The Department of
Water, Land and
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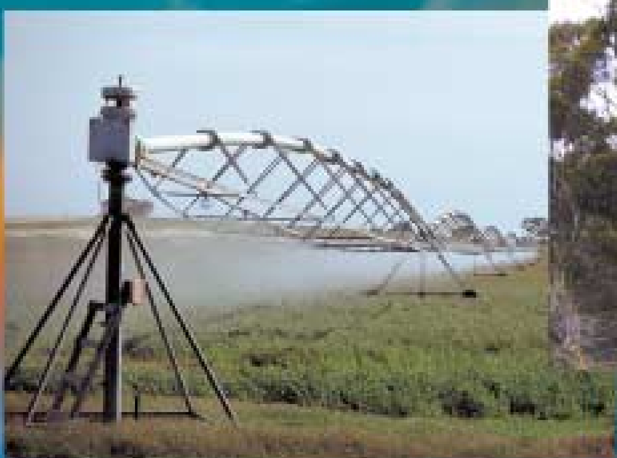
Conservation

Water Resource Assessment of the Tintinara - Coonalpyn Prescribed Wells Area.



Report DWLBC 2002/20

Government
of South Australia

The Department of Water, Land and Biodiversity Conservation

Water resource assessment of the Tintinara–Coonalpyn Prescribed Wells Area

Steve R. Barnett

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August 2002

Report DWLBC 2002/20

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of South Australia

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Foreword

South Australia's natural resources are fundamental to the economic and social wellbeing of the State. One of the State's most precious natural resources, water is a basic requirement of all living organisms and is one of the essential elements ensuring biological diversity of life at all levels. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of these resources changes the natural balance and may cause degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Understanding the cause and effect relationship between the various stresses imposed on the natural resources is paramount to developing effective management strategies. Reports of investigations into the availability and quality of water supplies throughout the State aim to build upon the existing knowledge base enabling the community to make informed decisions concerning the future management of the natural resources thus ensuring conservation of biological diversity.

Bryan Harris
Director, Resource Assessment Division
Department of Water, Land and Biodiversity Conservation

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INTRODUCTION

Background

There are six water management zones, covering an area of almost 20 000 km^2, in the South East region of South Australia (Fig. 1). Under the *Water Resources Act, 1997*, the South East Catchment Water Management Board (SECWMB) is required to prepare Water Allocation Plans for each of these six Prescribed Wells Areas (PWAs), giving consideration to Sections 101 (4) (b) and 101 (4) (e) of the Act. That is, the Plan must:

- *include an assessment as to whether the taking or use of water from the resource will have a detrimental effect on the quantity or quality of water that is available from any other resource*
- *assess the capacity of the resource to meet the demands for water on a continuing basis and provide regular monitoring of the capacity of the resource to meet those demands.*

In order to fulfil this requirement for the Tintinara–Coonalpyn PWA, the Department of Water, Land and Biodiversity Conservation (DWLBC), has been requested by the SECWMB to assess the water resources in the context of the above sections of the Act.

Nature and scope of work

This report provides an overview of the water resources for the Tintinara–Coonalpyn PWA (TCPWA) and includes:

- A general assessment of the groundwater resources for each of the aquifers in the PWA.
- A description (for both the unconfined and confined aquifers) of:
  - o The management approach adopted for the sustainable use of the resource (generally referred to as permissible annual volume) and a description of the manner in which the sustainable limits of use can be determined. Where separate management areas exist within the PWA, the adopted limits of sustainable groundwater use need to be tabulated. The assessment should identify any data deficiencies and requirements for future investigations.
  - o The historic and current demand (in terms of use) in each of the management areas within the PWA.
  - o The likely future demand for groundwater from this resource in the PWA.
  - o An assessment of whether the taking or use from the aquifers will have a detrimental effect on the quantity or quality of water that is available from any other water resource, both within and outside of the PWA; including a description of the likely nature and extent of any detrimental effects.
  - o An assessment of the current condition of the groundwater resources of both aquifers, taking into consideration available groundwater monitoring data to determine the capacity of both aquifers to meet the demands identified, on a continuing basis. This is to include recommendations for management intervention

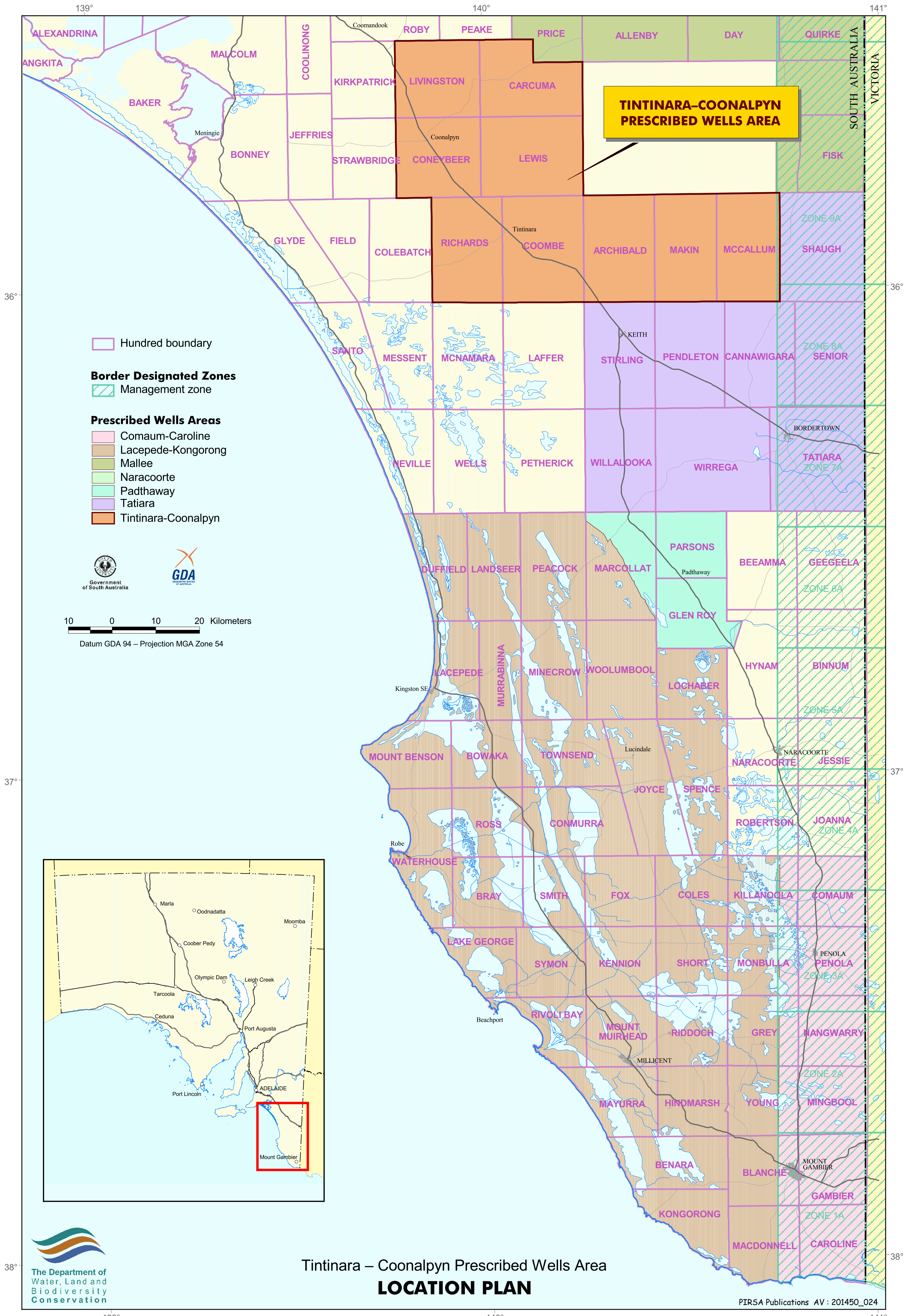
TINTINARA–COONALPYN PRESCRIBED WELLS AREA
Hundred boundary
Border Designated Zones
Management zone
Prescribed Wells Areas
Comaum-Caroline
Lacepede-Kongorong
Mallee
Naracoorte
Padthaway
Tatiara
Tintinara-Coonalpyn
Government of South Australia
GDA
10 0 10 20 Kilometers
Datum GDA 94 – Projection MGA Zone 54
SOUTH AUSTRALIA
VICTORIA
139°
140°
141°
36°
37°
38°
ALEXANDRINA
ANGKITA
MALCOLM
COOLINONG
ROBY
PEAKE
PRICE
ALLENBY
DAY
QUIRKE
BAKER
KIRKPATRICK
LIVINGSTON
CARCUMA
JEFFRIES
BONNEY
STRAWBRIDGE
CONEYBEER
LEWIS
FISK
GLYDE
FIELD
COLEBATCH
RICHARDS
COOMBE
ARCHIBALD
MAKIN
MCCALLUM
SHAUGH
ZONE 9A
SANTO
MESSENT
MCNAMARA
LAFFER
STIRLING
PENDLETON
CANNAWIGARA
SENIOR
ZONE 8A
NEVILLE
WELLS
PETHERICK
WILLALOOKA
WIRREGA
TATIARA
ZONE 7A
DUFFIELD
LANDSEER
PEACOCK
MARCOLLAT
PARSONS
BEEAMMA
GEEGEELA
ZONE 6A
GLEN ROY
LACEPEDE
MURRABINNA
MINECROW
WOOLUMBOOL
LOCHABER
HYNAM
BINNUM
ZONE 5A
MOUNT BENSON
BOWAKA
TOWNSEND
NARACOORTE
JESSIE
JOYCE
SPENCE
ROSS
CONMURRA
ROBERTSON
JOANNA
ZONE 4A
WATERHOUSE
BRAY
SMITH
FOX
COLES
KILLANOOLA
COMAUM
LAKE GEORGE
SYMON
KENNION
SHORT
MONBULLA
PENOLA
ZONE 3A
RIVOLI BAY
MOUNT MUIRHEAD
RIDDOCH
GREY
NANGWARRY
ZONE 2A
MAYURRA
HINDMARSH
YOUNG
MINGBOOL
BENARA
BLANCHE
GAMBIER
KONGORONG
ZONE 1A
MACDONNELL
CAROLINE
Coomandook
Meningie
Coonalpyn
Tintinara
KEITH
BORDERTOWN
Padthaway
Kingston SE
Lucindale
NARACOORTE
Robe
PENOLA
Beachport
MILLICENT
MOUNT GAMBIER
Marla
Oodnadatta
Moomba
Coober Pedy
Olympic Dam
Leigh Creek
Tarcoola
Ceduna
Port Augusta
Port Lincoln
ADELAIDE
Mount Gambier
The Department of Water, Land and Biodiversity Conservation
Tintinara – Coonalpyn Prescribed Wells Area
LOCATION PLAN
PIRSA Publications AV : 201450_024

Figure 1

in areas where it is considered that the resource may not have the capacity to meet future demands.

- o An assessment of the adequacy of the current groundwater monitoring network in the PWA for monitoring the capacity of the resource to meet demands, including recommendations for any additional monitoring requirements.

This report does not include an environmental assessment of groundwater-dependent ecosystems.

Study area

REGIONAL HYDROGEOLOGY

Geologically, the South East region lies predominantly within the Gambier Embayment of the Otway Basin. The TCPWA, however, is located on the southwestern margin of the Murray Basin. The two basins are partially separated by a basement high, called the Padthaway Ridge (Fig. 2). Both basins are still, however, hydraulically connected and have comparable geological and hydrogeological units, reflecting a similar evolutionary history (Cobb and Brown, 2000).

There are no extensive supplies of good-quality surface water in the South East, and therefore groundwater provides the main water resource for the region. While primarily used for irrigation, groundwater is also used for industrial, recreational and stock use, and for supplying reticulated water to a number of towns located in the area.

In both basins, groundwater flows through two major aquifer systems: a regionally unconfined limestone aquifer and an underlying confined aquifer with sand and bryozoal limestone (coral) layers. The two aquifers are separated by a low permeability aquitard usually made up of a dark-brown carbonaceous clay. The aquifers are hydraulically connected, but the degree of hydraulic connectivity between the two aquifers is poorly understood and is currently an area of active research (Cobb and Brown, 2000).

The upper, unconfined limestone aquifer is the most extensively used of the two aquifers. However, poor groundwater quality in this aquifer in some areas has resulted in the development of the underlying confined aquifer as a water resource.

About one million years ago, a marine transgression extended as far inland as Keith, Tintinara and Peake and eroded away the older Tertiary sands and limestone which underlie the higher Mallee landscape to the northeast. The Marmon Jabuk Scarp and the flat low-lying Coastal Plain was formed as a result of this transgression (Fig. 2). The regionally extensive unconfined limestone aquifer can therefore be subdivided into two regions. Beneath the Mallee Highlands, it consists mainly of calcareous sandstone and limestone of Tertiary age (~30 million years old) and is known as the Murray Group Limestone. The flat low-lying Coastal Plain is underlain by the younger Quaternary limestones of the Coomandook and Bridgewater Formations which are less than 1 million years old (Fig. 3).

The confined aquifer consists of quartz sands and bryozoal limestone (coral) layers, interbedded with dark-brown carbonaceous clays. The limestone layers occur in the Buccleuch Formation, whose extent approximates that of the Coastal Plain. This unit

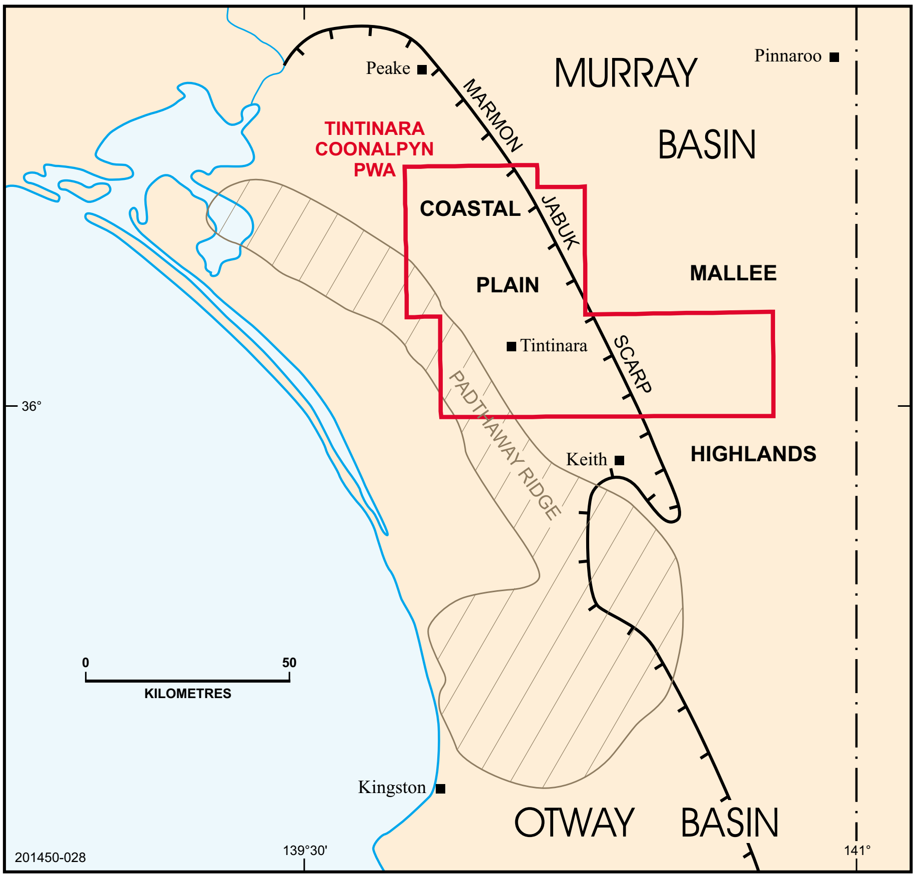

Figure 2 Geological provinces in South East Region

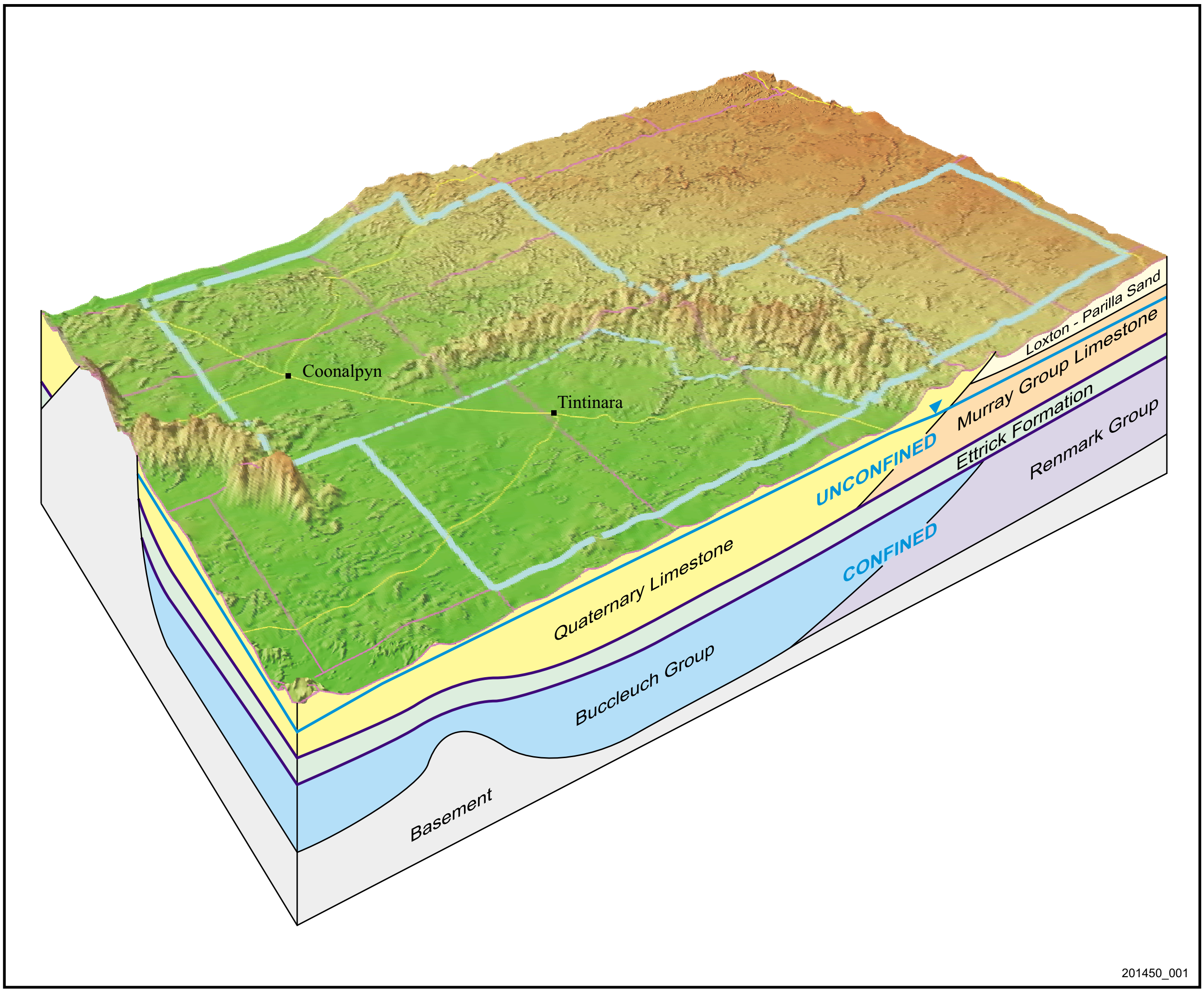

Figure 3 Block diagram of the hydrogeology of the Tintinara-Coonalpyn Prescribed Wells Area

merges laterally with the Renmark Group of the Murray Basin (Fig. 3), and is ~40 million years old. The confined aquifer, for management purposes, is treated regionally as one aquifer, but it is in reality a complex multi-aquifer groundwater system.

Recharge to the confined aquifer relies on downward leakage from the overlying unconfined aquifer. This occurs in the eastern margin of the region where the watertable in the unconfined aquifer is higher than the potentiometric head in the underlying confined aquifer, creating potential for downward leakage and recharge. To the west and south of the region, the head distribution is reversed and there is the potential for upward leakage and discharge from the confined aquifer to the unconfined aquifer.

Groundwater flow, for both the unconfined and confined aquifer systems, originates from the topographic high of the Dundas Plateau located in western Victoria. From there, the groundwater flows radially westward and southward to the coast, and northwards to the Murray River. The rate of movement of the groundwater through each aquifer depends on its hydrogeological properties, such as the permeability and the gradient of the watertable or pressure surface that is driving groundwater flow.

The salinity of the groundwater of the unconfined aquifer ranges from ~500 mg/L in the south, to more than 30 000 mg/L in the north. Groundwater salinity in the confined aquifer system is typically less than 500 mg/L in the south, around Mount Gambier, but increases gradually northwards to over 10 000 mg/L as the aquifer thins north of Kingston (Cobb and Brown, 2000).

The climate of the South East region is typified by hot, dry summers and cool, wet winters. Annual rainfall ranges from more than 800 mm in the south to about 450 mm in the north. Potential evapotranspiration increases from about 1400 mm in the south to about 1800 mm in the north. Precipitation exceeds potential evapotranspiration usually from May to September. Recharge to the upper unconfined aquifer generally occurs during this period.

