Water Resource Assessment: Tatiara Prescribed Wells Area *for the* South East Catchment Water Management Board

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WATER RESOURCE ASSESSMENT: TATIARA PRESCRIBED WELLS AREA FOR THE SOUTH EAST CATCHMENT WATER MANAGEMENT BOARD

By Michael Cobb and Keith Brown

EXECUTIVE SUMMARY

In the development of a Water Allocation Plan for the Tatiara PWA, the South East Catchment Water Management Board (SECWMB) appointed groundwater consultants Water Search Pty Ltd and the Department for Water Resources (DWR) to assess the water resources of the area. The study was funded jointly by the SECWMB and the DWR. This study provides an overview of the current status of the water resources in the Tatiara PWA and where applicable makes recommendations for its future management.

The Tatiara Prescribed Wells Area (PWA) is located approximately 250 kilometres southeast of Adelaide and covers an area of ~3500 km^2. The PWA can be divided by topography into a coastal plain to the west and the uplifted Pinnaroo Block to the east referred to as the eastern highlands area. The two terrains are separated by a fault scarp referred to as the Marmon Jabuk Scarp to the north of the PWA and the Kanawinka Fault to the south. The fault has no surface definition in the PWA being overlain by younger sedimentary deposits.

The main water resource is the regionally unconfined aquifer contained within the Murray Group Limestone in the eastern highlands and the Padthaway Formation on the coastal plain. Groundwater flow in the aquifer is generally from east to the west. In the eastern highlands groundwater flows predominantly through the Murray Group Limestone. The depth to water can be in excess of 40 metres, reflecting the elevated topography. Well yields from the aquifer range from 50 to 200 L/sec. On the coastal plain the Murray Group Limestone is absent. Groundwater flow in the unconfined aquifer continues mainly through the Padthaway Formation and the underlying Bridgewater Formation. The depth to water on the coastal plain is generally less than five metres. Well yields can be up to 300 L/sec.

The unconfined and the underlying confined aquifers are separated by a relatively thick, low permeability aquitard. For this reason the two aquifers can be managed independently.

The confined aquifer also flows in a westerly direction across the Tatiara PWA. Recharge to the aquifer is predominantly via lateral throughflow, possibly originating from the Dundas Plateau in western Victoria. Depth to the confined aquifer formation is generally more than 100 metres. Well yields range between 10 and 20 L/sec. but wells can produce fine sand when pumped.

The water resources of the Tatiara area were proclaimed in 1984. This followed concerns raised by the community that the observed irrigation expansion was having a negative impact on the water resources in the area. A subsequent hydrogeological study confirmed a long-term decline in water quality in the densely irrigated western portion of the region.

At the time of proclamation water licences were issued on the basis of established irrigation activity or proposed development. In 1987, the Tatiara PWA was divided into a number of sub-areas (these were mainly Hundreds) and vertical recharge volumes determined. The sub-areas were later altered to include the Border Zones. The hydrogeological investigation confirmed that the annual water use in the Hundred of Stirling was

approximately 25 000 ML. Rainfall recharge, however, was estimated to be only 19 260 ML.

In the Tatiara PWA there are currently 72 observation wells in the water level monitoring network of which, three of the wells monitor the confined aquifer. There are two salinity monitoring networks in the PWA, a government operated network and a private irrigation network. The combined total of observation wells in the salinity networks number 151, two of which are used to monitor the confined aquifer. Generally the number of observation wells in the monitoring networks are acceptable for the Tatiara PWA. The network could be improved by increasing the salinity network in the southern portion of the PWA and by adding one or two water level observation wells in the Hundred of Shaugh.

In the unconfined aquifer water levels in the north-western portion of the PWA, particularly Sub-area 7, are declining at a rate of more than 5 cm/yr. In parts of the same area, the salinity of the groundwater exceeds 7000 mg/L and is increasing by more than 100 mg/L annually. The major factors responsible for the salinity increase are considered to be groundwater recycling and over extraction.

Above 7000 mg/L TDS yields for lucerne seed, the major crop grown in the area, will decrease. The high groundwater salinity limits the options for alternative crops to be grown in the area should lucerne become uneconomical.

