Meteorological	Commenced 1969	Rainfall	BoM	BoM	BoM
M019004	Carrieton (Belton)	Meteorological	Commenced 1883	Rainfall	BoM	BoM	BoM
M019040	Quorn (Round Hill)	Meteorological	Closed (1882–1972)	Rainfall	BoM	BoM	BoM
M019020	Horseshoe Ranges	Meteorological	Closed (1886–1950)	Rainfall	BoM	BoM	BoM
M019058	Carrieton (Yanyarrie)	Meteorological	Closed (1882–1953)	Rainfall	BoM	BoM	BoM
M019056	Carrieton (Yackara)	Meteorological	Closed (1884–1985)	Rainfall	BoM	BoM	BoM
M019080	Carrieton (Pamatta)	Meteorological	Closed (1882–1935)	Rainfall	BoM	BoM	BoM
M019096	Quorn Railway	Meteorological	Closed (1888–1908)	Rainfall	BoM	BoM	BoM
M019038	Quorn	Meteorological	Commenced 1881	Rainfall	BoM	BoM	BoM
M019090	Quorn (Kingswood)	Meteorological	Closed (1888–1919)	Rainfall	BoM	BoM	BoM
M019009	Carrieton	Meteorological	Commenced 1882	Rainfall	BoM	BoM	BoM
M019008	Bruce	Meteorological	Commenced 1896	Rainfall	BoM	BoM	BoM

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M019108	Hammond (Coonatto)	Meteorological	Commenced 1988	Rainfall	BoM	BoM	BoM
M019089	Hammond (Rix)	Meteorological	Closed (1883–1905)	Rainfall	BoM	BoM	BoM
M019016	Hammond Post Office	Meteorological	Closed (1886–1988)	Rainfall	BoM	BoM	BoM
M019039	Wilmington (Range Vue)	Meteorological	Closed (1905–83)	Rainfall	BoM	BoM	BoM
M019072	Amyton East	Meteorological	Closed (1889–1937)	Rainfall	BoM	BoM	BoM
M019013	Carrieton (Eurelia)	Meteorological	Commenced 1881	Rainfall	BoM	BoM	BoM
M019000	Amyton (Pinda Section 63)	Meteorological	Closed (1902–55)	Rainfall	BoM	BoM	BoM
M019048	Wilmington	Meteorological	Commenced 1878	Rainfall	BoM	BoM	BoM
M019103	Wilmington (Stonehaven)	Meteorological	Commenced 1972	Rainfall	BoM	BoM	BoM
A5091002	Spring Creek at u/s Willowie Forest	Natural Steam	New station to replace AW509504. Commenced 01/08/2003	Recording 100 Water Level 450 Water Temperature 820 EC Streamflow from Rating Volume and Rate of Flow	DWLBC	DWLBC	DWLBC
A5091003	Spring Creek Pluvio at Willowie Forest	Meteorological Station	Commenced 01/08/2003 New site awaiting further details	Recording Rainfall	DWLBC	DWLBC	DWLBC
AW509504	Spring Creek at Terka	Natural Steam	Closed Positioned to provide streamflow information for the valuable higher runoff areas of the western boundary. Commenced 17/01/1973 Ceased 07/12/1976 Unstable control making data useless.	Recording 100 Water Level Streamflow from Rating Volume and Rate of Flow	SA Water		DWLBC

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M019042	Melrose (Para Gums)	Meteorological	Commenced 1889	Rainfall	BoM	BoM	BoM
M019011	Murray Town (Doughboy Creek)	Meteorological	Commenced 1883	Rainfall	BoM	BoM	BoM

Broughton River

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
A5071003	Rocky River at u/s Wirrabara	Natural Stream	New Site	Recording: 100 Water Level 450 Water Temperature 820 EC Streamflow from Rating Volume and Rate of Flow	DWLBC	DWLBC	DWLBC
M019052	Wirrabara	Meteorological	Commenced 1877	Rainfall	BoM	BoM	BoM
A5071004	Pine Creek at u/s Appila Creek	Natural Stream	New Site	Recording: 100 Water Level 450 Water Temperature 820 EC Streamflow from Rating Volume and Rate of Flow	DWLBC	DWLBC	DWLBC
M019001	Appila	Meteorological	Commenced 1882	Rainfall	BoM	BoM	BoM
M019043	Tarcowie	Meteorological	Commenced 1934	Rainfall	BoM	BoM	BoM
M019084	Pekina	Meteorological	Closed (1963–93)	Rainfall	BoM	BoM	BoM
M019053	Wirrabara Forest	Meteorological	Commenced 1878	Rainfall	BoM	BoM	BoM
M021031	Laura	Meteorological	Commenced 1875	Rainfall	BoM	BoM	BoM