GROUNDWATER MANAGEMENT AREAS

The South East Catchment Water Management Board was established under the *Water Resources Act 1997* and is responsible for the management of water resources in the South East region. It is under this Act that the water resources are prescribed in the six PWAs in the South East region. They include the established PWAs of Padthaway, Tatiara, Comaum–Caroline, and Naracoorte Ranges (prescribed under previous water resources acts) and the recently prescribed Lacepede–Kongorong and Tintinara–Coonalpyn PWAs (Fig. 1). To allow for more effective management of each PWA, the PWAs have been subdivided into zones, and sometimes sub-zones.

The other piece of water resource legislation of importance to the region is the *Groundwater Border Agreement Act (Governments of South Australia and Victoria) 1985*. This Act covers the water resources of the 40 km wide strip that is centred on the South Australian and Victorian border. The South Australian – Victorian Border Review Committee, comprising representatives from both States, is responsible for administering the water resources along the Border Zone, which abuts the eastern margin of the TCPWA.

HYDROGEOLOGY

Geographical setting

The TCPWA covers an area of ~3423 km^2 and includes the Hundreds of Archibald, Carcuma, Conybeer, Coombe, Lewis, Livingston, Makin, McCallum, and Richards (Fig. 1). Both major towns, Coonalpyn and Tintinara, lie on the main Adelaide–Melbourne highway that runs through the western part of the TCPWA in a southeast direction.

Geomorphology

The TCPWA can be divided into two discrete landforms, the low-lying Coastal Plain to the west and the highlands of the Mallee to the north and east. Separating the two terrains is the extension of the Marmon Jabuk Scarp (Fig. 2).

The Coastal Plain consists of jumbled sand dunes separated by broad, low-lying interdunal flats averaging 15–20 m above sea level. Basement rocks forming the Padthaway Ridge (Fig. 2), consist of early Palaeozoic igneous rocks (granite) and metasediments that outcrop at the surface as low, rounded hills (Mount Boothby). Soils are very sandy and can be quite thin over shallow limestone on the flats.

The surface of the Mallee Highlands consists of undulating plains that increase in height to the east, reaching a maximum altitude of 110 m above sea level. Overlying the undulating plains are remnant sand dunes, which generally trend east–west. Soils are generally sandy, although heavier clay soils are exposed in the lower interdunal flats.

Rainfall

The climate in the TCPWA is typical of the South East; with hot, dry summers and cool, wet winters. The average annual rainfall in Tintinara (1900 to present) is 470 mm, with annual evaporation estimated at 1670 mm. In Coonalpyn the average rainfall (1887 to present) is slightly less at 456 mm. To the east at Kangaringa (1950 to present), an average rainfall of 463 mm is recorded with an annual evaporation of ~1770 mm.

These figures show that rainfall is fairly uniform over the TCPWA, with a slightly higher evaporation rate toward the east and therefore a slightly higher irrigation requirement also to the east.

Surface water flows

There are no extensive supplies of good-quality surface water in the TCPWA. Diffuse recharge is therefore the dominant recharge mechanism in the area.

Local hydrostratigraphy

UNCONFINED AQUIFER

Groundwater flow in the unconfined aquifer in the TCPWA is generally from east to west, i.e. from the Murray Group Limestone beneath the Mallee through to the Padthaway and Bridgewater Formations beneath the Coastal Plain. These units are hydraulically continuous across the PWA.

The thickness of the unconfined aquifer varies considerably throughout the region but it generally thickens from southwest to northeast toward the centre of the Murray Basin. For example, in the southwest portion of the PWA (Hundred of Richards), the aquifer is ~25 m thick, with an increase to almost 100 m on the eastern boundary of the PWA. Aquifer thinning is more rapid in the southwest of the PWA near outcrops of granite basement as can be seen in Figure 3.

Coastal Plain

The depth to the watertable in the unconfined aquifer on the interdunal flats is generally >5 m. To the west of Tintinara, the watertable is >2 m below ground level and has caused extensive areas of dryland salinity. The unconfined aquifer is developed extensively for irrigation in the Hundreds of Coombe and Archibald.

The uppermost geological unit is the Padthaway Formation, which occurs only beneath the interdunal flats. The maximum recorded thickness is ~20 m in the Hundred of Stirling. It consists mainly of an off-white, well-cemented, non-fossiliferous, fine-grained limestone. A well-developed secondary porosity has resulted in a highly transmissive aquifer. Underlying the Padthaway Formation is the Bridgewater Formation. Lithology in the Bridgewater Formation does vary over the PWA, but it generally consists of fine to coarse-shelly quartz sandstone. High well-yields of up to 300 L/s in the Padthaway and Bridgewater Formations have enabled irrigators to adopt flood irrigation practices (Stadter and Love, 1987). The deepest of the geological units, the Coomandook Formation, is not used as an aquifer because it has a higher marl (calcareous clay) component than the overlying formations which, has resulted in lower well yields.

Mallee Highlands

In the eastern highlands area, the main geological unit of the unconfined aquifer is the Murray Group Limestone, which generally consists of a bryozoal and shelly limestone. The depth to the watertable varies from 25–50 m, reflecting the increasing elevation of the topography toward the east. Well yields range up to 60 L/s from production wells averaging 100 m in depth.

CONFINED AQUIFER

In the Murray Basin, the unconfined and confined aquifers are separated by a low permeability aquitard, comprising the Ettrick Formation (grey–green glauconitic marl) and the black lignitic clays at the top of the confined aquifer. The combined thickness of the aquitard is generally about 20 m.

In a similar pattern to the overlying unconfined aquifer, the confined aquifer thins to the southwest where it wedges out against rising basement (Fig. 3).

Vertical recharge to the confined aquifer from the overlying unconfined aquifer in the PWA is considered to be very low. Recharge to the aquifer is predominantly via lateral throughflow from the east, probably sourced from the Dundas Plateau in Victoria.

Coastal Plain

The confined aquifer in this area is referred to as the Buccleuch Formation, which generally consists of a series of interbedded bryozoal limestone and sand aquifers separated by thin carbonaceous clay units. It lies at a depth of ~60 m below ground. The sand units of the aquifer can be fine grained, and therefore difficult to screen. Well yields average 20–30 L/s with occasional supplies up to 50 L/s. At present, there are ~20 production wells drilled into the confined aquifer in the Hundreds of Coombe and Richards in areas where the salinity of the overlying unconfined aquifer is too high for irrigation use.

In the Hundreds of Conybeer and Livingston, and further north in the Hundreds of Peake and Sherlock, most stock and domestic bores are also completed in the bryozoal limestone, within the Buccleuch Formation, which overlies the Renmark Group.

Mallee Highlands

North of Tintinara, there are three sub-aquifers, namely the Upper Confined, Middle Confined and Lower Confined Aquifers. These three sub-aquifers are separated by clayey units with low permeability.

- The Upper Confined Aquifer consists of the bryozoal limestone within the Buccleuch Formation, which is found only in the western part of the PWA at depths of 90–100 m. Almost all confined stock and domestic bores, and smaller irrigation bores are completed in this aquifer.
- The Middle Confined Aquifer MCA comprises the Upper Sand Aquifer in the underlying Renmark Group, which is widespread throughout the area and lies at a depth of 130–160 m. Most of the higher yielding irrigation bores obtain their supplies from this aquifer.
- The Lower Confined Aquifer has a restricted distribution to the eastern part of the area as it wedges out against rising basement rock to the west and south. It lies at a depth of about 180 m and currently, there are only three operational bores completed in it.

The fact that extractions are occurring from these three different sub-aquifers separated by low permeability units will result in less intensive drawdowns in the areas of pumping, and much smaller impacts on shallower stock and domestic bores.

To the east of Tintinara in the Hundreds of Makin and McCallum, there are no bores penetrating the Renmark Group confined aquifer. This is because of the unknown capacity of the aquifer to provide irrigation supplies, the more expensive drilling requirements and the ready availability of low salinity water in the overlying limestone aquifer.

CURRENT STATUS OF THE WATER RESOURCES

Unconfined aquifer

GROUNDWATER FLOW

The watertable elevation contours for the unconfined aquifer are shown on Figure 4 and show groundwater movement from east to west. The changes in hydraulic gradient are inferred to represent changes in hydraulic conductivity in the aquifer. The gradient becomes steeper near the eastern boundary of the Hundred of Archibald, where the transition occurs from the Murray Group Limestone to the Bridgewater Formation. The gradient flattens to the west of the PWA and reflects high permeability in the Padthaway and Bridgewater Formations beneath the Coastal Plain.

WATER LEVEL TRENDS

Long-term water level hydrographs from observation wells located in the TCPWA are also shown in Figure 4. Only wells with data of more than five years were included in the assessment.

Coastal Plain

On the Coastal Plain, water levels in the unconfined aquifer have been rising up until 1993 in response to the increased vertical recharge resulting from the clearance of native vegetation. This rise occurred even when winter rainfall was average or slightly below average, at rates varying between 30 and 100 mm/y, depending on geological conditions. Observation wells ARC 7, CMB 6 and CMB 32 display these trends.

Since 1993, however, a series of dry winters (especially 1997–99) have reduced recharge, leading to a fall in water levels of about 1 m over the Coastal Plain area. The contribution to this fall from increased irrigation extractions cannot accurately be determined at this stage and further monitoring will be required to determine this impact. The fall in the watertable has the beneficial effect of delaying the spread of dryland salinity in an easterly direction from the low-lying areas to the west and south of Tintinara. It should be noted that the slightly above-average winter rainfall in 2000 and 2001 has led to a stabilisation in water levels.

Mallee Highlands

Because of the larger depth to the watertable in this area, variations in annual rainfall are generally filtered out and a continuous rise due to vegetation clearance is observed. The dry winters of 1997–99 mostly resulted in a stabilisation of water levels rather than a marked decline as observed on the Coastal Plain. The rising trend is continuing to the north of Tintinara (Hundred of Lewis) and also to the east (Hundreds of Makin, McCallum) in areas not influenced by irrigation (wells LEW 6, MKN 8 and MCA 3).

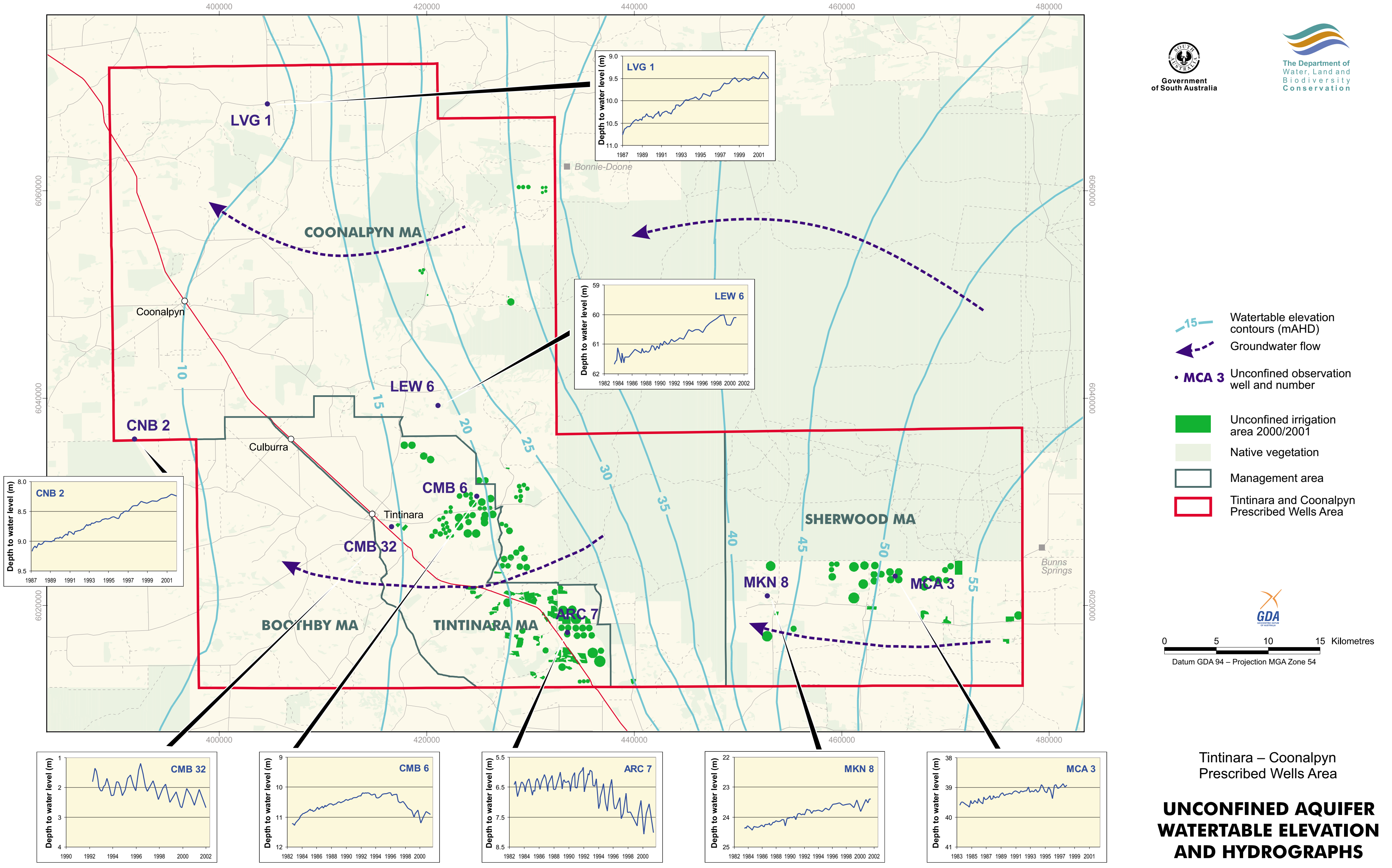

Figure 4

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SALINITY DISTRIBUTION

The salinity distribution for the unconfined aquifer in the TCPWA is shown on Figure 5. Generally, the salinity ranges from ~600 mg/L in the east to more than 30 000 mg/L in the west, where the watertable is close to the ground surface and dryland salinisation has occurred.

SALINITY TRENDS

Salinity graphs from a number of wells in the unconfined aquifer are also shown in Figure 5 and display several trends.

Coastal Plain

Irrigation bore ARC 8 has been monitored regularly since 1989 and is showing a rising trend of 18 mg/L/y. Of the remaining 95 irrigation bores, only 59 have two or three salinity readings and it is therefore difficult to determine long-term trends from them. However, 26 of these are showing a rising trend with 13 flood irrigation bores averaging a 125 mg/L/y rise, and 13 centre pivot irrigation bores averaging 70 mg/L/y.

Stock windmill CMB 18 has only six readings but shows a steady 23 mg/L/y rise up until 2000. Further monitoring of irrigation and other observation bores will be required over several more years to confirm any trends.

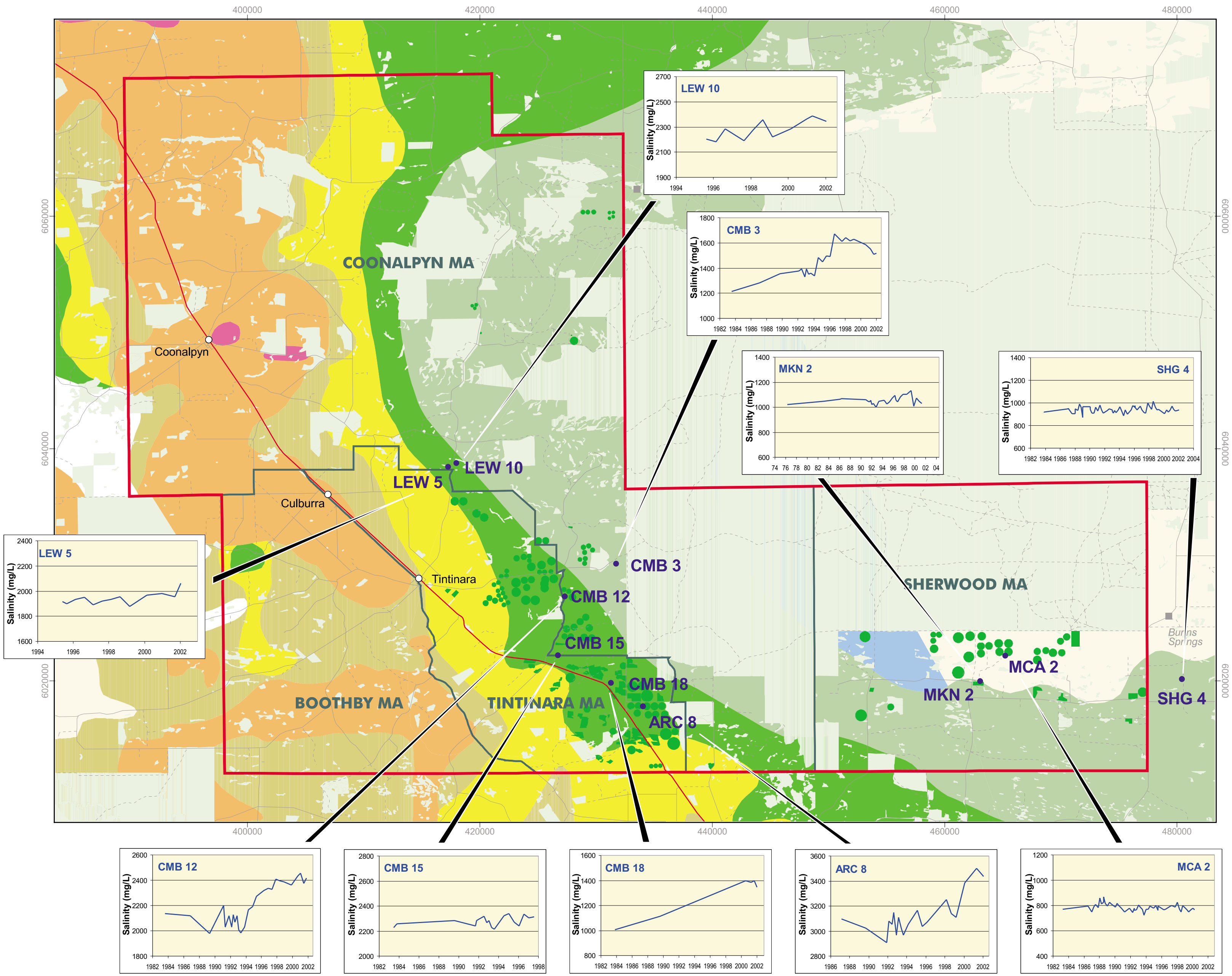
Lucerne, the major crop grown in the TCPWA, is a high water use crop. As water is drawn up through the root system, most of the dissolved salt is not taken up by the plant and accumulates in the root zone. This salt then percolates back down into the aquifer during subsequent irrigation applications or from rainfall recharge, resulting in a continuous cycle increasing the groundwater salinity every year. In some areas, the high concentration of irrigation activity in the area may compound the problem by not allowing the groundwater to move fast enough through the area to remove the salt.

Mallee Highlands

To the east of Tintinara, several bores with long-term monitoring records show a broad correlation with rainfall but no overall trend is apparent (MCA 2, MKN 2, SHG 4).

Immediately to the north and northeast of Tintinara on the elevated margins of the highland, rising trends are noticeable. To the northeast (CMB 3, 12), rises of about 30 mg/L/y have been measured with a steep increase coinciding with the below-average rainfall years of 1994–99. To the north (LEW 5, 10), rises are up to 25 mg/L/y, with the rate of rise being lower than to the east due to the greater depth to the watertable.

These increases are due to land clearing and the lack of recycling of irrigation water. Salt, which was previously stored in the root zone of the Mallee vegetation, is now being flushed down to the deep watertable following clearing. Drainage from irrigated areas will accelerate the process (Leaney et al., 1999; Leaney, 2000), depending on the efficiency of the irrigation. Very efficient irrigation, especially on heavier soils, will barely increase drainage above non-irrigated recharge rates, if at all.



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Salinity (mg/L)

- 500 to 1000
- 1000 to 1500
- 1500 to 3000
- 3000 to 7000
- 7000 to 14 000
- 14 000 to 35 000
- 35 000 to 100 000
- • CMB 3 — Unconfined observation well and number
- Unconfined irrigation area 2000/2001
- Native vegetation
- Management area
- Tintinara and Coonalpyn Prescribed Wells Area

GDA

0 5 10 15 Kilometres

Datum GDA 94 – Projection MGA Zone 54

Tintinara – Coonalpyn Prescribed Wells Area

SALINITY DISTRIBUTION AND TRENDS IN THE UNCONFINED AQUIFER

Figure 5

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It must be noted that if any accelerated flushing occurs, it will only take place beneath the actual irrigated area and not on a regional basis.

Confined Aquifer

GROUNDWATER FLOW

The potentiometric surface contours for the confined aquifer are shown on Figure 6 which shows groundwater movement from east to west, similar to the overlying unconfined aquifer.

WATER LEVEL TRENDS

Hydrographs of the confined aquifer monitoring wells are presented in Figure 6. In areas unaffected by pumping, the hydrographs closely match the trends in the overlying unconfined aquifer (CNB 3, LVG 2, SHG 6). This is most likely related to changes in the hydrostatic pressure resulting from changes in the watertable level in the unconfined aquifer (Barnett, 1995). A rising watertable results in more water being stored in the unconfined aquifer and therefore more weight pressing down on the confining layer, which increases the hydrostatic pressure on the underlying confined aquifer.

In areas affected by pumping, seasonal drawdowns of up to 8 m occurred in the Tintinara area during the 2001–02 irrigation season. There was little increase in drawdown compared to the previous year in the centre of the cone of depression as shown in Figure 6 (CMB 31). Elsewhere, the cone of depression expanded to the west due to an increase in pumping (RIC 4). No longer term trends have emerged due to the short monitoring record.