In the eastern highlands hydrographs are generally showing a slight long-term rise in the water table. Associated with the rise is an increase in groundwater salinity and these phenomena are attributed to clearance of native vegetation by early European settlers.

In the confined aquifer one of the hydrographs shows a slight long-term increase, while another shows a slight decrease. The third shows no appreciable change. The rising and falling potentiometric head are most probably a result of changes in overburden pressure related to corresponding water level changes in the unconfined aquifer. Salinity of the confined aquifer generally ranges between 1200 and 1300 mg/L.

The total allocation for the Tatiara PWA in the 1998/1999 irrigation season was 89 351 ML. Total groundwater usage was estimated to be 63 442 ML which equates to 71% of the total allocation. In two sub-areas, Zone 8A and Part Zone 9A small quantities of water are available for allocation. There is only one user of the confined aquifer in the Tatiara PWA.

In 1997 the allocation in Sub-area 7 (Hundred of Stirling) was voluntarily reduced by 35% to bring the allocation in line with the estimated rainfall recharge volume for the area. At the same time crop area ratios were altered for lucerne seed.

A water balance was determined on a sub-area basis for the Tatiara PWA. The results of the water balance would suggest that, save for a decline in storage as a result of falling water levels in the western portion of the PWA, the area is more or less in balance. Uncertainty in the groundwater parameters used in the balance may explain this discrepancy.

Of most concern is the long-term sustainability of the unconfined aquifer water resource in the western portion of the Tatiara PWA.

The water use figures probably underestimate the total groundwater extracted from the aquifer by many times. This is particularly so when flood irrigation practices are employed.

In the Tatiara PWA, the impact taking or use of water from one resource may have on the quantity and quality of water of another resource were assessed in the following situations:

- the impact of using surface water to artificially replenish the groundwater system.

- the impact taking groundwater from the unconfined aquifer may have on the confined aquifer.

- the impact taking groundwater from the confined aquifer may have on the unconfined aquifer.

Recharge to the unconfined aquifer via preferential flow paths, such as runaway holes or discharge wells, is fairly common in the Tatiara PWA. While both supply the unconfined aquifer with a valuable source of water, the discharge wells are designed mainly to reduce surface flooding during seasonally high levels of rainfall. Distinguishing between naturally occurring recharge systems and man-made systems can be subjective. A study into point source recharge into one of the major swamps in the area showed only localised impacts on the water resource of the unconfined aquifer, so it is unlikely that any man-made well used to artificially replenish the aquifer would show any significant impact.

A relatively thick, low permeability aquitard separates the unconfined and confined aquifers in the Tatiara PWA. The interconnectivity between the two aquifer systems is consequently reasonably low. It is unlikely therefore that taking groundwater from one aquifer would have any major impact on the other.

It is possible that extraction from Sub-area 7 is impacting across the boundaries of water management sub-areas. There is a long-term decline in Sub-area 7 of more than 5 cm/yr. Similar declines are also evident in the northern portion of Sub-area 3 (the Hundred of Willalooka) and the north-western portion of Sub-area 2 (the Hundred of Wirrega). It is unclear whether this is an expansion of a drawdown cone emanating from Sub-area 7 or the declining water table in the other sub-areas is a localised phenomenon.

In the long-term, a decline in groundwater quality is expected down-gradient of the densely irrigated area in Sub-area 7. This would occur outside the Tatiara PWA with the largest impact expected in the eastern portion of the Hundred of Laffer and possibly the Tintinara-Coonalpyn moratorium area.

INTRODUCTION

BACKGROUND

There are five water management zones, covering an area of almost 20 000 km^2, in the South East region of South Australia (Fig. 1). The South East Catchment Water Management Board (SECWMB) are in the process of preparing Water Allocation Plans for each of these five Prescribed Wells Areas (PWAs).

Under the *Water Resources Act (1997)* there is a requirement that in the preparation of each Water Allocation Plan, consideration must be given 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*": and
- "*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, the Department for Water Resources South Australia (DWR), and groundwater consultants Water Search Pty Ltd, have been jointly appointed by the SECWMB to assess the water resources of each PWA 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 Tatiara PWA and applies specifically to the principal term of reference namely addressing Sections 101 (4) (b) and 101 (4) (e) of the Act.