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M021006	Gladstone (Booyoolee)	Meteorological	Closed (1892–1949)	Rainfall	BoM	BoM	BoM
M021021	Gladstone	Meteorological	Commenced 1877	Rainfall	BoM	BoM	BoM
M021072	Huddleston (Willow Ponds)	Meteorological	Commenced 1957	Rainfall	BoM	BoM	BoM
A5071002	Rocky River d/s Thregold's Crossing	Natural Stream	Commenced 17/06/2003	Water Level Temperature EC	DWLBC	DWLBC	DWLBC
M021037	Narridy Post Office	Meteorological	Closed (1881–1993)	Rainfall	BoM	BoM	BoM
M021043	Port Pirie BHAS	Meteorological	Commenced 1877	Rainfall	BoM	BoM	BoM
M021116	Port Pirie Hurst Street	Meteorological	Closed (1972–76)	Rainfall	BoM	BoM	BoM
M021084	Port Pirie (Valencia)	Meteorological	Closed (1877–1933)	Rainfall	BoM	BoM	BoM
A5071001	Broughton River Basin at Cockeys Crossing	Virtual Site (Modelling)	(Catchment Yield 1978–98)	NLWRA 2000 Catchment Yield	DWLBC	DWLBC	DWLBC
	Broughton Cockey's Crossing	Natural Stream		Ambient and Macro-invertebrate	EPA	EPA	EPA
M021102	Crystal Brook Section 299	Meteorological	Commenced 1968	Rainfall	BoM	BoM	BoM
AW507502	Crystal Brook at Beetaloo Reservoir	Water Supply Infrastructure	Commenced 01/01/1941	Recording: 100 Water Level 130 Reservoir Level SA Reservoirs Catchment Yield (1941–97)	SA Water	DWLBC	SA Water
AW507506	Beetaloo Reservoir at Meteorological Station	Meteorological Station	Commenced 01/10/1980	Recording: 10.00 Rainfall	DWLBC	DWLBC	DWLBC
M021124	Beetaloo Res. Port Germein	Meteorological	Commenced 1981	Rainfall Evaporation (Class A Pan)	BoM	BoM	BoM
M019067	Laura (Hilpara)	Meteorological	Closed (1957–71)	Rainfall	BoM	BoM	BoM
M021114	Beetaloo Reservoir (Old Site)	Meteorological	Closed (1896–1982)	Rainfall	BoM	BoM	BoM

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
AW507508	Crystal Brook Pluvio at Depot	Meteorological Station	Closed Commenced 06/09/1988 Ceased 28/06/1996	Recording: 10.00 Rainfall			DWLBC
M021016	Crystal Brook	Meteorological	Commenced 1881	Rainfall	BoM	BoM	BoM
M021013	Caltowie	Meteorological	Commenced 1877	Rainfall	BoM	BoM	BoM
M021095	Georgetown (Springfield)	Meteorological	Closed (1881–1908)	Rainfall	BoM	BoM	BoM
M021020	Georgetown	Meteorological	Commenced 1874	Rainfall	BoM	BoM	BoM
M021090	George (Aylesbury Farm)	Meteorological	Closed (1883–1901)	Rainfall	BoM	BoM	BoM
M021098	Jamestown (Wylmhurst)	Meteorological	Closed (1886–1920)	Rainfall	BoM	BoM	BoM
M021027	Jamestown	Meteorological	Commenced 1877	Rainfall	BoM	BoM	BoM
M021060	Jamestown DPI	Meteorological	Commenced 1951	Rainfall	BoM	BoM	BoM
M021008	Bundaleer Forest Reserve	Meteorological	Closed (1878–1989)	Rainfall	BoM	BoM	BoM
M021064	Georgetown (Flairville)	Meteorological	Closed (1957–61)	Rainfall	BoM	BoM	BoM
M021074	Spalding (Washpool)	Meteorological	Closed (1957–94)	Rainfall	BoM	BoM	BoM
AW507504	Bundaleer Reservoir	Water Supply Infrastructure	Commenced 31/03/1899 Currently there is levels monitoring by SA Water but DWLBC does not receive these figures. Rainfall and evaporation are also measured by SA Water who forward data to BoM and relevant record is kept in HYDSTRA under M021009 (being updated once a year)	SA Reservoirs Yield Catchment Yield 1941–97	SA Water	SA Water	SA Water
M021009	Spalding (Bundaleer Reservoir)	Meteorological	Commenced 1899	Rainfall Evaporation (Class A Pan)	BoM	BoM	BoM
M021070	Jamestown (Lucernedale)	Meteorological	Closed (1957–86)	Rainfall	BoM	BoM	BoM