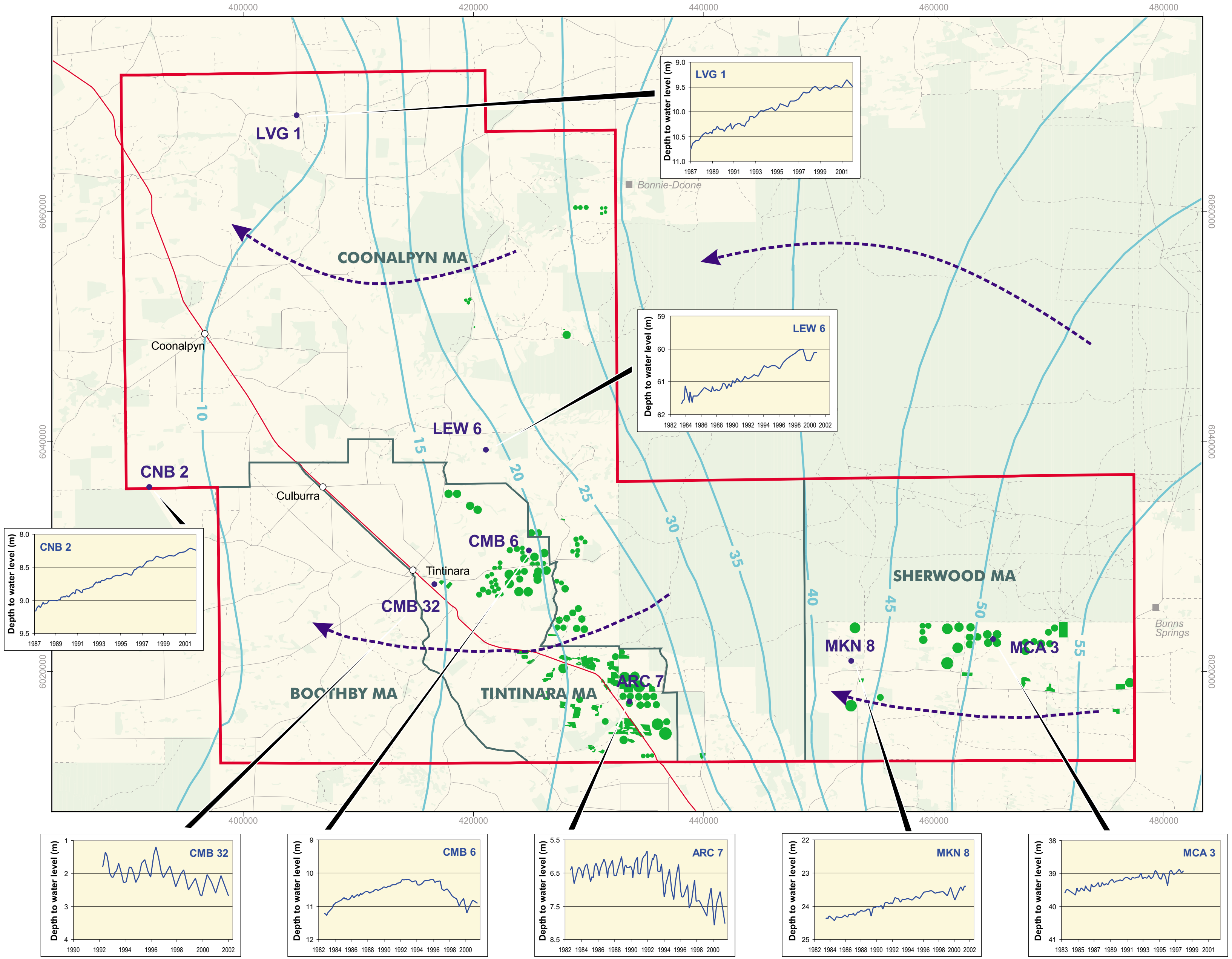
To the north, irrigation of olive plantations from the Middle Confined Aquifer and Lower Confined Aquifer has resulted in seasonal drawdowns of 6–7 m in these aquifers within the plantation boundaries (LEW 11, Fig. 6). Elsewhere, the only measured drawdown is 400 mm in the Upper Confined Aquifer at 4 km from the centre of pumping.

SALINITY DISTRIBUTION

The salinity distribution in the confined aquifer is similar to the overlying unconfined aquifer (Fig. 7). It increases from ~600 mg/L in the east to more than 30 000 mg/L in the west, where the aquifer wedges out against rising basement. Extensive sampling carried out during a field survey to the west of Tintinara has improved the accuracy of this plan.

SALINITY TRENDS

There are no obvious trends apparent as yet, mostly because of the short monitoring record from observation wells shown in Figure 7.



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Tintinara – Coonalpyn Prescribed Wells Area

UNCONFINED AQUIFER WATERTABLE ELEVATION AND HYDROGRAPHS

Figure 6

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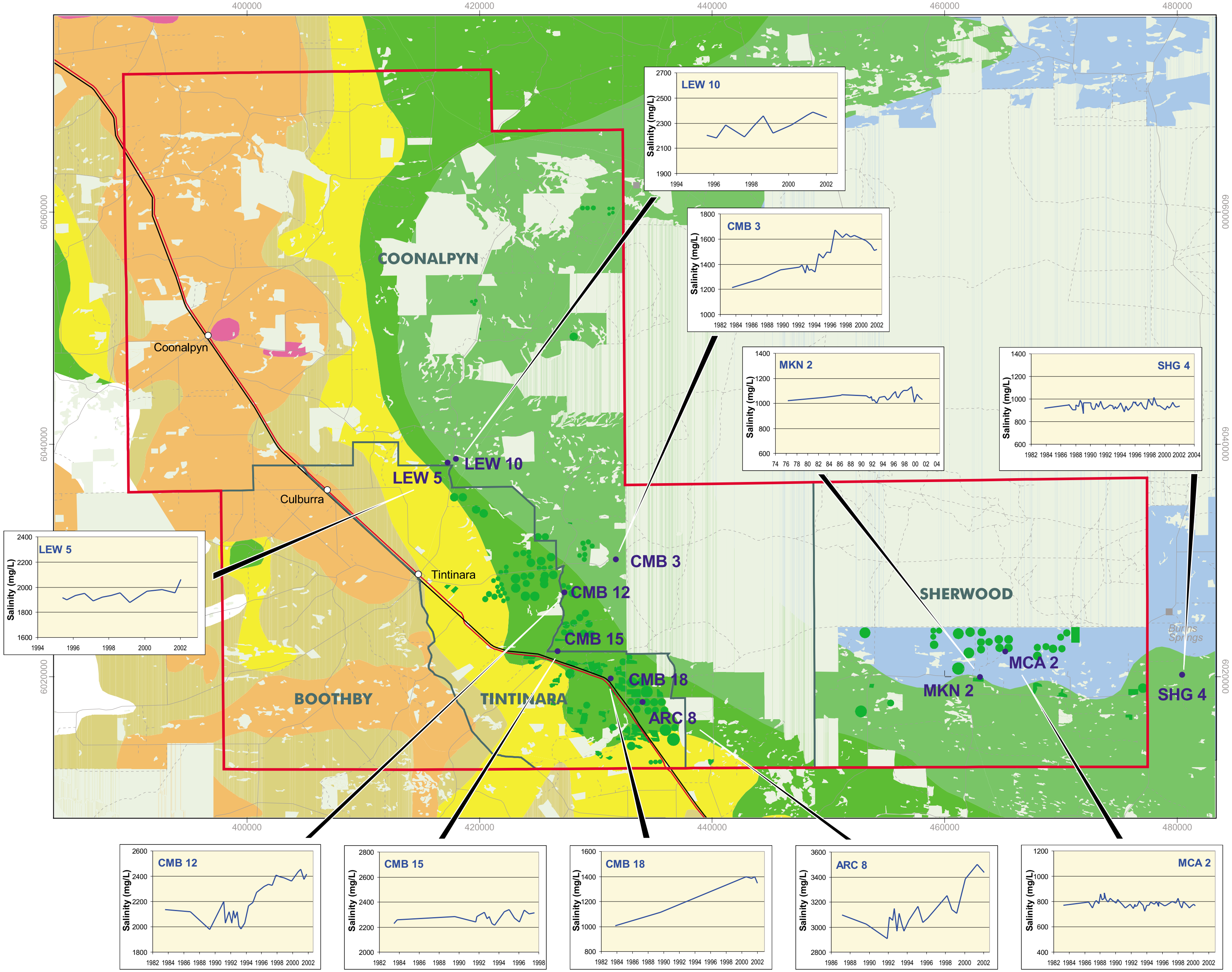

Salinity (mg/L)

- 500 to 1000
- 1000 to 1500
- 1500 to 3000
- 3000 to 7000
- 7000 to 14 000
- 14 000 to 35 000
- 35 000 to 100 000
- • CMB 3 Unconfined observation well and number
- Unconfined irrigation area 2000/2001
- Native vegetation
- Management area
- Tintinara and Coonalpyn Prescribed Wells Area

GDA

0 5 10 15 Kilometres

Datum GDA 94 – Projection MGA Zone 54

Tintinara – Coonalpyn Prescribed Wells Area

SALINITY DISTRIBUTION AND TRENDS IN THE UNCONFINED AQUIFER

Figure 7

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MONITORING NETWORKS

Unconfined aquifer

The DWLBC and its predecessors have been monitoring groundwater levels in the TCPWA since 1983, when concerns were first expressed about falling watertables. Salinity monitoring began in the Mallee Highlands area in 1987 to monitor the impacts of land clearing. Whilst this monitoring has so far been concentrated in areas of better quality groundwater where irrigation is occurring, the network will be expanded to include areas of saline groundwater where the relationship between vegetation health and groundwater depth and salinity will be investigated under the National Action Plan for Salinity and Water Quality.

WATER LEVEL MONITORING NETWORK

The water level monitoring network in the TCPWA has been in operation for more than 17 years. The network has recently been upgraded and expanded to monitor the increase in irrigation development. There are currently 27 wells monitored for water level. These wells are measured approximately quarterly (March, June, September and December) or at appropriate times to monitor the beginning and end of the irrigation season. This monitoring is carried out by the DWLBC and contractors.

The locations of the current water level monitoring wells for the unconfined aquifer are shown on Figure 8. The number of water level monitoring wells in the network is currently considered adequate for the TCPWA. The network can be quickly expanded when necessary to monitor new areas of irrigation.

SALINITY MONITORING NETWORK

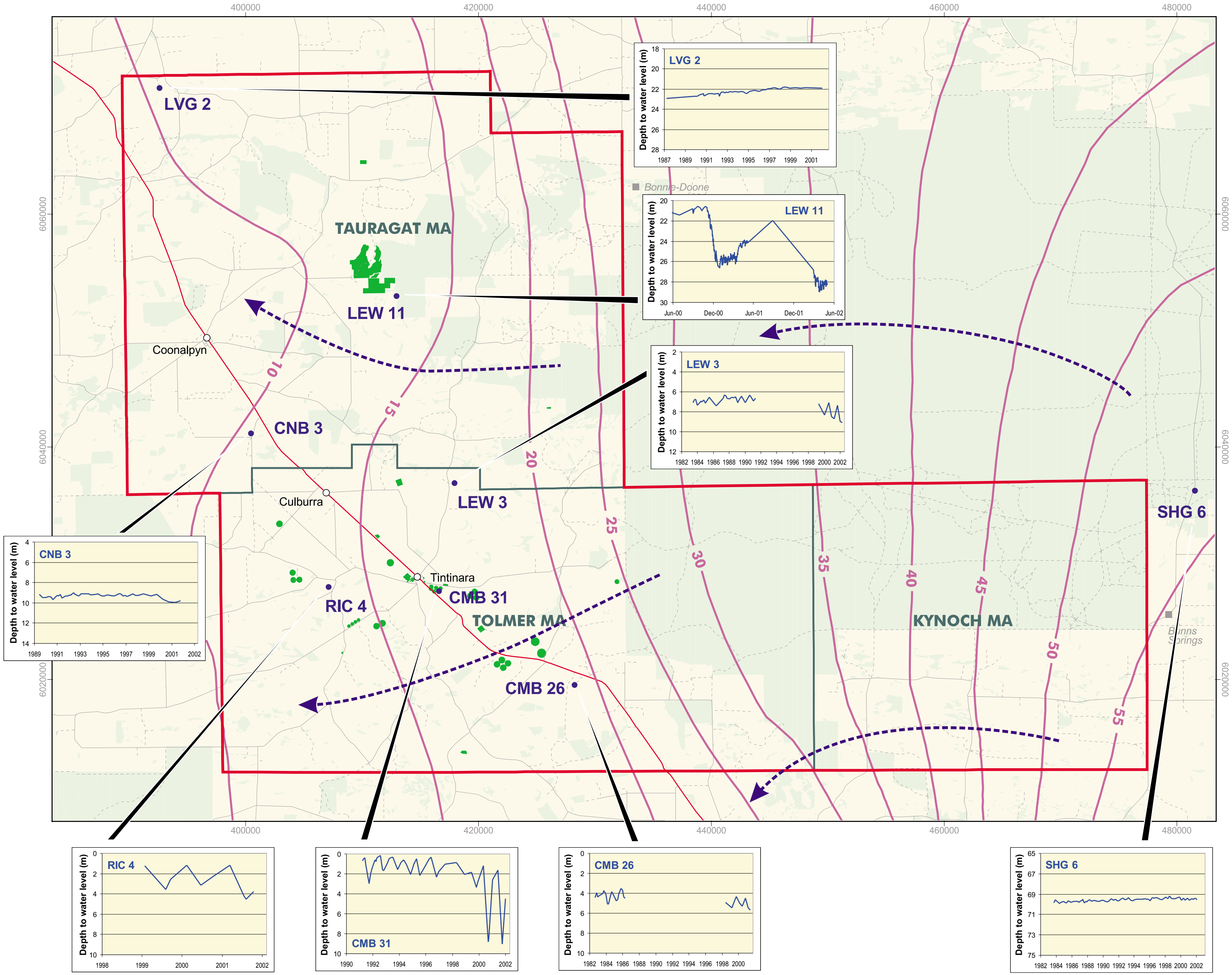
There are currently a total of six observation wells monitoring salinity in the TCPWA. Most of these were selected to monitor the salinity impacts of land clearing beneath the Mallee Highlands. Sampling is undertaken by the DWLBC or contractors with a sampling frequency of six months. The location of wells in the salinity monitoring network for the unconfined aquifer are shown on Figure 8. This network should be expanded by adding at least another five bores.

In 2000, a program to sample all private irrigation wells on an annual basis began, initially on the Coastal Plain to determine any effects of groundwater recycling in the shallow unconfined aquifer. This should be continued.

Confined aquifer

WATER LEVEL MONITORING NETWORK

There are currently 13 water level observation wells monitoring the confined aquifer in the Coastal Plain region of the TCPWA, two of which are equipped with data loggers for continuous readings. There are also 15 observation wells located in the Hundreds of



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15 Watertable elevation contours (mAHD)

Groundwater flow

• SHG 6 Confined observation well and number

Confined irrigation area 2000/2001

Native vegetation

Management area

Tintinara and Coonalpyn Prescribed Wells Area

GDA

0 5 10 15 Kilometres

Datum GDA 94 – Projection MGA Zone 54

Tintinara – Coonalpyn
Prescribed Wells Area

CONFINED AQUIFER POTENTIOMETRIC SURFACE ELEVATION AND HYDROGRAPHS

Figure 8

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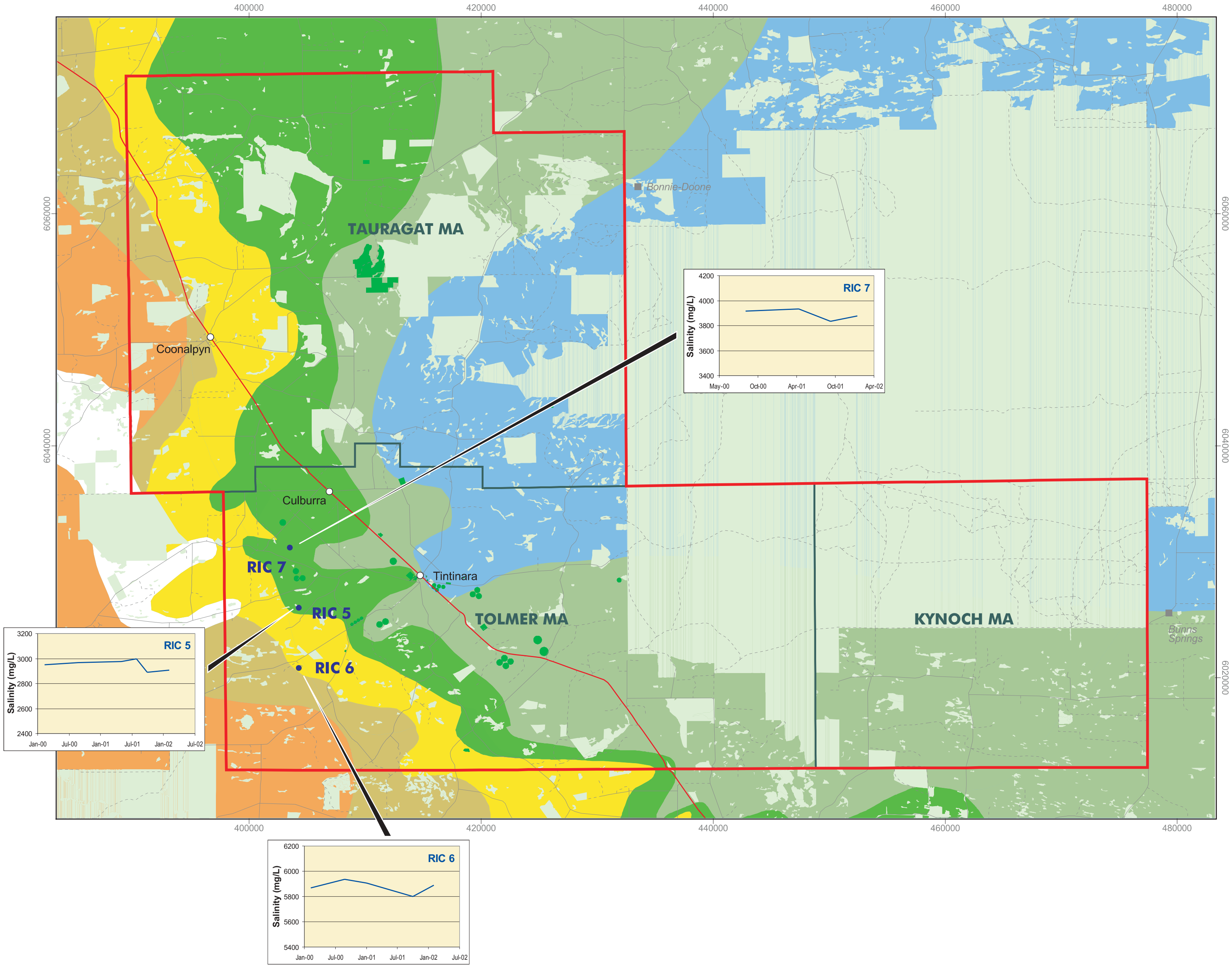
Lewis and Carcuma to monitor drawdowns due to the irrigation extractions for olive plantations (three have data loggers). The locations of these wells are shown in Figure 9. The only monitoring well in the Mallee Highlands to the east of Tintinara is SHG 6 which lies just outside the eastern boundary of the TCPWA.

The network can be quickly expanded when necessary to monitor new areas of irrigation.

SALINITY MONITORING NETWORK

There are eight monitoring wells currently used to monitor groundwater salinity in the confined aquifer, mostly to the west of Tintinara, where they will provide early warning for any increases in salinity due to reversal of groundwater flow caused by drawdown if it occurs.



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Salinity (mg/L)

- 500 to 1000
- 1000 to 1500
- 1500 to 3000
- 3000 to 7000
- 7000 to 14 000
- 14 000 to 35 000
- 35 000 to 100 000

• **RIC 7** Confined observation well and number

Confined irrigation area 2000/2001

Native vegetation

Management area

Tintinara and Coonalpyn Prescribed Wells Area

GDA

0 5 10 15 Kilometres

Datum GDA 94 – Projection MGA Zone 54

Tintinara – Coonalpyn Prescribed Wells Area

SALINITY DISTRIBUTION AND TRENDS IN THE CONFINED AQUIFER

Figure 9

PIRSA Publishing Services CD:201450_007

GROUNDWATER MANAGEMENT APPROACH

History

In 1998, the Tintinara – Coonalpyn area was placed under a Notice of Restriction pursuant to the *Water Resources Act, 1976*. This was considered necessary because of concerns from the community that the rapid expansion of irrigation activity in parts of the area could have a detrimental impact on the water resource. It was later proclaimed on 2 November 2000.

At the time of proclamation, authorisations were issued on the basis of established irrigation activity and on proposed development, pending an initial assessment of permissible annual volumes (PAVs) for the PWA.

Management areas

UNCONFINED AQUIFER

Management of salinity increases is the main concern in this aquifer. Four management zones, each with common aquifer characteristics, are proposed to address this issue (Fig. 10). A summary appears in Appendix A.

Tintinara MA — Coastal Pain

This zone comprises most of the Hundred of Coombe and the western part of Hundred Archibald and has the following characteristics:

- Quaternary limestone aquifer with the watertable 0–15 m below ground surface
- groundwater salinity below 8000 mg/L
- centre pivot and flood irrigation of lucerne
- recharge rates averaging 50 mm/y
- salinity rises in 50% of sampled irrigation bores averaging 125 mg/L/y for flood and 70 mg/L/y for pivots.

Management issues to be addressed include:

- salinity increases due to recycling of irrigation water
- rising watertable due to clearing, resulting in the eastward expansion of dryland salinity.