To meet this commitment each assessment of a PWA includes:

- a general description of the groundwater resources for each of the aquifers in the PWA
- for both the unconfined and confined aquifers:
    - 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.
    - the historic demand (in terms of use) and current demand (in terms of the level of allocations and use) in each of the management areas within the PWA, by major categories (irrigation, industrial, municipal, stock and domestic supplies).
    - the likely future demand for groundwater from this resource in the PWA, where possible differentiating between major use categories (irrigation, industrial, municipal, stock and domestic supplies).

- an assessment of whether the taking or use from either aquifer 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.

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

- 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.

The project brief does not include an environmental assessment of groundwater dependent ecosystems as this is being undertaken by a separate consultancy.

STUDY AREA

Regional Hydrogeology

Geologically the South East region lies predominantly within the Gambier Embayment of the Otway Basin. The Tatiara PWA however is located on the south-western margin of the Murray Basin. The two basins are partially separated by a basement high, of the Padthaway Ridge (Fig. 2). Both basins are still however hydraulically connected. With the exception of the Glenelg River, which lies predominantly over the State border in Victoria, there are no extensive supplies of good quality surface water flows in the South East. Groundwater, therefore, provides the main water resource for the region. While primarily used for irrigation, the groundwater is also used for industrial, recreational and stock use, and for supplying municipal water to a number of towns located in the area.

The South East region is characterised by several extensive low-lying flats interspersed with a series of north-west trending remnant sand dune ridges. Beyond the Kanawinka Fault (east of Naracoorte) the topography rises into higher inland plains which extend into western Victoria (maximum elevation of ~300 metres).

The geological and hydrogeological units of the Otway and Murray Basins are easily comparable and reflect a similar basin evolutionary history. The names of the stratigraphic and hydrostratigraphic units do however differ. A comparison of the nomenclature for the two Basins is shown on Figure 3.

In both Basins groundwater flows through two major aquifer systems: a regionally unconfined limestone aquifer and an underlying confined quartz sand aquifer. 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.

The upper, unconfined aquifer is the most extensively used of the two aquifers. However the recent introduction of water management policies which effectively caps it's use, coupled with poor groundwater quality in the aquifer in some areas, has resulted in increased interest in the confined aquifer as a water resource.

The regionally extensive unconfined aquifer consists mainly of calcareous sandstone and limestone deposited during the latter part of the Tertiary Period through to the Quaternary (~ 30 million years ago to present). It incorporates the Gambier Limestone (referred to as the Murray Group Limestone in the Murray Basin), Coomandook, Bridgewater, and Padthaway Formations.

Recharge to the confined aquifer relies on downward leakage from the overlying unconfined aquifer. This occurs in the eastern margin of the region. Here the water table in the unconfined aquifer is higher than the potentiometric head in the confined aquifer hence there is potential for downward leakage (recharge) to the confined aquifer. To the west and south of the region the head distribution is reversed and there is the potential for upward leakage from the confined aquifer to the unconfined aquifer.

The confined aquifer consists of non-calcareous quartz sands, interbedded with dark brown carbonaceous clays. Together these units make up the Dilwyn Formation (referred to as the Renmark Group in the Murray Basin). Deposition of the Dilwyn Formation occurred during the early part of the Tertiary Period.

The confined aquifer, for management purposes, is treated regionally as one aquifer, but it is in reality a complex multi-aquifer groundwater system. Lack of data means there is little real understanding on the hydraulic interconnection between these sub-aquifers. The confined aquifer is very thin or absent in much of the northern margins of the South East.

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 the groundwater moves through each aquifer depends on its hydrogeological properties. Higher rates of groundwater flow are most evident in the upper unconfined aquifer where a secondary porosity has developed.