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M021105	Spalding (Tatara)	Meteorological	Commenced 1969	Rainfall	BoM	BoM	BoM
M021047	Spalding	Meteorological	Commenced 1902	Rainfall	BoM	BoM	BoM
M021120	Whyte-Yarcowie (Gum Park)	Meteorological	Commenced 1940	Rainfall	BoM	BoM	BoM
M021062	Hallett (Old Canowie)	Meteorological	Commenced 1883	Rainfall	BoM	BoM	BoM
M021065	Hallett (Melton Stud)	Meteorological	Closed (1957–65)	Rainfall	BoM	BoM	BoM
M021067	Hallett (Ashrose)	Meteorological	Commenced 1957	Rainfall	BoM	BoM	BoM
M021024	Hallett (Lorraine Old Greenfields)	Meteorological	Commenced 1898	Rainfall	BoM	BoM	BoM
M021004	Booborowie	Meteorological	Commenced 1924	Rainfall	BoM	BoM	BoM

Light River catchment

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M023315	Saddleworth	Meteorological	Commenced 1874	Rainfall	BoM	BoM	BoM
M023314	Riverton	Meteorological	Commenced 1875	Rainfall	BoM	BoM	BoM
M023306	Riverton (Maroomba)	Meteorological	Commenced 1957	Rainfall	BoM	BoM	BoM
M023038	Riverton (Maroomba)	Meteorological	Commenced 1957	Rainfall	BoM	BoM	BoM
M023355	Riverton (Leaward)	Meteorological	Commenced 1968	Rainfall	BoM	BoM	BoM
M023365	Tarlee (Hazelton)	Meteorological	Commenced 1958	Rainfall	BoM	BoM	BoM
M023319	Tarlee	Meteorological	Commenced 1882	Rainfall	BoM	BoM	BoM
M023370	Stockport (Clifton)	Meteorological	Commenced 1959	Rainfall	BoM	BoM	BoM
M023316	Stockport	Meteorological	Closed (1886–1989)	Rainfall	BoM	BoM	BoM
M023837	Hamley Bridge Post Office	Meteorological	Commenced 1884	Rainfall	BoM	BoM	BoM
M021119	Waterloo	Meteorological	Closed (1975–76)	Rainfall	BoM	BoM	BoM
M023304	Glen Garrie	Meteorological	Closed (1906–60)	Rainfall	BoM	BoM	BoM

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M023311	Marrabel	Meteorological	Commenced 1883	Rainfall	BoM	BoM	BoM
M023361	Kapunda (Hamilton)	Meteorological	Commenced 1963	Rainfall	BoM	BoM	BoM
M023364	Anlaby	Meteorological	Closed (1957–77)	Rainfall	BoM	BoM	BoM
M023323	Eudunda (Tarnma)	Meteorological	Commenced 1957	Rainfall	BoM	BoM	BoM

Wakefield River catchment

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M021033	Mintaro	Meteorological	Commenced 1890	10.10 Rainfall	BoM	BoM	BoM
M021076	Manoora (Cooinda)	Meteorological	Commenced 1957	10.10 Rainfall	BoM	BoM	BoM
M021081	Mintaro (Kadlunga)	Meteorological	Closed (1886–1916)	10.10 Rainfall	BoM	BoM	BoM
M021123	Mintaro (Martindale)	Meteorological	Commenced 1981	10.10 Rainfall	BoM	BoM	BoM
AW506501	Eyre Creek at Watervale	Natural Stream	Commenced 27/04/1995 Purpose: To determine the effect of land use on Eyre Creek. Related Station: AW506502	Recording: 10 Rainfall 100 Water Level 450 Water Temperature 821 Conductivity Streamflow from Rating Volume and Rate of Flow	DWLBC	DWLBC	DWLBC
M021048	Watervale (Springvale)	Meteorological	Closed (1900–50)	10.10 Rainfall	BoM	BoM	BoM
M021054	Watervale BoM Met Station	Meteorological	Commenced 31/01/1882	10.10 Rainfall	BoM	BoM	BoM
A5061009	Eyre Creek Pluvio at Watervale	Meteorological Station	Commenced 01/04/2003 Related Station: AW506501	Rainfall	DWLBC	DWLBC	DWLBC
AW506502	Eyre Creek at Auburn	Natural Stream	Commenced 27/04/1995	Recording:	DWLBC	DWLBC	DWLBC