Boothby MA — Coastal Pain

This zone comprises most of the Hundred of Richards and has the following characteristics:

- Quaternary limestone aquifer with the watertable 0–10 m below ground surface
- groundwater salinity above 8000 mg/L

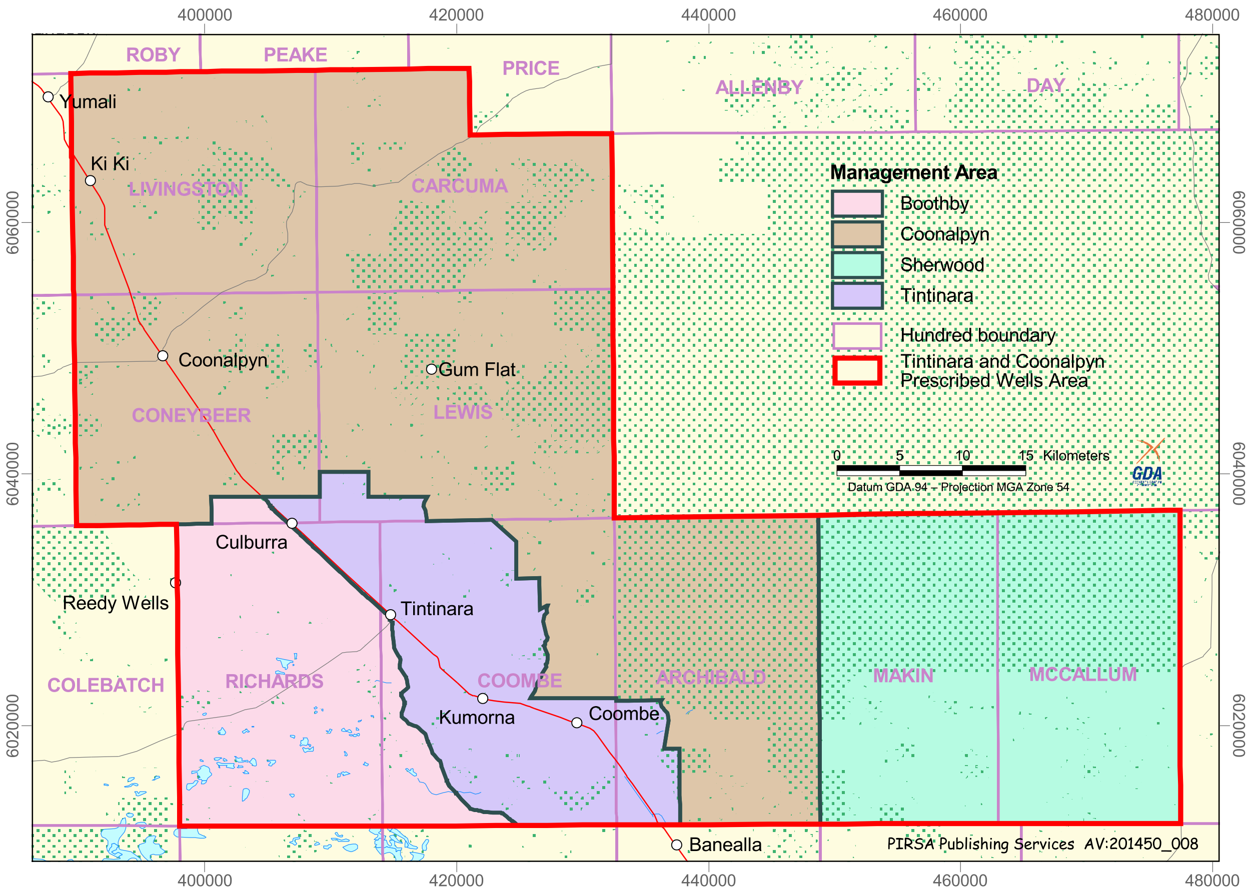


Figure 10 Management areas for the Tintinara–Coonalpyn Prescribed Wells Area – unconfined aquifer

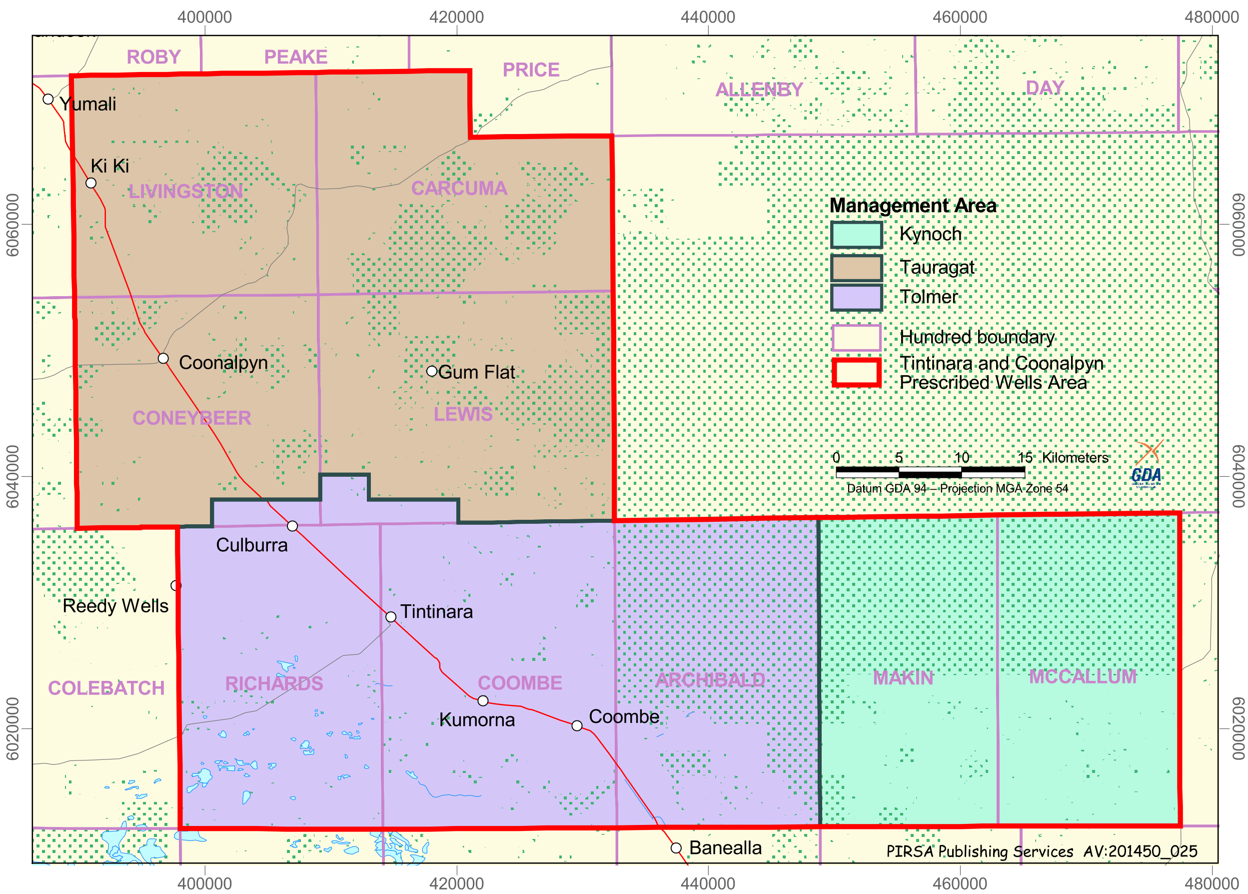


Figure 11 Management areas for the Tintinara–Coonalpyn Prescribed Wells Area – confined aquifer

- recharge rates averaging 50 mm/y.

The main management issue to be addressed is the rising watertable due to clearing, resulting in dryland salinity.

Sherwood MA — Eastern Mallee Highlands

This zone comprises the Hundreds of McCallum, Makin and the eastern part of Archibald and has the following characteristics:

- Murray Group Limestone Aquifer with the watertable 25–50 m below ground surface
- centre pivot irrigation of lucerne and vegetables with minor flood irrigation and drip-irrigated olives
- extensive shallow clay layer 5–10 m thick
- recharge rates averaging 15–20 mm/y
- watertable rise averaging 50 mm/y
- no salinity increase observed.

The main management issue to be addressed is the flushing of salt down from the unsaturated zone to the deep watertable after clearing, which is accelerated by irrigation (only beneath the actual areas irrigated, depending on irrigation efficiencies).

Coonalpyn MA — Northern Mallee Highlands

This zone comprises the Hundreds of Carcuma, Conybeer, Lewis and the northeastern part of Coombe and has the following characteristics:

- Murray Group Limestone Aquifer with the watertable 15–60 m below ground surface
- centre pivot irrigation of lucerne
- no extensive shallow clay layer
- recharge rates over 30 mm/y
- watertable rise averaging 100–300 mm/y
- salinity rises due to clearing averaging 10–25 mg/L/y.

The main management issue to be addressed is the flushing of salt down to the deep watertable after clearing, which is accelerated by irrigation (only beneath the actual areas irrigated, depending on irrigation efficiencies).

CONFINED AQUIFER

Although different management issues apply to the confined aquifer, namely the impact of drawdowns resulting from extractions, the same management zones can be broadly applied with minor boundary changes (Fig. 11).

Tolmer MA — Coastal Pain

The confined aquifer is the only water supply to the west of Tintinara. The low topography has resulted in:

- the confined aquifer being artesian on the interdunal flats where flowing bores have been used for stock and domestic supplies
- centre pivot irrigation of lucerne being carried out over shallow rising saline watertable.

Management issues to be addressed include:

- drawdowns of several metres due to irrigation, which have caused some bores to stop flowing
- shallow saline watertable, causing corrosion of uncemented steel casing resulting in localised contamination of supplies.

Sherwood MA — Eastern Mallee Highlands

There are currently no extractions from the confined aquifer in this zone. Because of the impending salinisation of the overlying unconfined aquifer, it is proposed to reserve the confined aquifer for future stock and domestic use and not provide any allocations for irrigation use.

Tauragat MA — Northern Mallee Highlands

Extractions for large olive plantations dominate water use from the confined aquifer in this zone. Management issues to be addressed include the:

- impacts of regional drawdowns on other users and the possibility of drawing in more saline groundwater from the west
- possibility of excessive drawdowns in individual wellfields.

WATER DEMAND

Prior to the proclamation of the TCPWA, there was no formal mechanism for the provision of annual reports from water users that could be used to estimate the volume extracted from both aquifers. Table 1 shows the results of a phone survey in 1990–91 and land use surveys carried out in 1999 and 2000, within the management zones. These volumes are based on an application rate of 5 ML/ha for pivot irrigation of lucerne (which is supported by some metering information), and a recharge of 40–50% of pumped volumes back down to the aquifer from flood irrigation. In other words, Table 1 represents groundwater use by crops, not necessarily volumes pumped.

Table 1. Water demand in the TCPWA (ML/y)

Management area	Aquifer	1990–91	1998–99	1999–2000	2000–01	Stock
TINTINARA TOLMER	Unconfined	6 140	13 850	15 620	17 500	500
	Confined	1 210	1 790	2 160	2 260	350
SHERWOOD	Unconfined	1 700	2 750	3 850	4 050	350
	Confined					
COONALPYN TAURAGAT	Unconfined		1 500	2 500	3 100	150
	Confined		250	630	850	150
Total		**9 050**	**20 140**	**24 760**	**27 760**	**1 500**

The most dramatic increase in irrigation since 1990–91 occurred in the Tintinara MA, where extractions from the unconfined aquifer more than doubled. There was a further 25% increase in extractions from 1998–99 to 1999–2000 with the latter use representing about 70% of the authorised volumes. The Sherwood and Coonalpyn MAs have shown a steady increase in unconfined pumping.

Using a technique outlined in Cobb and Brown (2000), the estimated stock water use (using Australian Bureau of Statistics stock numbers for the 1996–97 season) is ~1500 ML/y (Table 1). The use of reticulated water for stock use in some areas was taken into account. There are no data on domestic groundwater use but the extensive use of rainwater tanks would suggest this component would be a small fraction of the overall water budget.

FUTURE DEMAND

It is expected that there will be increases in extraction demand brought about by irrigators wishing to develop the areas delineated in successful licence applications, over a specified development timetable.

There is also expected to be be an increase in demand for pumping from the confined aquifer over the next decade or so, as salinities rise in the overlying unconfined aquifer, especially in the Tintinara MA. If this were to be allowed, increases in irrigation efficiencies could occur as confined aquifer yields are generally too small to support flood irrigation. However, confined aquifer drawdowns could increase.

Future demands could also occur from new industries wishing to move into the region. The quantity and quality requirements of such industries cannot be predicted with certainty.

POTENTIAL IMPACTS OF USE

The potential detrimental impacts that taking, or using, water from the TCPWA may have on the quantity or quality of water of another resource and vice versa, were considered in the following situations:

- The impact of taking groundwater from both the unconfined and confined aquifers may have on each other.
- The impact of taking groundwater from both the unconfined and confined aquifers may have on adjacent water resources, prescribed or not.
- The impact of taking groundwater from adjacent water resources (prescribed or not), may have on the resources of the TCPWA.

The impacts on any aquifer due to pumping from the same aquifer will be covered later in discussions on sustainable yield estimates. As the effects of point source recharge to the unconfined aquifer are localised it is unlikely that there would be any impacts across water management boundaries.

There is the potential to contaminate the unconfined aquifer with nutrients including those ions or organic compounds containing nitrogen (NO_2^-, NO_3^-, NH_4^+) and phosphorus. These can come from fertilisers or sewage that may be collected by run-off and flows directly into the aquifer. This type of contamination can also occur through diffuse recharge processes so it would be difficult to pinpoint an individual source.

Impact of using the unconfined aquifer

CONFINED AQUIFER

The aquitard that separates the unconfined and confined aquifers in the TCPWA is generally more than 20 m thick and has a very low vertical permeability. Where the head in the unconfined is higher than the head in the confined aquifer (Sherwood MA), the low permeability would inhibit downward leakage to the confined aquifer. It is therefore unlikely that any use in the unconfined aquifer would directly affect the confined aquifer.

ADJACENT WATER RESOURCES

Because the groundwater is saline in the western part of the PWA, there are no extractions and hence no impacts on resources to the west of the TCPWA. To the north, there are large areas of uncleared native vegetation and therefore any impacts are inconsequential in these areas.

There may be small drawdown impacts on adjacent resources if extractions are concentrated close to TCPWA boundaries to the south and the east (Tatiara PWA). This also applies to the northeast boundary of the Hundred of Carcuma.

Because of the east–west groundwater movement, there will be no salinity impacts on adjacent resources due to extractions in the TCPWA.

Impact of using the confined aquifer

UNCONFINED AQUIFER

For the same reasons as outlined above the low permeability aquitard would make it most unlikely that extraction from the confined aquifer would directly impact on the unconfined aquifer.

However, if groundwater were to be taken from the confined aquifer in the Sherwood and Tauragat MAs, it could have an indirect effect by accelerating the flushing of the unsaturated zone salt down to the watertable and increasing the salinity of the unconfined aquifer. Olive irrigation in Tauragat MA is the only current scenario where this may occur and here, the unconfined aquifer may be too saline for irrigation use.

ADJACENT WATER RESOURCES

Just like the unconfined aquifer, there will be no impacts to the west of the TCPWA due to the high salinity in the confined aquifer. There will be no impact to the east (and north of Sherwood MA) due to there being no extractions from the confined aquifer in Sherwood MA.

There may be drawdown impacts to the south (Tatiara PWA) but they will be inconsequential because there are no extractions from the confined aquifer in this PWA. Olive irrigation in Coonalpyn MA may cause drawdowns to the north in the Hundred of Peake, which is not in any PWA but also has several small irrigated olive developments.

Impact of using adjacent water resources

UNCONFINED AQUIFER

There may be drawdown impacts if extractions in the Tatiara PWA are concentrated close to TCPWA boundaries to the south and the east. Although water level monitoring has shown very little (if any) drawdown in Sherwood MA due to pumping, either from within the zone or from the adjacent Hundred of Shaugh (Tatiara PWA), a small decrease in lateral inflows from the east would be expected.

A similar situation applies to the east of the northeast boundary of the Hundred of Carcuma, where several irrigation bores are located just to the south of the Mallee PWA. The drawdown impacts are not likely to be excessive.

CONFINED AQUIFER

The only area where extractions from the confined aquifer may impact on the TCPWA is in the Hundred of Peake. This area is outside any PWA and is also outside the SECWMB area. Although current extraction levels are unlikely to have any impact, there are currently no restrictions on any further development. A monitoring network has been established in the area to detect any impacts from such development.

WATER BALANCE

A water balance has been determined for the unconfined aquifer in each zone in the TCPWA. The figures are based on recharge values obtained by CSIRO (Leaney, 2000) and groundwater modelling undertaken by DWLBC. Current groundwater use (1999–2000) and future use after 25 years (if all applications were approved), are based on some metered extractions, preliminary PIRSA estimates of crop water requirements; an application rate of 5 ML/ha for pivot irrigation of lucerne and a recharge of 40–50% of pumped volumes back down to the aquifer from flood irrigation. Table 2 displays these values that represent the net inflows and outflows from the aquifer and not necessarily actual volumes pumped.

Table 2. Water balance for unconfined aquifer in the TCPWA (ML/y)

	Tintinara MA		**Sherwood MA**		**Coonalpyn MA**	
	Current use	*After 25 y*	*Current use*	*After 25 y*	*Current use*	*After 25 y*
Inputs						
Groundwater inflow	6 530	6 230	4 170	4 610	14 100	14 100
Rainfall recharge	20 170	20 170	7 150	7 150	19 500	19 500
Total	26 700	26 400	11 320	11 760	33 600	33 600
Outputs						
Groundwater outflow	6 630	7 310	6 545	7 310	15 100	15 100
Groundwater use	14 970	19 310	3 895	7 770	3 130	7 200
Total	21 600	26 620	10 440	15 080	18 230	22 300
Balance	+5 100	–220	+ 880	–3 320	+15 370	+11 300
Storage	4 000 000		5 000 000		13 000 000	

The water budget calculations of groundwater inflows and outflows from the groundwater model should be considered order of magnitude estimates only to within +/-30%. There is agreement between those management areas with a positive balance and the trend of rising watertables due to clearing. It should also be noted that the volumes of groundwater in storage are several orders of magnitude greater than volumes of pumping, recharge or lateral throughflow. This means the groundwater resource is very robust with the large storage acting as a buffer against short-term fluctuations in recharge and pumping. For example, if there was no more recharge into Sherwood MA from any source, the resource could sustain current extractions for 500 years.

A water balance for the confined aquifer was not prepared because there is no vertical recharge from rainfall and lateral inflows will always balance extractions due to pumping. As pumping rates increase, the cone of drawdown also increases in size which then induces greater lateral inflows over time.

SUSTAINABLE YIELD

Definition

The *State Water Plan 2000* accepts the definition of sustainable yield as proposed by the National Groundwater Committee of Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), namely that the sustainable yield is:

> *the groundwater extraction regime, measured over a specified planning timeframe, that allows acceptable levels of stress and protects the higher value uses associated with the total resource.*

The State Water Plan also states that the time frame must take into account delayed ecological impacts and that the sustainable yield may not necessarily be a fixed annual volume. A precautionary approach must be taken with lower sustainable yields in areas with little information and in areas of high use.

The higher value uses may be agriculture, ecosystems, infrastructure, industry or other activities that are to some extent dependent on groundwater, and which the community reasonably expects will be maintained or developed for a defined period. The task of determining and ranking the value of potential uses or demands for any aquifer is likely to be a subjective process that will require a combination of community input and expert opinion (Evans et al., 1998).

The following case studies show that there is no one method of determining sustainable yield that can be applied in all situations.

MOUNT LOFTY RANGES

The Mount Lofty Ranges are underlain by hard basement rocks. Groundwater is stored and moves through joints and fractures in these rocks (as opposed to the pore spaces in the sediments in the TCPWA). Recharge to these aquifers occurs directly from rainfall that percolates down through the soil profile. Groundwater moves from the higher points in the landscape to the lowest where discharge occurs to the streams as an ‘overflow’ from the aquifers. Intensive groundwater pumping for irrigation or industry, may reduce groundwater discharge to the streams and hence may reduce streamflow with a resultant degradation in their environmental value.

If the sustainable yield was based on the average annual recharge and pumping was allowed to increase to this level, there would no ‘overflow’ to discharge to the streams to maintain ecosystems. Because of the lack of information on the environmental requirements, precautionary estimates of sustainable yields for catchments in the Mount Lofty Ranges have been made based on only 75% of the average annual recharge (Barnett and Zulfic, 1999).

MALLEE PWA

This area is currently managed using a controlled depletion or ‘mining’ policy that allows aquifer storage to be accessed as well as recharge as part of a sustainable yield volume. In a strict aquifer water balance sense, this practice is not sustainable, however, much depends on the planning timeframe chosen. In the Mallee PWA, the annual inflows total ~8000 ML, yet the PAV is 53 000 ML (current use is ~20 000 ML).

This can be justified because the Murray Group Limestone Aquifer (the same as in Sherwood MA of the TCPWA), averages over 100 m in thickness and contains ~100 million ML in storage. If the extractions were to increase up to the PAV, the resource would only be depleted by 15% after 300 years (Barnett and McKee, 1999).

Sustainability issues

The issues that must be considered in determining the sustainable yield for each aquifer will be discussed on the basis of the proposed management zones. The processes impacting on the groundwater resources will also be examined, together with a proposed management response. A summary appears in Appendix A.