There are a number of major faults in the area. The two most prominent are the NW trending Kanawinka Fault and the W–NW trending Tartwaup Fault (Fig. 2). Kanawinka Fault has a pronounced lineament and is downthrown to the south-west. The west-northwesterly trending Tartwaup Fault is expressed as a monoclinal structure. Downthrow is generally in a southerly direction. The potentiometric surface of both aquifers indicate a significant steepening of slope immediately up-gradient of each Fault. While the effect faulting has had on groundwater flow can be inferred from the head gradients in both aquifers, the mechanisms responsible for this are poorly understood.

The salinity of the groundwater of the unconfined aquifer ranges from ~ 500 mg/L in the south, to more than 7000 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.

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*. The Board is responsible for the management of the water resources in the South East region. It is under the Act that the water resources are prescribed. In total there are five Prescribed Wells Areas in the South East region. They include the established PWAs of Padthaway, Tatiara, Comaum-Caroline, and Naracoorte Ranges (these were proclaimed/prescribed under previous Water Resources Acts) and the recently prescribed Lacepede-Kongorong PWA (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 that is important 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 kilometre 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.

Formal boundaries have yet to be established for the confined aquifer in the South East region. For this report the confined aquifer boundaries were assumed to be those proposed by the SA/Vic Border Technical Review Committee (Fig. 13).

GROUNDWATER ALLOCATION METHOD (LICENSING SYSTEM)

For the purposes of managing the unconfined aquifer, groundwater is allocated on the basis of the estimated average yearly vertical recharge to the water table. The underlying principle behind this approach is that lateral throughflow is maintained in the aquifer, thereby allowing any salts accumulated during the recharge process to be flushed down-gradient. Average rainfall, soil type (and its properties), land use (and vegetation cover), and water level changes (both seasonal and long-term) are taken into consideration in the vertical recharge calculation.

The sustainability of the resource is therefore defined as total vertical recharge to each PWA (ie. the Permissible Annual Volume (PAV)). Theoretically, licences would then be issued to take water up to the limit of the PAV. Allocation of a water licence is based on area and the irrigated crop water requirement relative to a reference crop (Crop Area Ratio system). The area based system does not take into account irrigation inefficiencies. It assumes any excess water pumped from the aquifer, and not used by the crop or lost to evaporation, percolates back down into the unconfined aquifer.

The same water allocation system is used for the confined aquifer. However the excess irrigation water does not return to the confined aquifer but to the unconfined aquifer. Therefore this method considerably underestimates water use from the aquifer.

HYDROGEOLOGY OF THE TATIARA PWA

GEOGRAPHICAL SETTING

The Tatiara PWA covers an area of approximately 3500 km^2 and includes the Hundreds of Cannawigara, Pendleton, Senior, Shaugh, Stirling, Tatiara, Willalooka, and Wirrega and a small part of McCallum that lies within the 20 kilometre border strip (Fig. 4). The northern part of Zone 7A, all of Zone 8A and the southern part of Zone 9A of the Border Zone are located inside the Tatiara PWA. Both the major towns, Keith in the west of the PWA and Bordertown in the east, lie on the main Adelaide-Melbourne highway that runs through the Tatiara PWA in a southeast direction.

GEOMORPHOLOGY

The Tatiara PWA can be divided into two discrete land-forms, a low-lying coastal plain to the west and the uplifted highlands of the Pinnaroo Block to the east. Separating the two terrains is the Marmon Jabuk Fault scarp in the north and the Kanawinka Fault in the south. In the Tatiara PWA the fault scarp is covered by a remnant dunal ridge that rises approximately 50 to 60 metres above the plain.

The coastal plain consists of a succession of stranded coastal dunes that run sub-parallel to the present coastline. The ridges are separated by a series of low-lying interdunal flats. Underlying the coastal plain sediments is the regional basement high of the Padthaway Ridge. The basement consists of early Palaeozoic igneous rocks and metasediments that outcrop at the surface at a number of locations throughout the coastal plain.

The surface of the eastern highlands consists of undulating plains which increase in height to the northeast, reaching a maximum altitude of 130 m above sea level. Overlying the undulating plains are remnant sand dunes and E-S-E trending sand sheets.

RAINFALL

The climate in the Tatiara PWA is typical of the South East; hot, dry summers and cool wet winters. The average annual rainfall in Bordertown (1881 to present) is 488 mm. In Keith the average rainfall (1906 to present) is slightly less at 469 mm. The lower rainfall in Keith is consistent with a decreasing rainfall trend from south to north observed in the South East region. The annual potential evapotranspiration is approximately 1700 mm (Stadter *et al.*, 1995).