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
			Related Station: AW506501	100 Water Level 450 Water Temperature 821 Conductivity Streamflow from Rating Volume and Rate of Flow			
	Skillogalee Creek Hoyleton Road	Natural Stream		Ambient and Macro-invertebrate	EPA	EPA	EPA
A5061008	Skillogalee Creek at Goodonga	Natural Stream	Commenced 24/06/2003	Recording: 100 Water Level 450 Water Temperature 821 Conductivity	DWLBC	DWLBC	DWLBC
M023310	Manoora BoM Met Station	Meteorological	Commenced 1891	10.10 Rainfall	BoM	BoM	BoM
M023350	Koonowla BoM Met Station	Meteorological	Closed (1899–1907)	10.10 Rainfall	BoM	BoM	BoM
M023324	Tuela BoM Met Station	Meteorological	Closed (1957–92)	10.10 Rainfall	BoM	BoM	BoM
M023345	Rhynie BoM Met Station	Meteorological	Closed (1899–1929)	10.10 Rainfall	BoM	BoM	BoM
AW506500	Wakefield River at near Rhynie	Natural Stream	Commenced: 30/06/1941 Purpose: Base Station Environmental flow monitoring site in conjunction with the National Action Plan (NAP) to determine the state of the health of our rivers and streams. Site used as initial test site Comments: A continuous, high quality record only exists from 1977 (A-Type recorder installed) Related Stations:	Recording: 10 Rainfall 100 Water Level Streamflow from Rating Volume and Rate of Flow Rainfall Commenced: 23/09/1985 Latest Streamflow Gauging:18/10/2004	DWLBC	DWLBC	DWLBC

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
			A5061001, A5061002, A5061003, A5061004, A5061005, A5061006, A5061007				
			Catchment Yield NLWRA:				
			January 1978 – January 1998 Gauged daily flow				

Mambray Coast catchment

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M019199	Mt Remarkable National Park	Meteorological	1970 – current	Rainfall	BoM	BoM	BoM
M019112	Port Germein (Gowan Brae)	Meteorological	1996	Rainfall	BoM	BoM	BoM
M019066	Port Augusta Power Stn	Meteorological	1958	Rainfall	BoM	BoM	BoM
M019071	Mt Remarkable (Alligator Gorge)	Meteorological	1974	Rainfall	BoM	BoM	BoM
M019030	Quorn (Olive Rove)	Meteorological	1881	Rainfall	BoM	BoM	BoM
AW508500	Baroota Creek at Baroota Reservoir	Reservoir monitoring	04/04/1979–current	10.00 Rainfall (mm)			DWLBC
			17/11/1978–current	130.00 Res Level (m)			
AW508501	Mambray Creek at Black Hill		07/08/1972–08/11/1988 (Closed)	100.90 Level (m) Field Reading			
AW508502	Back Creek at Port Germein Gorge		22/07/1997–22/07/1997 (Single measurement only)	800.91 TDS (mg/L)			
AW508503	Saltia Creek at Saltia		14/03/1979–19/08/1991 Ceased)	100.00 Level (m)			
			21/09/1983–28/03/1989 (Ceased)	800.91 TDS (mg/L) 2015 Instantaneous			
AW508504	Baroota Reservoir catchment	Rainfall	05/09/1989–current	10.00 Rainfall (mm)			

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
	Pluvio at Glenlossie						
AW508505	Saltia Creek catchment Pluvio at Saltia		29/08/1988–05/12/1995 (Closed)	10.00 Rainfall (mm)			
AW508506	Baroota Reservoir Met Stn	Met					

Yorke Peninsula

The only surface water monitoring undertaken in this region is daily rainfall monitoring done by the BoM.

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M019199	Mt Remarkable National Park	Meteorological	1970–current	Rainfall	BoM	BoM	BoM

Southern Lake Frome Basin

The only surface water monitoring undertaken in this region is daily rainfall monitoring done by the BoM.

Site Number	Site Name	Type	Commencement/Purpose/ Related Stations	Parameters	Funding Agency	Data Collection	Data Custodian
M019084	Pekina	Meteorological	Closed (1963–93)	Rainfall	BoM	BoM	BoM

B. SURFACE WATER MONITORING STATION CATEGORIES

(Modified from Greenwood 2001)

Station Category	Purpose	Minimum Parameters	Duration	Frequency of Data Collection	Priority
Base Station	To monitor outflow from the major yielding section(s) of the catchment	Rainfall Water Level / Streamflow Stream Salinity (EC and Temp)	Ongoing 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 / Streamflow 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 / Streamflow	Medium Term (10 years)	Download Quarterly	High
Representative Stations	Streamflow from areas representing particular features for example hydrological characteristics, vegetation types or land use practices. Can be independent of catchment	Water Level / Streamflow 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 (5 years) but variable.	Project Specific	Medium / Low
Environmental Station	Sites considered significant for monitoring the water requirements of aquatic ecosystems	Water Level / Streamflow Stream Salinity (EC and Temp) Other parameters as required	Short to Medium Term (5–10 years)	Project Specific	Medium / Low