As mentioned previously, the large volumes of groundwater in storage result in a very robust resource. Consequently, an aquifer response management approach is recommended which can be flexible and based on trends observed over several years. Any adverse impacts due to pumping will take years to manifest themselves. In this situation, the sustainability of the resource can be determined initially by monitoring the actual performance of the aquifers under pumping stress, rather than relying only on theoretical estimates. Modelling predictions will become more accurate as more accurate pumping data and extensive monitoring data becomes available.

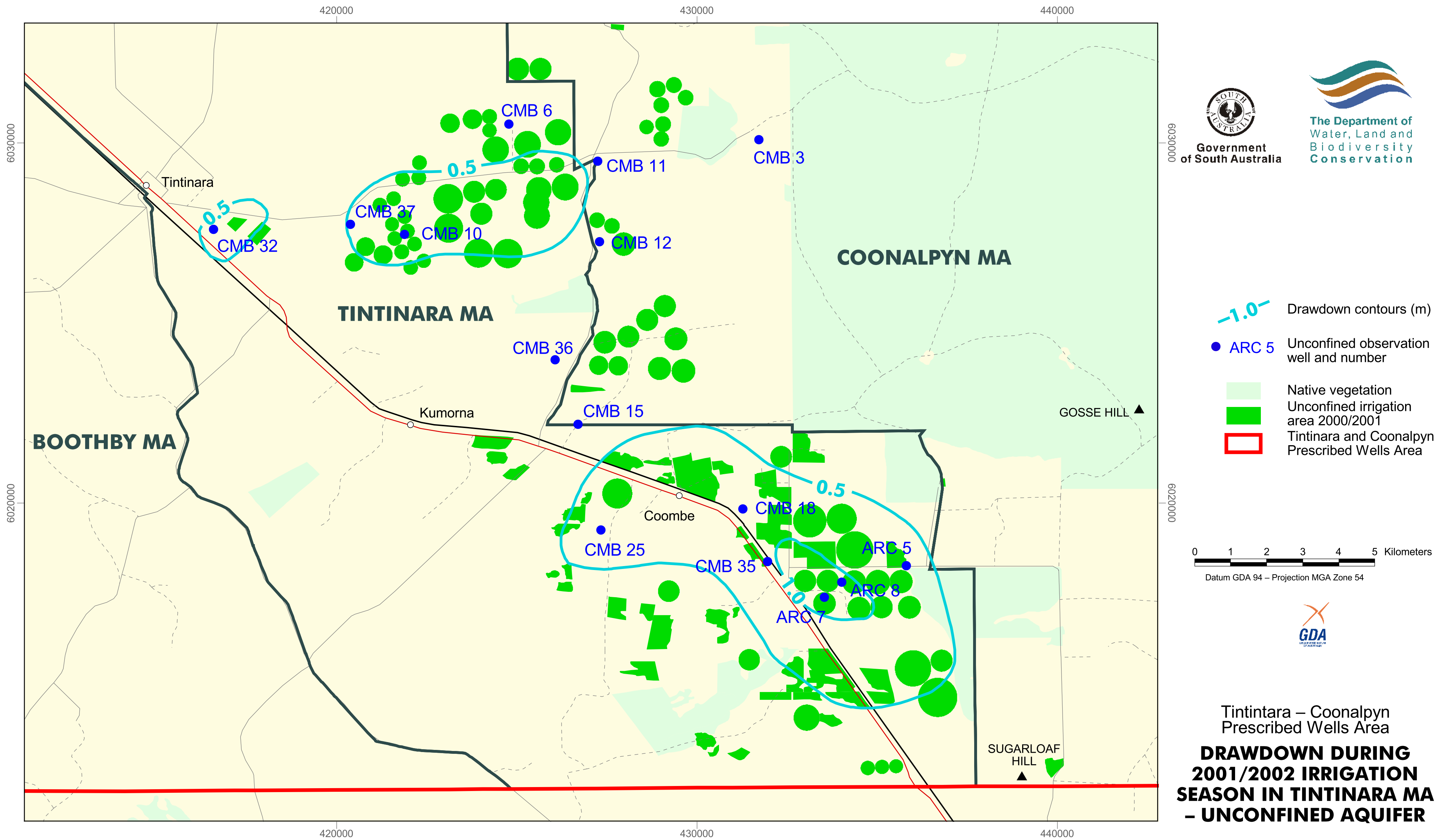
UNCONFINED AQUIFER

Tintinara MA — Coastal Pain

The main issue is the potential for salinity increases due to the recycling of irrigation water. About 50% of the sampled irrigation bores are showing a rising trend with the highest trends associated with flood irrigation. Because of the very permeable nature of the Quaternary limestone aquifer, drawdowns are quite small for the amount of groundwater extracted (Fig. 12).

Another issue is the rising watertable due to clearing resulting in the eastward expansion of dryland salinity from the west of Tintinara. This will render increasing areas of land unsuitable for agriculture and will increase the groundwater salinity where the watertable rises to within about 2 m of the ground surface.

Figure 13 shows the more detailed salinity distribution on the Coastal Plain using the observed salinities from irrigation bores. Several ‘hotspots’ of elevated salinity can be observed beneath areas of flood irrigation. By extrapolating the observed trend of increasing salinity in irrigation bores, the projected salinity distribution in the year 2025 was calculated and presented in Figure 14. Together with an increase in the area affected by dryland salinity, a significant increase in the area above 3000 mg/L is predicted, with the ‘hotspots’ increasing to over 8000 mg/L.



Tintintara – Coonalpyn Prescribed Wells Area

DRAWDOWN DURING 2001/2002 IRRIGATION SEASON IN TINTINARA MA – UNCONFINED AQUIFER

Figure 12

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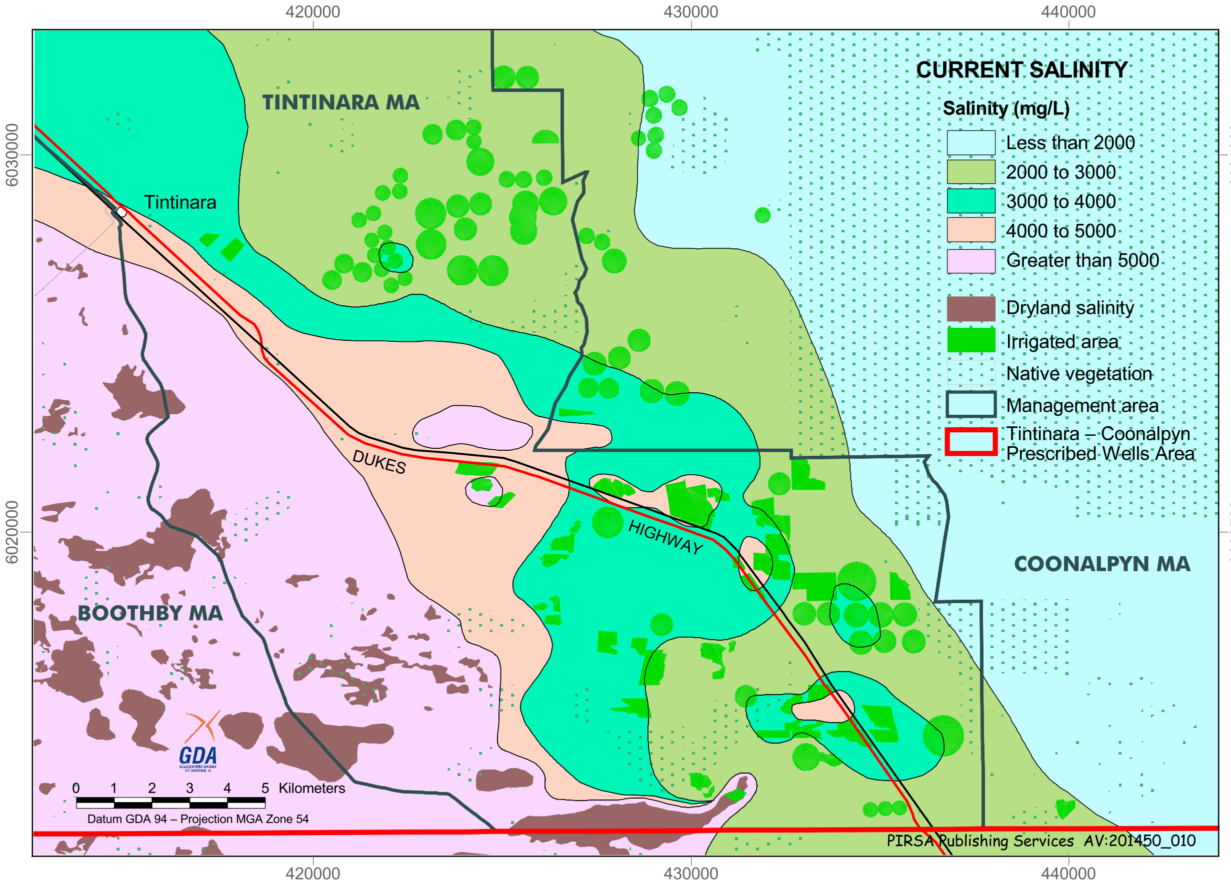

Figure 13 Current salinity distibution in Tintinara MA – unconfined aquifer

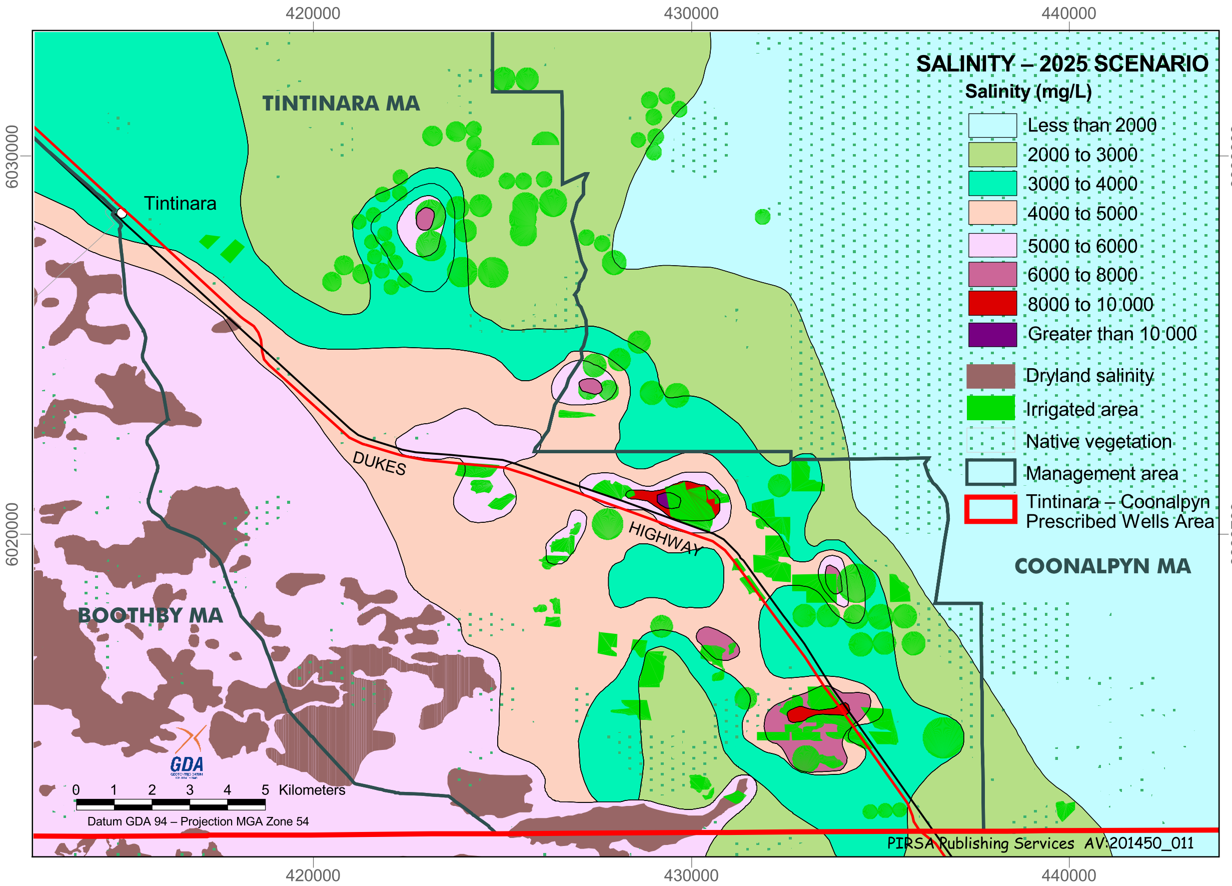

Figure 14 Extrapolated salinity distribution for 2025 in Tintinara MA – unconfined aquifer

Management response

Because salinity increases are the main issue and not drawdowns, a sustainable yield based on recharge would not control salinity and would not be appropriate. Instead, a buffer zone around existing irrigation developments is recommended to allow better throughflow of groundwater by minimising drawdown, and to allow some dilution of groundwater by recharge and dispersion. This buffer will protect new developments from the impacts of existing irrigation, as well as protecting existing development from the impacts of new irrigation.

Figure 15 shows buffer zones of both 1 and 2 km around existing irrigation areas that could apply to all new licences or transfers. It can be seen that these zones cover almost all the area under 4000 mg/L and if applied, would act as a virtual cap on further development. A precautionary approach would suggest an initial buffer of 2 km with a potential reduction to 1 km if warranted. This buffer should be applied after all eligible areas for licence allocation are approved (which would result in an increase in irrigated area of only 10–15%).

An investigation into groundwater dependent ecosystems (URS, 2001) found that rising watertables due to clearing were a threat to native vegetation. Because of this risk, any drawdowns resulting from irrigation would be of benefit, provided they were not excessive (say, greater than 10 m). This scenario also supports the buffer approach rather than restricting pumping volumes.

If required, a PAV for the area of irrigation quality below 8000 mg/L could be derived by totalling the volumetric allocations for the eligible areas within the buffer zone (~33 000 ML), and adding a nominal figure for possible development outside the buffer zone (~5000 ML). This would make a total PAV of 38 000 ML.

Establishing a rigid upper salinity limit allowable for irrigation (e.g. 5000 mg/L) would introduce an arbitrary control. It also requires management intervention to enforce cessation of irrigation if the limit is exceeded, which could raise difficult issues. Studies have shown that in the Hundred of Stirling, lucerne seed and dry matter crop yields only decrease when the salinity of irrigation water exceeds 7000 mg/L (DENR, 1997). It could be argued that the highest value use of 5000 mg/L groundwater is flood irrigation of lucerne. It is also the last opportunity to use this groundwater before it flows westward at a rate of 10–15 m/d and is salinised in areas where the watertable is shallow.

A similar argument can be raised against the use of salinity trigger levels in this case. A trigger level, which again would be an arbitrary one, implies a follow up action. If this action is a review of trends, the five yearly review of the Water Allocation Plan would be quite sufficient because at least five years of sampling is required before any trends become evident. If there were to be any sudden and unforseen impacts on the groundwater resource, Section 37 of the Water Resources Act allows the Minister to reduce water allocations before the Water Allocation Plan timeframe elapses.

Regular and extensive salinity monitoring (which could be funded by levies), together with incentives to phase out flood irrigation should be coincident with the buffer zone approach. Over the next five years, the monitoring results and salinity modelling of salt balances may enable more refined management strategies to be recommended in the next Water Allocation Plan.

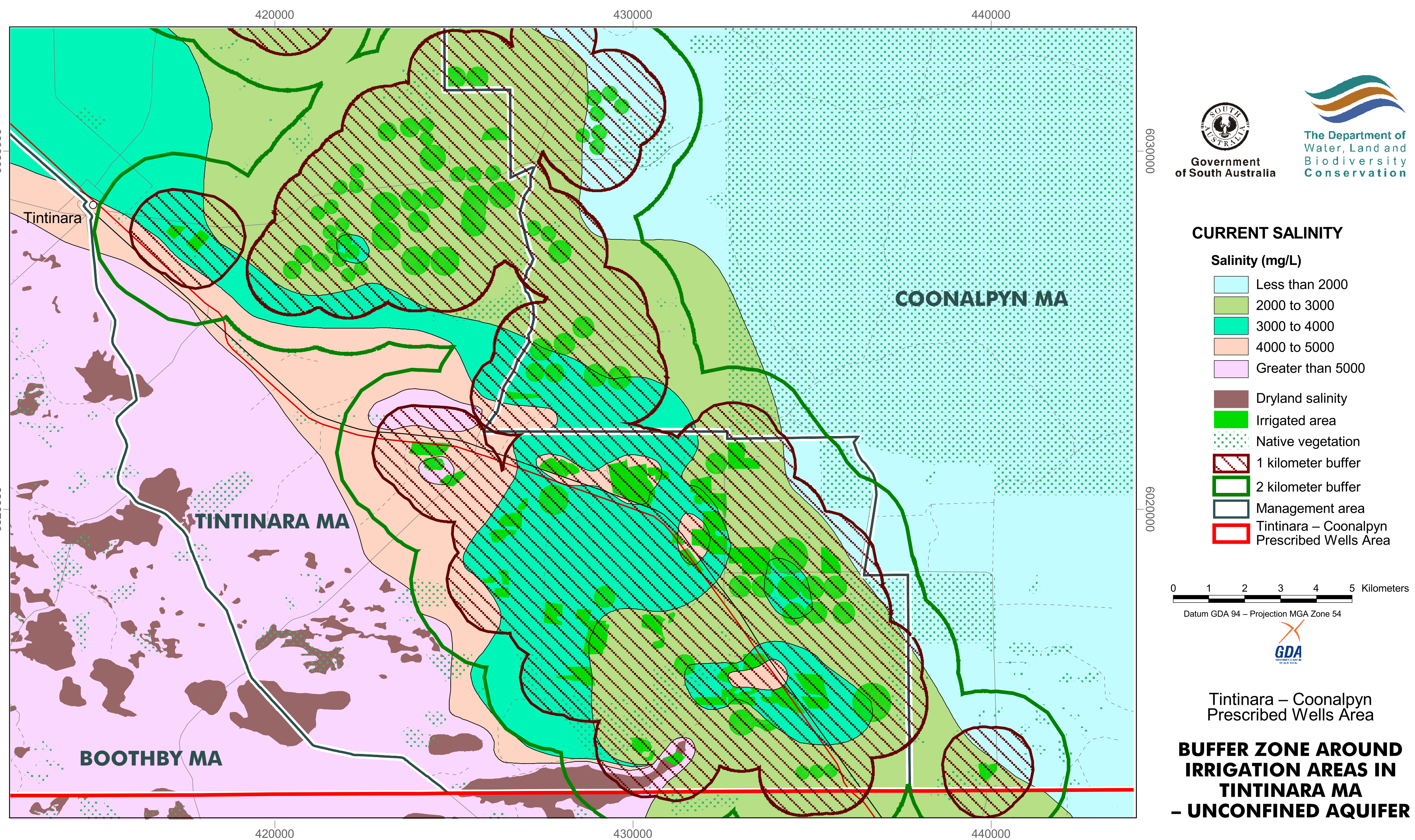

Figure 15

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There may be a concern that the resource would be no longer useable for stock purposes in some areas as a result of irrigation-induced salinity increases. However, the underlying confined aquifer contains low salinity groundwater and can be used for stock and domestic purposes (as it has been already).

Boothby MA — Coastal Pain

In order not to inhibit the development of saline groundwater over 8000 mg/L for innovative purposes in the future, (e.g. aquaculture, mineral production etc.), the Boothby MA is proposed to have a PAV nominally based on recharge of 20 000 ML with no buffer zone requirement.

Sherwood MA — Eastern Mallee Highlands

The main issue is the flushing of salt down to the deep watertable after clearing, which is accelerated by irrigation (only beneath irrigated areas). This means that irrigation and domestic use are at risk regardless of whether irrigation occurs or not. Figure 16 shows the current salinity distribution for the limestone aquifer, while Figure 17 depicts the projected salinity increases for 2050 based on CSIRO estimates of salt flushing time frames. It is obvious that these increases will render the aquifer unusable for domestic and irrigation purposes in the future. Because the limestone aquifer is unconfined and very permeable, drawdowns due to extractions are expected to be minimal and quite manageable.

Management response

Monitoring has so far shown virtually no impact on the resource from the current level of extraction that is estimated at almost 4000 ML/y for development of about 70% of the areas eligible for licence allocation. The maximum seasonal drawdown observed is only 0.5 m near the centre of concentrated pumping in the centre of Sherwood MA (Fig. 18). This however, is only based on the two year monitoring period so far. Further concentration of pumping is undesirable, not only from a drawdown perspective, but also to prevent long-term salinity impacts due to flushing of unsaturated zone salt.

Again, a 2 km buffer zone around the existing and eligible areas is recommended as shown in Figure 19. This will protect existing and future users and will prolong the life of the resource for irrigation. Because of the robustness of the resource, there is no urgency to determine a volumetric PAV at this stage, and to manage according to the aquifer response to pumping. A PAV could then be established by summing up all the volumetric allocations of the approved licences (~11 000 ML), and adding another 5000 ML which would be available based on area outside the buffer zones. Further development may occur within this area in the future, if evaluation of the monitoring programs shows no adverse impacts.

Coonalpyn MA — Northern Mallee Highlands

The same issue applies as in Sherwood MA, i.e. the increase in salinity due to clearing which will occur even if irrigation is not carried out. The difference in Coonalpyn MA is that irrigation using the confined aquifer can still cause flushing of salt down to the unconfined aquifer beneath irrigated areas (depending on the irrigation efficiency). These areas are insignificant compared to the total area of the zone. Figures 20 and 21 show the current salinity distribution for the limestone aquifer as well as the projected increases for 2050.