SURFACE WATER FLOWS

There are two ephemeral water courses in the Tatiara PWA namely Tatiara Creek and Nalang Creek. Both drain from the elevated Pinnaroo Block in the east. The catchment areas for these creeks are more than 500 km^2 and extend into western Victoria. Tatiara Creek discharges into Poochers Swamp and Scowns runaway hole, while Nalang Creek discharges into Mundulla swamp.

The flow in the creeks can last anywhere from a few days to a few weeks. Total annual flow volumes in the Tatiara Creek ranged from 1300 to 20 000 ML between 1987 to 1991 (Herczeg *et al.*, 1997).

If the flows from the creeks are sufficient, the swamps form small lakes. This usually occurs in late winter. The capacity of each swamp is estimated to be 425 ML for Poochers Swamp and 3500 ML for Mundulla Swamp (DENR, 1997).

Water from the swamps then recharges the unconfined aquifer via a series of runaway (sink) holes. These are preferred flow paths that allow the surface water to directly recharge the aquifer. The annual input via these recharge holes is calculated to be less than 10% of the total recharge (Herczeg, *et al.*, 1997). Diffuse recharge is therefore the dominant recharge mechanism in the Tatiara PWA.

LOCAL HYDROSTRATIGRAPHY

Unconfined Aquifer

Groundwater flow in both the unconfined and confined aquifers in the Tatiara PWA is generally from east to west. The unconfined aquifer is a multi-lithological system which is hydraulically continuous across the PWA. In the east, in the uplifted Pinnaroo Block, groundwater flows through the Murray Group Limestone Formation. The limestone is absent west of the fault. Groundwater flow thereafter passes through the dune ridge consisting of the Bridgewater Formation before continuing through the Padthaway and Bridgewater Formations beneath the coastal plain.

The thickness of the unconfined aquifer varies considerably throughout the region but generally it thins from east to west. For example in the central portion of the PWA the aquifer is more than 80 metres thick in the east (Hundred of Senior) but thins westward to be less than 40 metres thick on the western boundary of the Hundred of Stirling. Aquifer thinning is more rapid in the south west of the PWA as the sediments near outcrops of granite basement. Depth to water on the interdunal flat is generally less than five metres. In the east the depth to water can be in excess of 60 metres reflecting the increased topography. A schematic east-west cross section through the Tatiara PWA highlighting the main geological units is shown in Figure 5.

Coastal Plain

The unconfined aquifer beneath the coastal plain flows through the Padthaway, Bridgewater and Coomandook Formations. The aquifer is exploited extensively for irrigation in the Hundreds of Stirling, Willalooka, Wirrega and Pendleton.

The uppermost geological unit is the Padthaway Formation which occurs only beneath the interdunal flat. The maximum recorded thickness is approximately 20 metres 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 generally it consists of fine to coarse shelly quartz sandstone. High well yields (up to 300 L/sec. (Stadter and Love, 1987)) in the Padthaway and Bridgewater Formations have enabled irrigators to adopt flood irrigation practises particularly in the Hundred of Stirling. The deepest of the geological units, the Coomandook Formation, is not used as an aquifer in the Tatiara PWA because it has a higher marl (calcareous clay) component than the overlying formations which has resulted in lower well yields.

Eastern Highlands

In the eastern highlands area, the main geological unit of the unconfined aquifer is the Murray Group Limestone Formation. The Murray Group Limestone generally consists of a bryozoal and shelly limestone. Groundwater from the aquifer is primarily used for irrigation but it is also used for the town water supply of Bordertown. Well yields range from 50 to 200 L/sec. The aquifer can be semi-confined depending on its saturated thickness and the presence of an overlying clay referred to as the Upper Tertiary Aquitard. The north-eastern portion of Zone 9A in the Tatiara PWA is considered confined (Stadter *et al.*, 1995).

The Murray Group Limestone Formation pinches out before it reaches the coastal plain and is replaced by the Bridgewater Formation in the form of a remnant dune ridge.