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

Abbreviations Commonly Used Within Text

Abbreviation		Name	Units of measure
TDS	=	Total Dissolved Solids (milligrams per litre)	mg/L
EC	=	Electrical Conductivity (microSiemens per centimetre)	µS/cm
pH	=	Acidity	
δD	=	Hydrogen isotope composition	°/oo
CFC	=	Chlorofluorocarbon (parts per trillion volume)	pptv
$\delta^{18}O$	=	Oxygen isotope composition	°/oo
^{14}C	=	Carbon-14 isotope (percent modern Carbon)	pmC
ppm	=	Parts per million	
ppb	=	Parts per billion	

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.

AMO — Airport Meteorological Office.

ANZECC — Australia New Zealand Environmental Consultative 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.

BACI — Before–After–Control–Impact.

Baseflow — Stream flow that is not directly affected by rainfall but may be maintained by groundwater recharge.

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

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

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

BoM — Bureau of Metrology, Australia.

Catchment — That area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

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

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

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 the South Australia Department of Water, Land and Biodiversity Conservation (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 — Abbreviation for electrical conductivity. 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C. Commonly used to indicate the salinity of water.

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.

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

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

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

EPA — Environment Protection Agency.

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.

EWR — Environmental Water Requirement.

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.

GIS (geographic information system) — Computer software allows for the linking of geographic data (e.g. land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis.

Groundwater — *See undergroundwater.*

Habitat — The natural place or type of site in which an animal or plant, or communities of plants and animals, lives.

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers. *(See hydrology.)*

HYDSTRA — A timeseries 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.

Hyporheic — The area below the streambed where water percolates through spaces between the rocks and cobbles.

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 a part of implementation monitoring.

Indigenous species — A species that occurs naturally in a region.

LWA — Land and Water Australia.

Macro-invertebrates — Animals without backbones that are typically of a size that is visible to the naked eye. They are a major component of aquatic ecosystem biodiversity and fundamental in food webs.

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

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, and so forth.

Microphyte — A microscopic plant (e.g. bacterium, fungus, alga).

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.

NAB — Northern Adelaide and Barossa catchment.

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

NHT — Natural Heritage Trust.

NLWRA — National Land and Water Resources Audit.

Nonpoint-source pollution — A contributory factor to water pollution that cannot be traced to a specific spot; e.g. pollution that results from water runoff from urban areas, construction sites, agricultural and silvicultural operations, and so forth.

Natural resources — Soil; water resources; geological features and landscapes; native vegetation, native animals and other native organisms; ecosystems.

Natural Resources Management (NRM) — All activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

NRMB — Natural Resources Management Board.

NYNRM — Northern and Yorke Natural Resources Management region.

OBSWELL — Observation well network.

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.

Pollution, point source — A localised source of pollution.

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.

PRA — Prescribed Resources Area.

Prescribed water resource — A water resource declared by the Governor to be prescribed under the Act, and includes undergroundwater to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Prescribed well — A well declared to be a prescribed well under the *Water Resources Act 1997*.

PWA — Prescribed Wells Area.

Refugia pools — A pool within a watercourse that retains water at a minimum level and quality on a permanent basis, where obligate aquatic biota can persist during periods when available habitat becomes restricted due to seasonal, climatic or ecological conditions.

Reticulated water — Water supplied through a piped distribution system.

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

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

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

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

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

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

SA Water — South Australian Water Corporation.

Siltation — The deposition or accumulation of silt.

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

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) 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, stream flow, and salinity data collected from a network of surface water monitoring sites located throughout South Australia.

SWMCC — State Water Monitoring Coordination Committee.

TDS — Total Dissolved Solids.

Tertiary aquifer — A term used to describe a water-bearing rock formation deposited in the Tertiary geological period (from 1 to 70 millions 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.

TN — Total Nitrogen.

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

TP — Total Phosphorus.

TWS — Town Water Supply.

Undergroundwater (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

Water allocation — (a) in respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence; (b) in respect of water taken pursuant to an authorisation under s. 11 means the maximum quantity of water that can be taken and used pursuant to the authorisation.

Water allocation plan (WAP) — A plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with Division 3 of Part 7 of the Act.

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

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

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

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

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

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

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

Wetlands — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic/intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six metres.

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