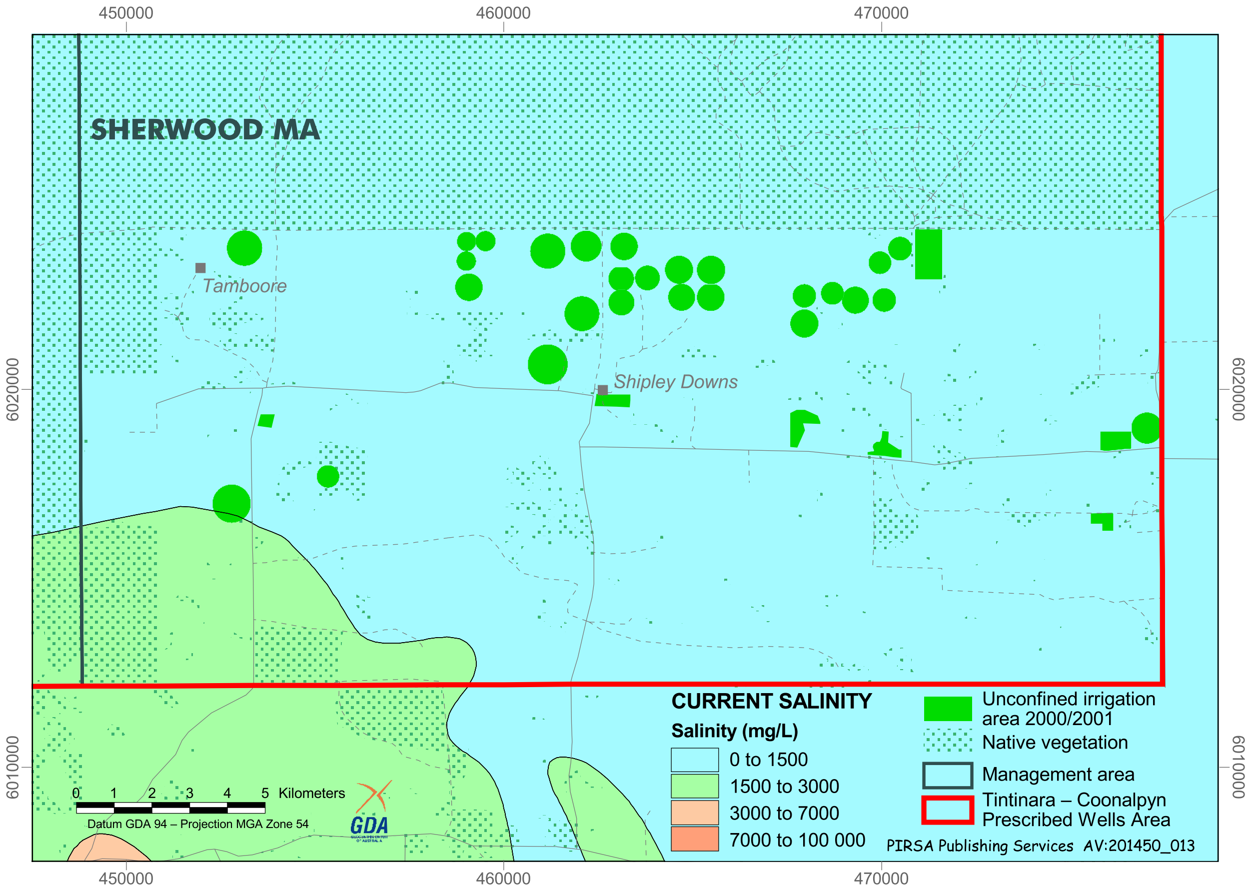

Figure 16 Current salinity distibution in Sherwood MA – unconfined aquifer

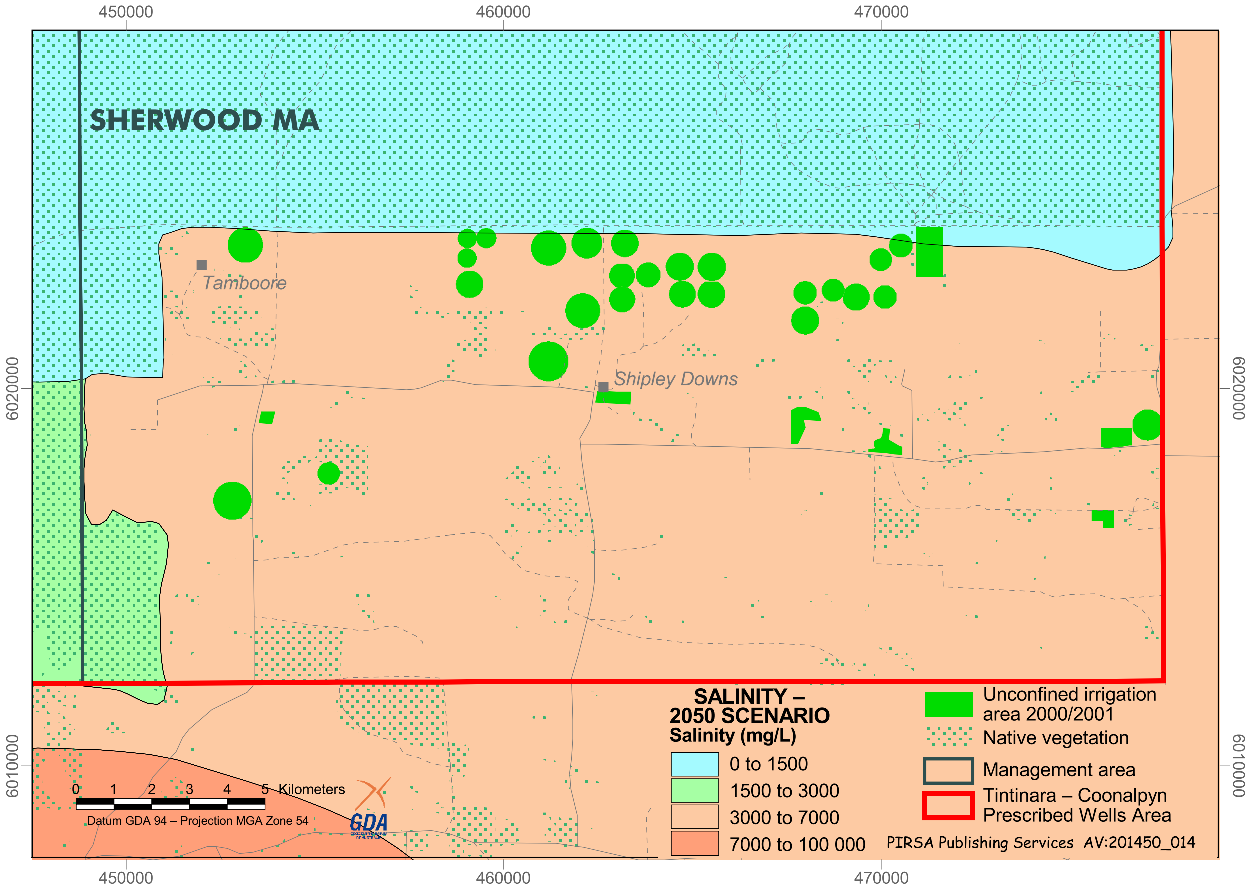

Figure 17 Extrapolated salinity distribution for 2050 in Sherwood MA – unconfined aquifer

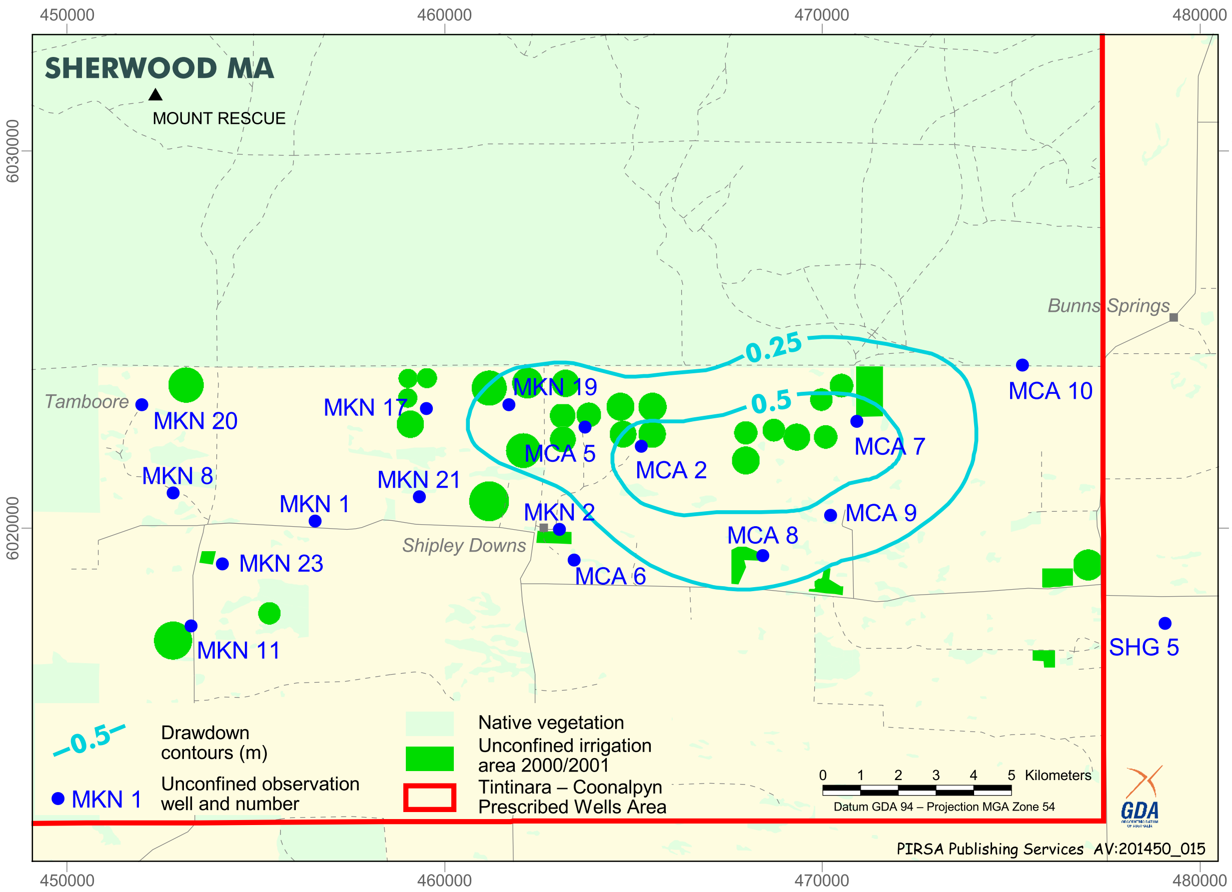

Figure 18 Drawdown during the 2001/2002 irrigation season in Sherwood MA – unconfined aquifer

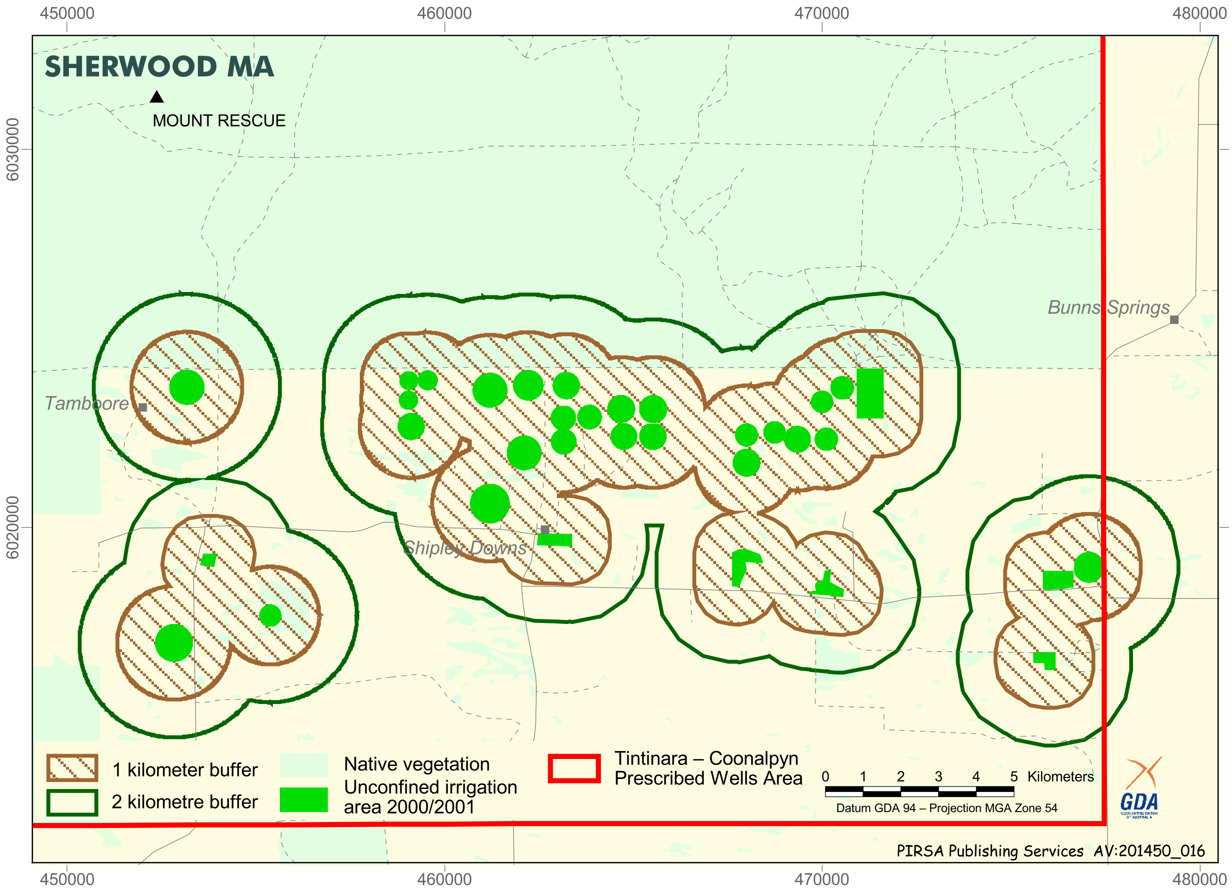

Figure 19 Buffer zones around irrigation in Sherwood MA – unconfined aquifer

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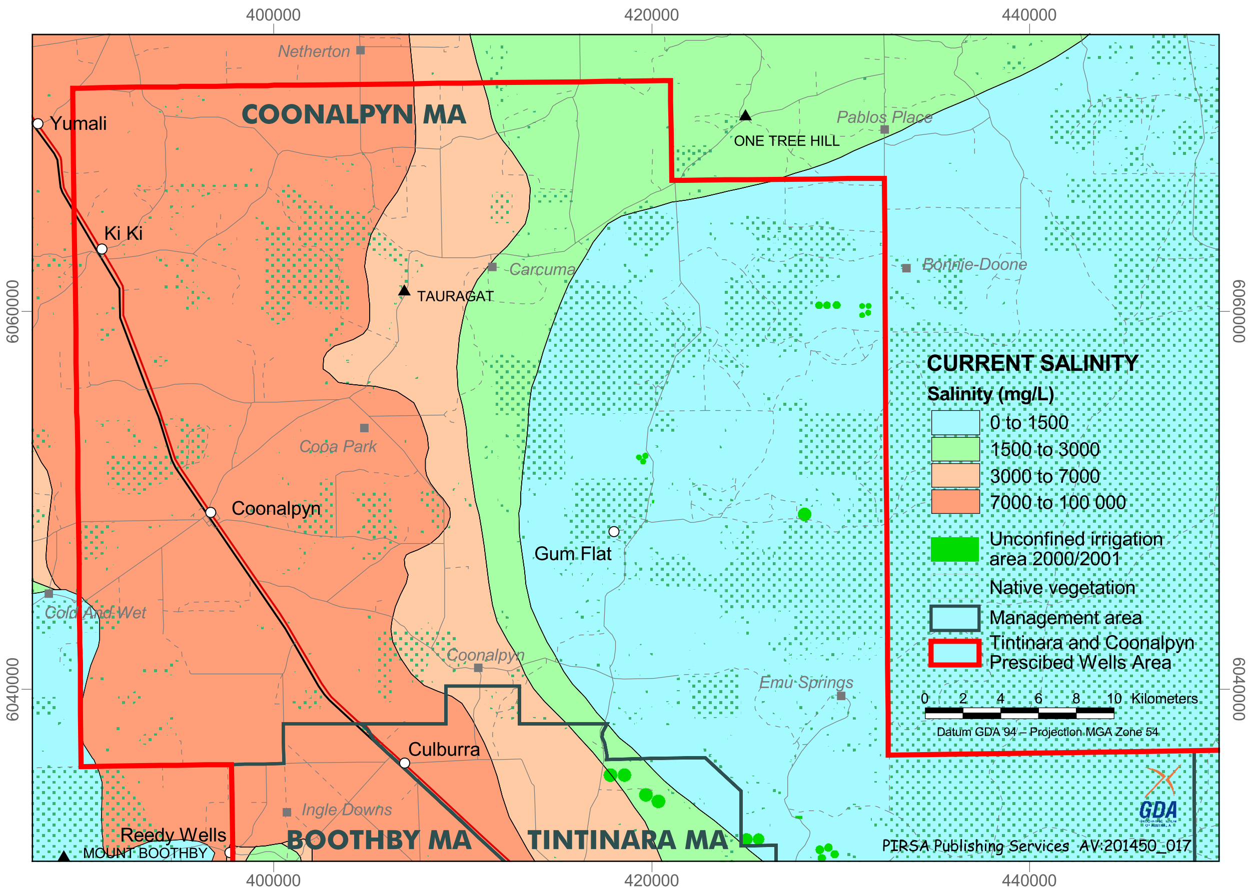

Figure 20 Current salinity distibution in Coonalpyn MA – unconfined aquifer

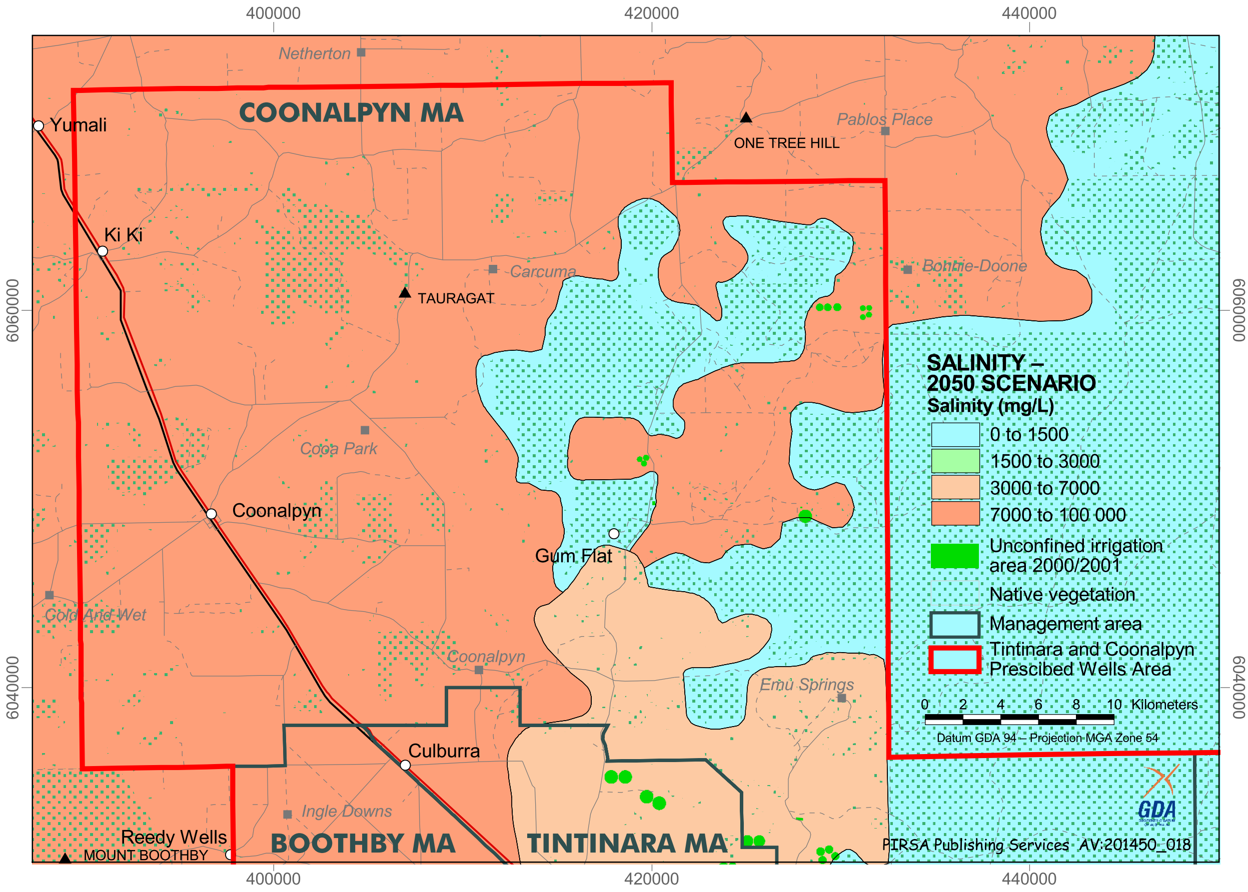

Figure 21 Extrapolated salinity distribution for 2050 in Coonalpyn MA – unconfined aquifer

Again as for Sherwood MA, these increases will render the aquifer unusable for domestic and irrigation purposes. Similarly, drawdowns are not expected to be an issue of concern due to the permeable nature of the aquifer.

Management response

A PAV based on an estimated recharge of 19 500 ML/y, as determined by groundwater modelling and CSIRO investigations, should be used with a 2 km buffer zone applied for future developments to minimise long-term salinity impacts.