Confined Aquifer

In the Murray Basin, the unconfined and confined aquifers are separated by a low permeability aquitard comprising the Ettrick Formation and the Buccleuch Beds. The Ettrick Formation consists of glauconitic marl while the Buccleuch Beds are mainly carbonaceous clays. The combined thickness of the aquitard is generally more than 20 metres.

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, possibly sourced from the Dundas Plateau.

The confined aquifer in the Tatiara PWA is referred to as the Renmark Group. It has a similar wedge shape as the unconfined aquifer in that it thins appreciably from the east to the west. Depth to the Renmark Group is more than 100 metres in the Tatiara PWA.

Generally the confined aquifer consists of a series of thin interbedded limestone and sand aquifers separated by thin carbonaceous clay units. It differs from its counterpart in the Otway Basin (the Dilwyn Formation) in that the top lithological units can consist of a fossiliferous sandstone or limestone.

The sand units of the aquifer can be fine grained, and therefore difficult to screen. Well yields are relatively low compared to the unconfined aquifer (10–20 L/sec.). There have been a relatively low number of wells drilled into the confined aquifer in the Tatiara PWA. There is only one known operational confined aquifer well in the PWA.

GROUNDWATER MANAGEMENT APPROACH

HISTORY

In 1984 the Tatiara area was proclaimed under the South Australian *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 was having a detrimental impact on the water resource. This was later confirmed by Stadter (1984), who showed that there was a long-term decrease in groundwater quality in the western part of the region.

At the time of proclamation, water licences were issued on established irrigation activity and on proposed development. There was therefore no initial assessment of PAVs for the area.

In 1986, the Tatiara Proclaimed Area was expanded to the east to include the Border Zone area. A subsequent study (Stadter and Love, 1987) showed the rate of extraction was near or exceeding recharge in some areas. As part of the assessment vertical recharge (ie. PAVs) were determined for each Hundred.

In 1988, a management plan for the Tatiara Proclaimed Wells Region was adopted and the area was divided in to a number of sub-areas. At this time the allocation in the Hundred of Willalooka was increased from 7900 ML/yr to approximately 10 000 ML/yr. There was also an increase in the North Pendleton sub-area from 2092 ML/yr to 7000 ML/yr.

Allocations were voluntarily reduced at the beginning of the 1997/1998 irrigation season by 35% in the Hundred of Stirling. A 35% reduction in the groundwater allocation would bring it in line with the estimated vertical recharge to the Hundred. At the same time changes were introduced to the crop area ratios for ‘starter or finisher’ lucerne, spring lucerne, spring and autumn lucerne, lucerne seed, lucerne spring fodder and seed and lucerne “full”. The current irrigation equivalents and amended crop area ratios (after Desmier and Schrale, 1988) are attached in Appendix A.

In 1997, the allocation volume in that part of Zone 9A in the Tatiara PWA was increased from 2450 ML/yr to 4840 ML/yr following a reassessment of the aquifer parameters for the zone.

MANAGEMENT ZONES

Unconfined Aquifer

The Tatiara PWA is divided into eight sub-areas as shown on Figure 4. They are:

- **Sub-area 2** – includes the Hundred of Wirrega, the southern part of the Hundred of Pendleton, the south-western corner of the Hundred of Cannawigara and the western edge of the Hundred of Tatiara.
- **Sub-area 3** – is the Hundred of Willalooka.
- **Sub-area 5** – is the Hundred of Cannawigara.
- **Sub-area 6** – is the northern part of the Hundred of Pendleton.
- **Sub-area 7** – is the Hundred of Stirling.
- **Part Zone 7A** – in the northern part of Border Zone 7A located in the Tatiara PWA and includes most of the Hundred of Tatiara.
- **Zone 8A** – is Border Zone 8A. It includes the Hundred of Senior, the southern part of the Hundred of Shaugh, the eastern portion of the Hundred of Cannawigara and a small part of the Hundred of McCallum.
- **Part Zone 9A** – is that part of Border Zone 9A located within the Tatiara PWA. It includes the Hundred of Shaugh and a small slice of the eastern part of the Hundred of McCallum.