CONFINED AQUIFER

Tolmer MA — Coastal Pain

In low lying areas to the west of Tintinara, the pressure level of the confined aquifer is normally a metre or so above ground level (i.e. artesian). However, the shallow limestone aquifer is saline in this area and corrodes the steel casing of older bores that are not pressure cemented. This can result in leakage of the shallow saline water into the bore casing and contamination of the artesian supply.

A sudden salinity increase in operational bores is the first sign of casing corrosion in a leaking well. Normally, the pressure level is higher than the saline watertable resulting in leakage of low salinity water out into the shallow saline aquifer. However drawdowns due to pumping from the bore itself or nearby irrigation will lower the pressure level to below the saline watertable, inducing saline flows into the bore. This process has raised several management issues.

Acceptable drawdowns

Drawdowns in a confined aquifer occur more quickly and are greater than drawdowns in an unconfined aquifer because they are a pressure response. In an unconfined aquifer, drawdowns only occur when water physically drains out of the sediments, which is a much slower process. While drawdowns are not undesirable in themselves and are a natural response to pumping, it is the consequences of drawdown that may have impacts on sustainability depending on local conditions.

The are two consequences in this area – induced downward leakage from the unconfined aquifer and reversal of groundwater flow in the confined aquifer which would move more saline groundwater into the area from the west. Drawdowns due to irrigation for the 2001–02 season are shown in Figure 22, and range up to 6–8 m. These drawdowns are not large compared with those in confined aquifers in other PWAs, (e.g. 15 m in the Mallee, 50 m in the Northern Adelaide Plains), and represent the response to developing about 75% of the total area fulfilling the licence application criteria. In other words, drawdowns are not likely to be much greater than they are now if full development occurred.

Figure 23 shows the groundwater flow direction in the confined aquifer at the same time as the drawdown in Figure 22 occurred. It shows the east–west movement of groundwater predominates, even at times of peak drawdown. More importantly, the area where reversal of flow occurred is restricted to a small zone extending 5 km west from Tintinara. Therefore the likelihood of flow reversal bringing in saline groundwater from the western margins of the PWA is virtually nil, even at full development of eligible licence

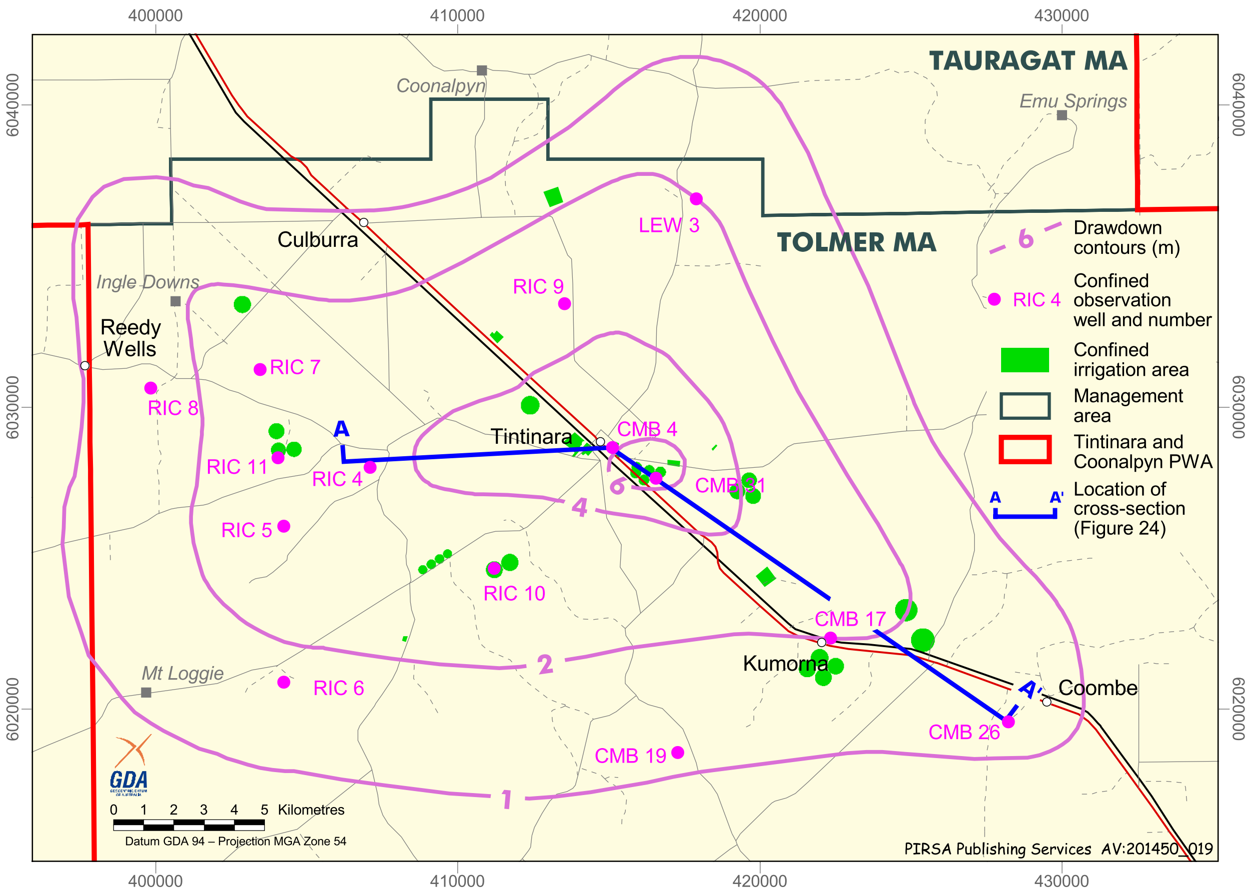

Figure 22 Drawdown during the 2001/2002 irrigation season in Tolmer MA – confined aquifer

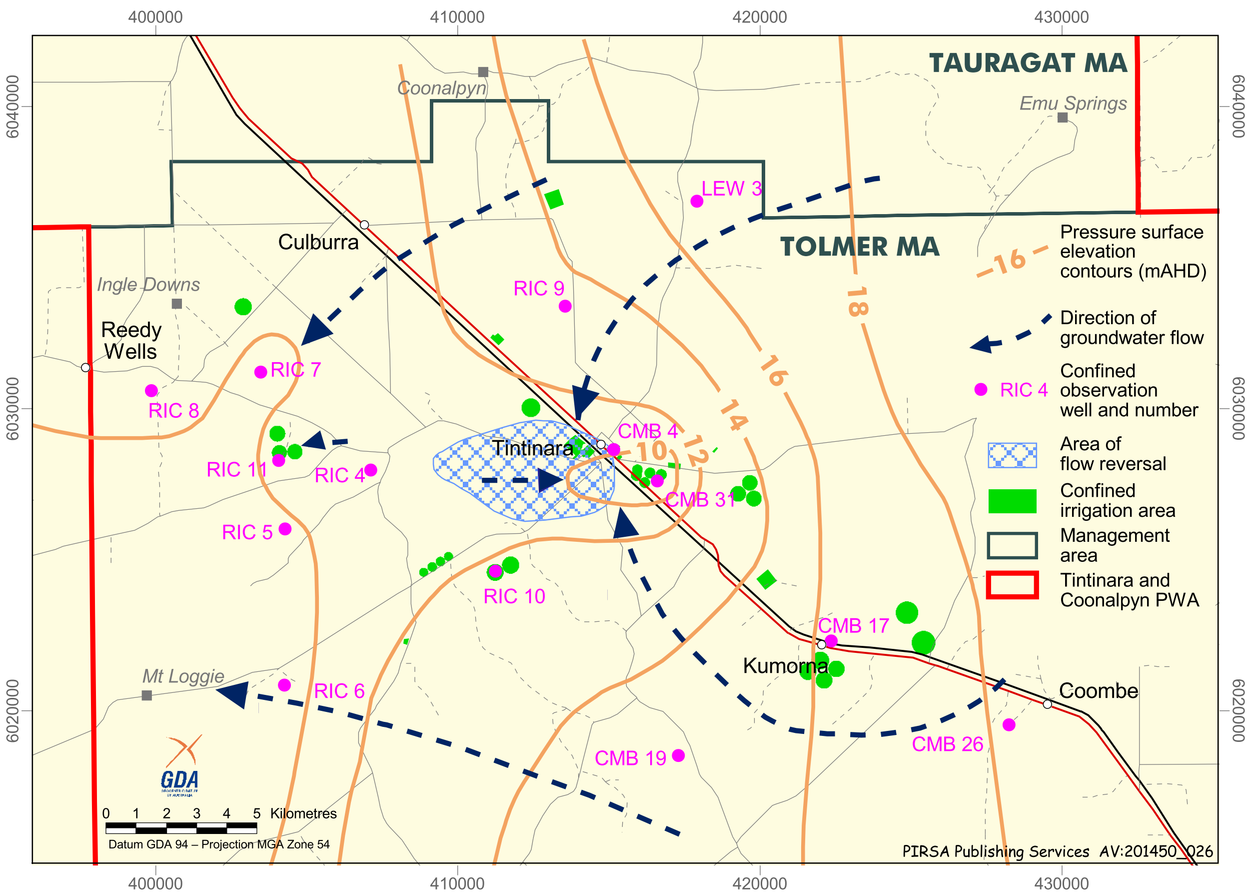

Figure 23 Groundwater flow during the 2001/2002 irrigation season in Tolmer MA – confined aquifer

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applications. A cross-section through the drawdown cone is displayed in Figure 24 and shows the potentiometric surface elevation at various times of the year.

A groundwater modelling exercise tested various pumping scenarios and predicted the impacts of the drawdowns produced. Generally, modelled regional drawdowns are considered a ‘worst case’ scenario due to simplifying assumptions made when constructing the groundwater model, i.e. the confined aquifer is uniform in its properties and is of infinite areal extent. These conditions never exist in the real world with the confined aquifer being irregular in thickness and having varying degrees of connection between the permeable layers within it. This would result in the actual drawdown being much less than the model predictions.

Nevertheless, even with large modelled drawdowns of 30 m in the vicinity of Tintinara township during the irrigation season, groundwater at observation bore RIC 5 (Fig. 24), after 25 years pumping, would have reversed in flow direction and moved only 200 m to the east, with a consequent increase in salinity at RIC 4 of only 15 mg/L. Because the likely drawdowns at full development are going to be much less (~10 m maximum), the salinity impacts are going to be negligible, or even undetectable.

2 inch bores

Drawdowns have caused some of the artesian bores to stop flowing and normally, this would simply mean equipping the bore with a pump. However after corrosion of bore casing occurs, rather than abandoning and backfilling the affected bores and drilling a new one, some landholders chose the cheaper option to reline them by cementing smaller diameter (2 inch) PVC casing inside the corroded steel casing.

In some cases, this PVC casing is too small to enable pumps to be installed when the pressure level falls below ground level, causing water supply problems during the irrigation season. Levels return to artesian when irrigation pumping stops. In addition, there are several bores about 40–50 years old that were originally completed with 2 inch casing at the time of drilling.

The ARMCANZ has developed a national framework for improved groundwater management in Australia. One of the recommendations states that:

> *in preparing groundwater management plans, States should ensure that efficient utilisation of groundwater resources is not compromised by protection of existing users with inefficiently designed or constructed wells (particularly stock and domestic wells).*

It can be strongly argued that 2 inch bores fit into the ‘inefficient construction’ category because artesian conditions are required for them to operate successfully (in supplying small volumes up to 0.5 L/s for stock supplies). Therefore any development of the confined aquifer that results in a drawdown of only a metre or more (which would prevent these bores from flowing), would be prohibited indefinitely if the 2 inch bores were to continue to operate.

Leaking bores

A management issue arises for non-operational or abandoned bores that have not been backfilled, and could leak undetected for years. This could cause localised salinity increases in the confined aquifer and disadvantage future users if not managed. A recent survey failed to find any trace of about 20 confined aquifer wells in the >2 m drawdown

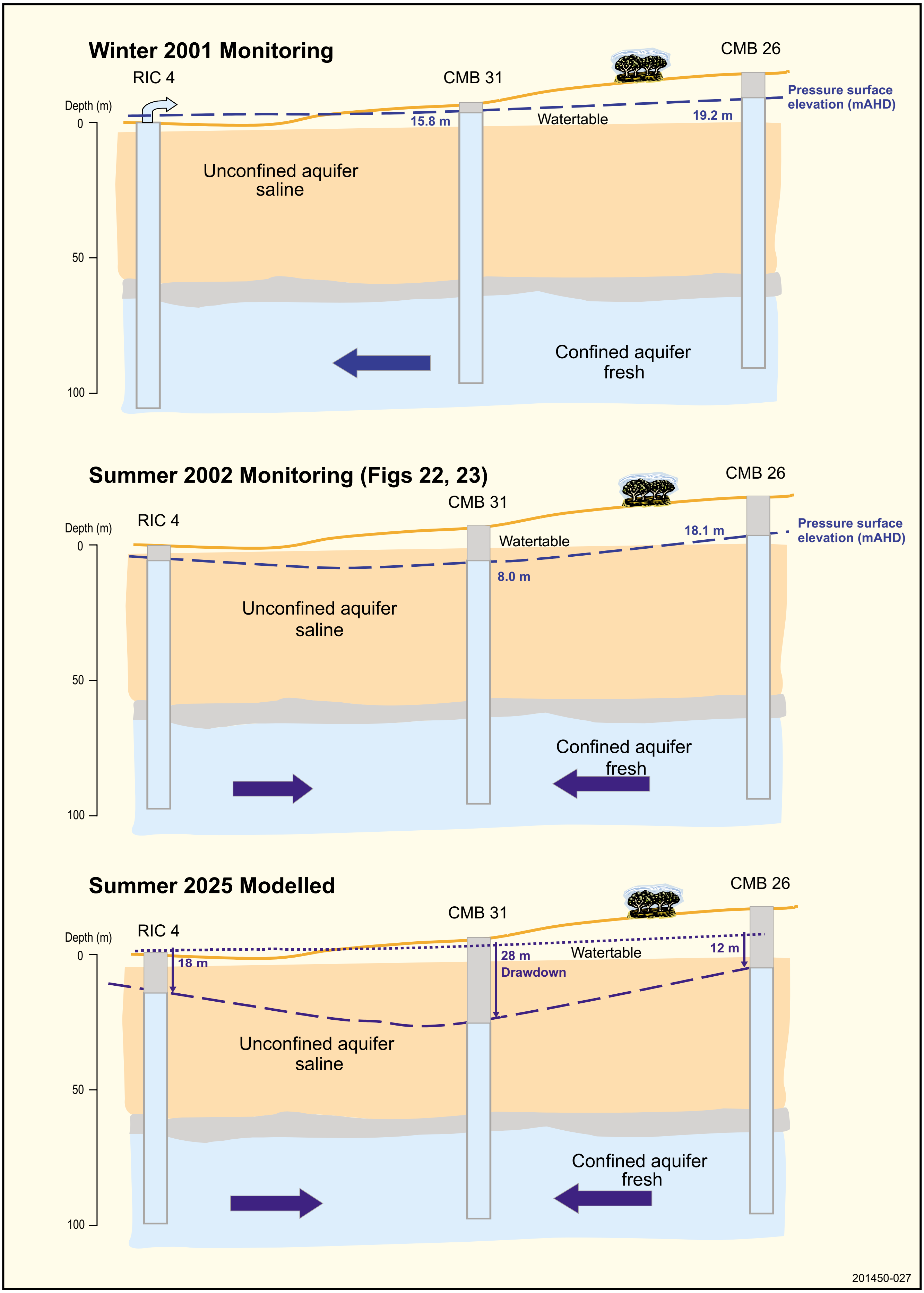

Figure 24 Cross-section of drawdown cone in Tolmer MA confined aquifer

zone that were drilled at least 40 years ago. If it is assumed that 10 of these bores were somehow still leaking at a rate of 0.1 L/s during the irrigation season, the total leakage would approximate only 10 ML/y which is very close to the modelled estimate of irrigation-induced leakage through the confining layer of 9 ML/y. In addition, the salinity of the unconfined aquifer in the area of maximum drawdown is generally below 5000 mg/L.

Management response

There is a complication in establishing a PAV for the confined aquifer in Tolmer MA because the constraint to development is not necessarily sustainability issues but community acceptance of drawdown impacts. A further difficulty is that whilst the drawdown impacts are being monitored, the volumes being pumped to cause those impacts are not known with certainty (due to the lack of metering so far). Although the areas irrigated are known, the requirement to issue volumetric licences needs negotiation with the 10 or so irrigators to establish approximate volumes pumped during the 2001–02 season. The drawdown impacts can then be tied to a known pumped volume. An interim volumetric allocation and PAV should be made on current areas irrigated. A staged approach to the further development and an increase in PAV (about a 25% increase if all eligible areas are to be irrigated) should then be attempted over several years to gain community acceptance provided drawdown impacts are not large.

Regular sampling of equipped stock and domestic bores within the area of drawdown is strongly recommended to detect any leakage at an early stage. It must be remembered that it is the landowner's responsibility to rehabilitate any leaky bores on their property. Any unequipped or abandoned holes should be sampled or geophysically logged to determine the condition of the casing.

Determination of actual volumes pumped over the next two years will enable the groundwater computer model to be calibrated more accurately against the observed drawdowns.

Kynoch MA — Eastern Mallee Highlands

Because there are no extractions, there are no sustainability issues worth considering. It is recommended that no allocations be made for the confined aquifer in this zone, and hence no PAV is required.

Tauragat MA — Northern Mallee Highlands

Three separate aquifers have been identified as being part of the confined aquifer in this management area as shown in Figure 25:

- the upper confined aquifer consisting of a coral limestone from the Buccleuch Group
- the middle confined aquifer comprising the first sand aquifer in the Renmark Group
- the lower confined aquifer of limited areal extent consisting of sands and gravels, also from the Renmark Group.

There are two aspects to sustainability of the confined aquifer groundwater resource in this area — regional and local.

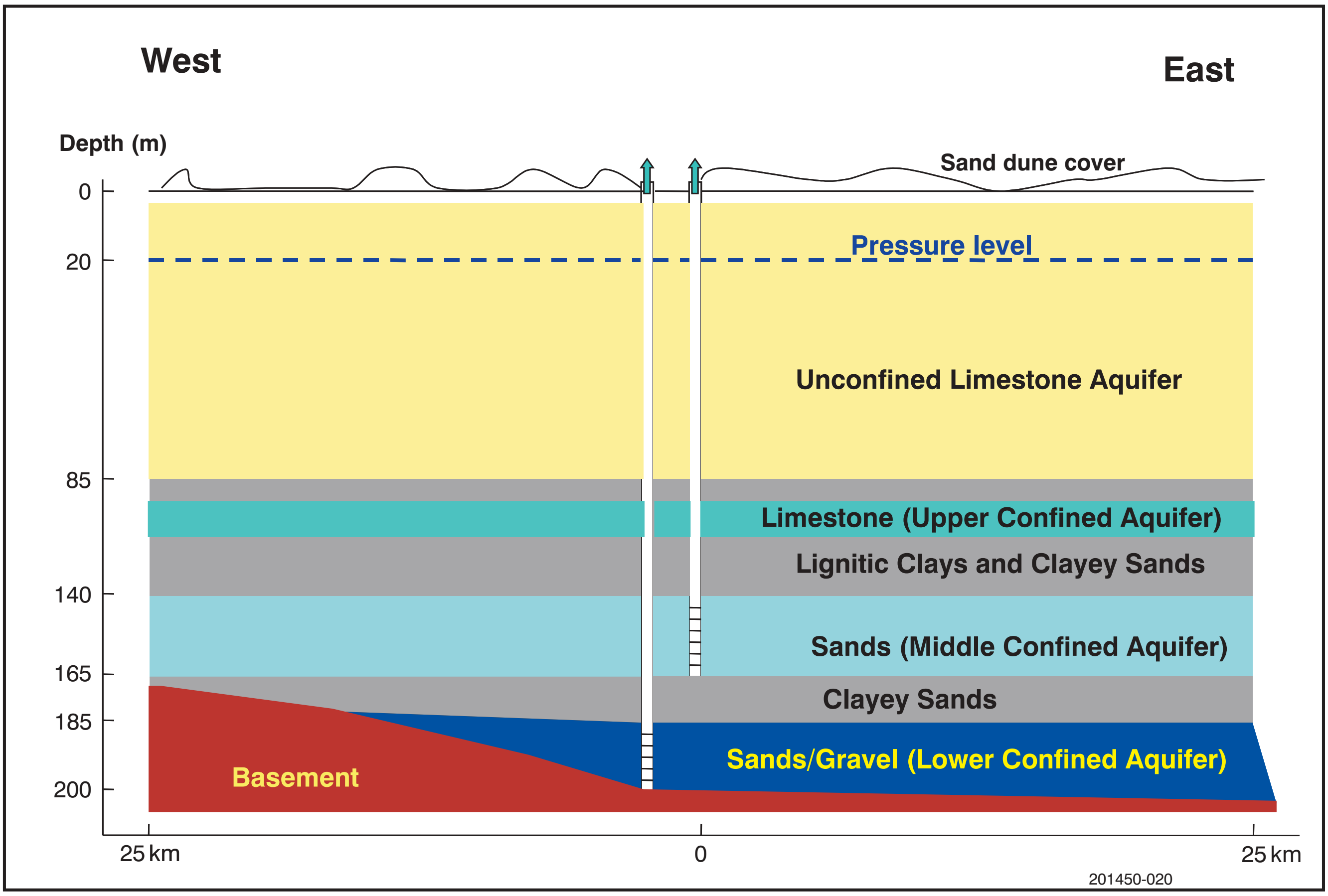

Figure 25 Cross-section of confined aquifers in Tauragat MA.

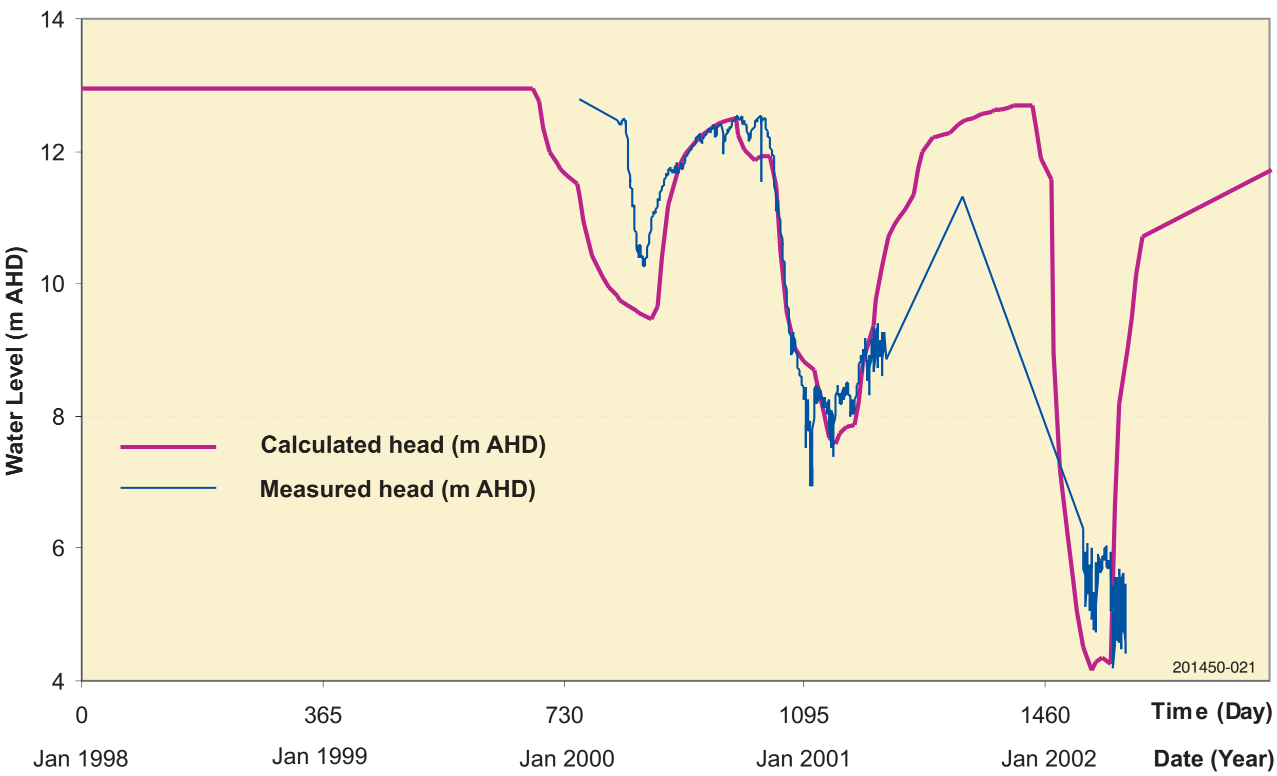

Figure 26 Model calibration in Tauragat MA middle confined aquifer

Regional sustainability

This issue is concerned with the capacity of the resource to meet the demands for irrigation over long periods without adverse impacts on groundwater levels and salinity. In a worst case scenario, groundwater with salinities over 3000 mg/L, which occur in the western part of the zone, could be drawn eastwards if any drawdowns are excessive, and adversely affect other users. However, the slow groundwater movement means that the drawdowns associated with concentrated pumping can be monitored and managed by controlling extractions before any increase in salinity occurs.

Almost all of the stock and domestic bores are completed in the coral layer of the Buccleuch Group which is not in direct connection with the sand aquifers of the Renmark Group which are being developed for olive irrigation.

Local sustainability

This concerns the capacity of the production bores to provide the yields required for irrigation, and is dependent on aquifer permeability and borehole construction. Excessive drawdowns where the pressure level drops below the top of the aquifer and possibly the sandscreen, will lead to high pumping costs, possible aquifer instability around the bore and corrosion due to aeration.

Management response

A groundwater model of the confined aquifer has been constructed for the Tauragat MA and has been calibrated using observed drawdowns in response to extractions that have been metered as shown in Figure 26 (Yan and Barnett, in prep.). The predicted seasonal drawdowns after 25 years pumping are presented in Figures 27 and 28. As mentioned previously for Tolmer MA modelling, the simplifying assumptions made when constructing the model lead to an overestimation of regional drawdowns. The limitations in the lateral extent and continuity of the confined aquifers will result in regional drawdowns being much less than model predictions. This is supported by the fact that at least six intended irrigation bores were abandoned because of the poor aquifers encountered.

Extractions totalling 11 000 ML/y result in sustainable drawdowns with suitable buffers between pumping water levels and the top of the aquifers. An conservative interim PAV of 11 000 ML/y is therefore recommended which would be made up of 4800 ML/y from the lower confined aquifer and 6200 ML/y from the middle confined aquifer.

Further water level monitoring and model calibration in areas to the west should be carried out before attempting to model any movement of more saline groundwater from the west.

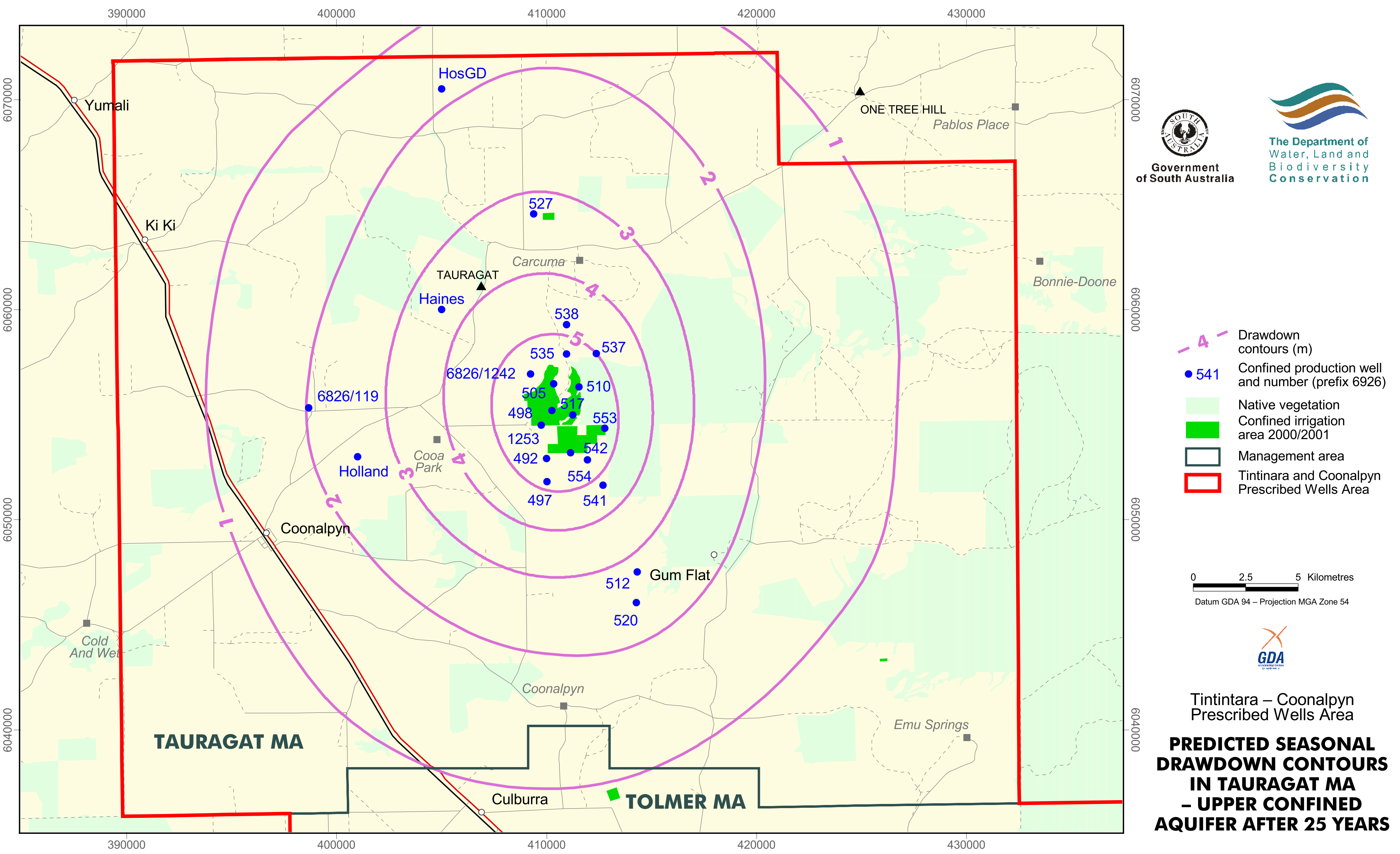

Figure 27

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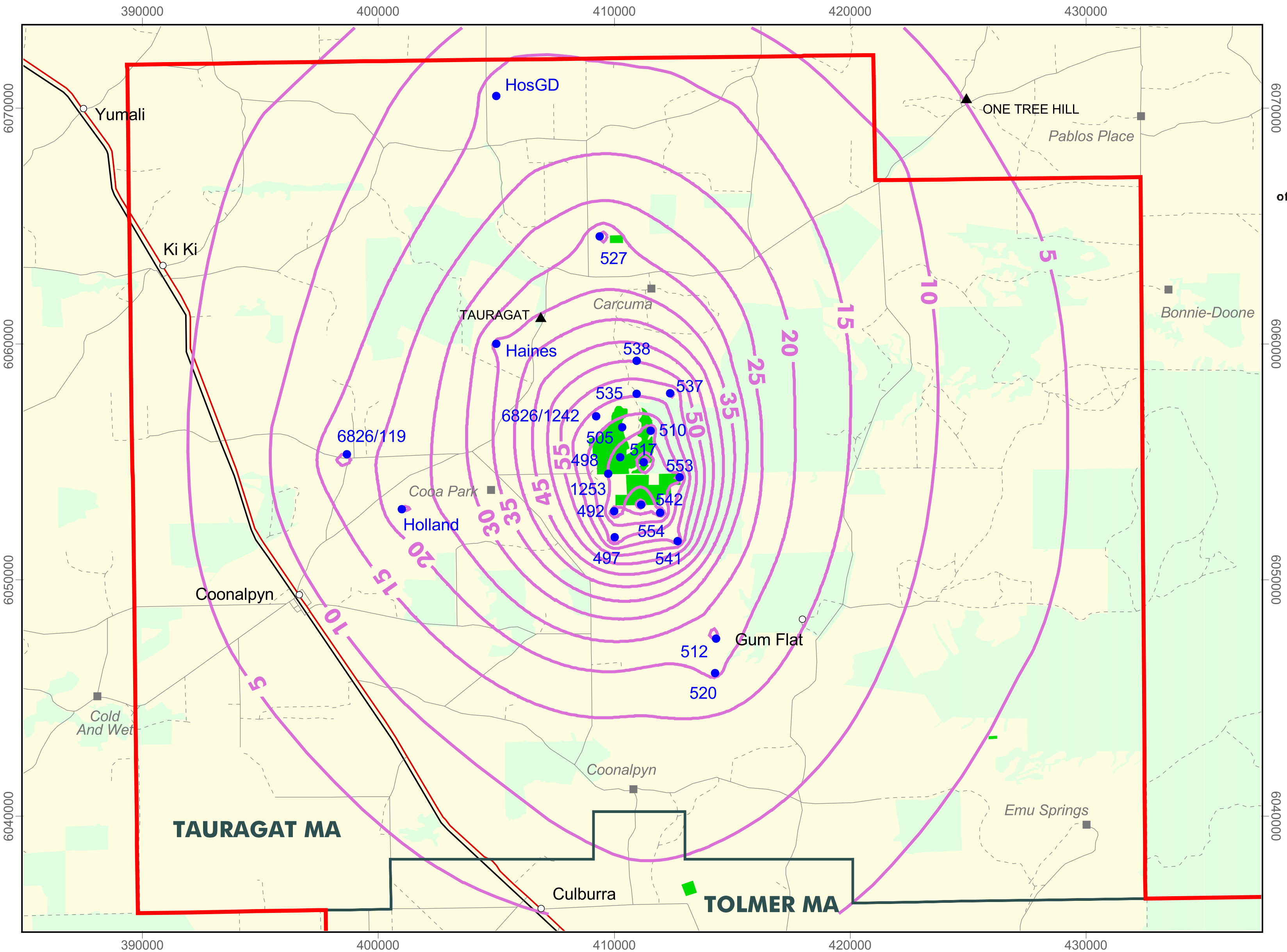

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Drawdown contours (m)

541 Confined production well and number (prefix 6926)

Native vegetation

Confined irrigation area 2000/2001

Management area

Tintinara and Coonalpyn Prescribed Wells Area

0 5 Kilometres

Datum GDA 94 – Projection MGA Zone 54

GDA

Tintintara – Coonalpyn Prescribed Wells Area

PREDICTED DRAWDOWN CONTOURS IN TAURAGAT MA – MIDDLE CONFINED AQUIFER AFTER 25 YEARS

Figure 28

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CONCLUSIONS AND RECOMMENDATIONS

The TCPWA contains two aquifer systems (confined and unconfined) which underlie two different landforms (low-lying Coastal Plain and Mallee Highlands). Management areas have been defined on the basis of different hydrologic processes which each require a unique management approach.

Unconfined aquifer

The unconfined limestone aquifer is a robust resource, with the volume of groundwater in storage in the aquifer averaging 500 times the annual recharge. Because it is also very permeable, drawdowns due to extraction are not an issue of concern (especially if there may be an environmental benefit if groundwater levels do fall in some areas to counteract dryland salinity). Aquifer response management is proposed in the Sherwood and Coonalpyn MAs to monitor the response of the aquifer to extractions, with increases proposed if impacts are acceptable.

Managing salinity impacts is the main sustainability issue for the unconfined aquifer. Although there are two different processes increasing groundwater salinity, (irrigation recycling on the low-lying Coastal Plain, and flushing of salt from the unsaturated zone beneath the Mallee Highlands), the recommended management approach is the same — to prevent any further concentration of irrigation by imposing a 2 km buffer around existing irrigated areas. This will allow better throughflow of groundwater by minimising drawdown, and to allow some dilution of groundwater by recharge and dispersion in order to benefit users downgradient.

In the Tintinara MA (Coastal Plain), the buffer zone will act as a cap on further development in groundwater below 4000 mg/L. As only ~50% of irrigation bores are showing a rising trend, and taking into consideration the concept of the higher value use of the groundwater, a reduction in extraction is not warranted at this stage. In any case, there are as yet, no demonstrable salinity benefits from reducing pumping volumes.

Confined aquifer

Drawdowns are the main management issue for the confined aquifer. In the Tolmer MA where the confined aquifer is artesian, numerous 2 inch diameter bores have stopped flowing due to irrigation induced drawdowns of only 1–2 m. The difficulty is that the aquifer can experience sustainable drawdowns at a level higher than stock and domestic users in area may accept. A cost sharing arrangement for lowering pumps should help ease concerns. A management approach to hold the area irrigated to current levels is recommended to enable drawdowns to stabilise and to enable the installation of meters to determine what volumes are being pumped to cause the observed drawdowns.

In the Tauragat MA, drawdowns due to olive irrigation are the main management issue. There are few stock and domestic wells in the area, and in any case, are completed in the uppermost confined limestone aquifer of the Buccleuch Group. Pumping is occurring from the underlying Renmark Group. A PAV of 11 000 ML/y has been established, based on modelled drawdowns in the pumping wellfields from a well calibrated groundwater model.

Regional drawdowns from the model are considered very much to be an overestimate because the model is assuming the aquifer to be continuous throughout the area. This is not the case because at least six intended irrigation bores had to be abandoned because of the poor aquifers encountered. A monitoring network has been established to help calibrate the model.

Recommendations

The following recommendations are made:

- Regular sampling of equipped stock and domestic bores within the area of confined aquifer drawdown in the Tolmer MA should be carried out to detect any leaking wells. Any unequipped or abandoned holes should be sampled or geophysically logged to determine the condition of the casing.
- Regular and extensive salinity monitoring of unconfined irrigation bores in the Tintinara MA should continue to determine long-term salinity trends. Salinity modelling of the unconfined aquifer should be attempted.
- The salinity monitoring network in Sherwood MA should be expanded to determine long-term salinity trends due to clearing.
- Groundwater levels in the saline shallow aquifer should be monitored beneath areas of confined aquifer irrigation in the Boothby MA.
- Further monitoring of the various confined aquifers in the Tauragat MA should be carried out to assist in calibration of the groundwater model.

GLOSSARY

Confined aquifer

The coral limestone of the Buccleuch Group or the underlying sands and gravels of the Renmark Group which both occur beneath the brown–black clays of the confining layer.

Drawdown

The occasional, seasonal or permanent lowering of the watertable or reduction in pressure (head) of an aquifer resulting from the extraction of underground water.

Permissible annual volume (PAV)

The volume of water that can be used or allocated from any aquifer on an annual basis in a particular management area.

Potentiometric level

The level to which water rises in a well due to water pressure in the confined aquifer. May also be referred to as the “potentiometric surface” or the “potentiometric head”.

Unconfined aquifer

The limestone sediments occurring above the brown–black clays of the confining layer which contain the watertable.

SHORTENED FORMS

Measurement

Name of unit	Symbol	Definition in terms of other metric units	
Day	d		time interval
Gram	g		Mass
Hectares	ha		area
Kilometre	km	10^3 m	Length
Litre	L	10^{-3} m^3	Volume
Litres per second	L/s		
Megalitre	ML	10^6 m^3	Volume
Megalitres per hectare	ML/ha		
Megalitres per year	ML/y		
Metre	m		Length
Metres per day	m/d		
Milligram	mg	10^{-3} g	Mass
Milligrams per litre	mg/L		
Milligrams per litre per year	mg/L/y		
Millimetre	mm	10^{-3} m	Length
Millimetres per year	mm/y		
Second	s		time interval
Year	y		time interval

General

Shortened form	Description
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AHD	Australian height datum
DWLBC	Department of Water, Land and Biodiversity Conservation
MA	management area
PAV	Permissible annual volume
PWA	prescribed wells area
SECWMB	South East Catchment Water Management Board
TCPWA	Tintinara–Coonalpyn Prescribed Wells Area

Salinity conversion

Abbreviation		Name	Conversion
mg/L	=	Milligrams per litre	= 1 ppm
gpg	=	Grains per gallon	= 14.3 mg/L

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APPENDIX A Management Responses

UNCONFINED AQUIFER

	Tintinara and Boothby MAs Coastal Plain	**Sherwood MA** Eastern Mallee	**Coonalpyn MA** Northern Mallee
Characteristics	• Quaternary limestone aquifer with the watertable 0–15 m below ground surface • Centre pivot and flood irrigation of lucerne • Recharge rates averaging 50 mm/y • Salinity rises in 50% of irrigation bores averaging 125 mg/L/y for flood and 70 mg/L/y for pivots	• Murray Group Limestone Aquifer with the watertable 25–50 m below ground surface • Centre pivot irrigation of lucerne, vegetables and drip irrigated olives • Recharge rates averaging 15–20 mm/y • Watertable rise averaging 50 mm/y, but no salinity increase observed	• Murray Group Limestone Aquifer with the watertable 15–60 m below ground surface • Centre pivot irrigation of lucerne • Recharge rates over 30 mm/y • Watertable rise averaging 100–300 mm/y • Salinity rises due to clearing averaging 10–25 mg/L/y
Management Issues	ç Salinity increases due to recycling of irrigation water ç Rising watertable due to clearing resulting in the eastward expansion of dryland salinity	ç The flushing of salt down from the unsaturated zone to the deep watertable after clearing, which is accelerated by irrigation	ç The flushing of salt down from the unsaturated zone to the deep watertable after clearing, which is accelerated by irrigation
Management Response	ü Establish hydrogeological test to disperse future irrigation ü Establish PAV from total of volumetric allocations for existing and eligible irrigated areas (Tintinara MA) ü Establish PAV of 20 000 ML for development where salinity above 8000 mg/L (Boothby MA)	ü Establish hydrogeological test to disperse future irrigation ü Establish PAV from total of volumetric allocations for existing and eligible irrigated areas ü Continue water level and salinity monitoring	ü Establish hydrogeological test to disperse future irrigation ü Establish PAV of 19 650 ML/y based on recharge from CSIRO investigations and modelling

CONFINED AQUIFER

	Tolmer MA Coastal Plain	**Kynoch MA** Eastern Mallee	**Tauragat MA** Northern Mallee
Characteristics	• Confined aquifer is artesian on the interdunal flats where flowing bores have been used for stock and domestic supplies • Centre pivot irrigation of lucerne being carried out over shallow rising saline watertable	• No extraction	• Extractions for large olive plantations dominate water use
Management Issues	ç Drawdowns of several metres due to irrigation have caused some bores to stop flowing ç Shallow saline watertable causing corrosion of uncemented steel casing resulting in localised contamination of supplies	ç No issues	ç The impacts of regional drawdowns on other users and the possibility of drawing in more saline groundwater from the west ç The possibility of excessive drawdowns in individual wellfields
Management Response	ü Establish interim PAV based on current use with staged increase if drawdown impacts acceptable ü Carry out sampling to detect leaky wells	ü No allocation	ü Establish PAV of 11 000 ML/y based on modelled drawdowns