Confined Aquifer

Boundaries are yet to be established for the confined aquifer in the South East region however proposed boundaries have been recommended. In the Border strip zone boundaries have been maintained, hence Zone 8A, and parts of Zones 7A and 9A are included in the Tatiara PWA along with the management areas of Wirrega and Keith west of the Border area (Fig. 13).

THE MONITORING NETWORK

UNCONFINED AQUIFER

Current Monitoring Network

The Department for Water Resources and its predecessors have been monitoring groundwater levels in the Tatiara PWA since 1975. Salinity monitoring began in 1978.

Water Level Monitoring Network

The water level monitoring network in the Tatiara PWA has been in operation for more than 25 years. Over this period, the network has been upgraded and expanded to match the agricultural development in the PWA. There are currently 69 wells monitored for water level. These wells are measured quarterly (March, June, September and December) by the Department for Water Resources.

The locations of the current water level monitoring wells are shown on Figure 6. The number of water level monitoring wells in the network is adequate for the Tatiara PWA. The majority of wells are understandably concentrated in the area of highest risk, namely the intensely irrigated area of the Hundred of Stirling. There are only two observation wells in the Hundred of Shaugh but this reflects the low level of irrigation activity in this sub-area.

Salinity Monitoring Network

There are currently a total of 149 observation wells broken up into two salinity monitoring networks in the Tatiara PWA. The Tatiara Monitoring Network is the main network in the PWA. There are currently 37 wells in this network. Sampling is undertaken by the Department for Water Resources and the sampling frequency is the same as for the water level monitoring network.

The majority of salinity observation wells are in the Tatiara Irrigation Network. These are privately owned wells that are sampled on an irregular basis. A number of wells are also sampled regularly for full major ion chemistry.

The location of wells in the salinity monitoring network are shown on Figure 7. The distribution of the wells in the salinity monitoring network is similar to the water level monitoring network in that most are located in Sub-area 7, the Hundred of Stirling.

CONFINED AQUIFER

Water Level Monitoring Network

There are three water level observation wells in the confined aquifer in the Tatiara PWA. They are located in the Hundreds of Shaugh, Tatiara and Wirrega.

Salinity Monitoring Network

The two water level monitoring wells in the Hundreds of Shaugh and Wirrega have also been used to monitor groundwater salinity in the confined aquifer.

CURRENT STATUS OF THE WATER RESOURCES

UNCONFINED AQUIFER

Groundwater Flow

The water table elevation zones for the unconfined aquifer are shown on Figure 8. The direction of groundwater flow is generally from the South Australian – Victorian Border in the east towards the coast in the west. The changes in hydraulic gradient as reflected in the spacing of the zones are inferred to represent changes in hydraulic conductivity in the aquifer. The gradient becomes steeper near the eastern boundary of the Hundreds of Stirling and Willalooka. This is the transition from the Murray Group Formation to the Bridgewater Formation. It therefore could represent lower permeability in the Bridgewater Formation or it could be related to the Kanawinka Fault. 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 trends from hydrographs located in the Tatiara PWA are shown on Figure 9. Only wells with more than five years data were included in the assessment. In the intensely irrigated part of the Hundred of Stirling, long-term water level trends from bore hydrographs show a general decline in the water table of up to 14 cm/yr. The decline in water level would suggest the current level of extraction in the Hundred of Stirling is too high and therefore not sustainable in the long-term. Representative hydrographs from each of the sub-areas are included in Appendix B.

There is also an observed long-term decline in the water table of approximately 2.5 cm/yr in an area south-west of Bordertown. At this stage the reason for the decline has not been investigated.

In the southern portion of the PWA water levels in the unconfined aquifer are rising in excess of 5 cm/yr. The rise in the water table is considered to have been caused by increased vertical recharge resulting from the clearance of native vegetation by early European settlers.

At the present time this is not considered a major issue as the depth to water is more than 15 metres in this area and the average annual increase is only 5 cm. The area should however be monitored for any further significant changes.

Salinity Distribution

The salinity distribution for the Tatiara PWA is shown on Figure 10. Generally, the salinity ranges from approximately 1000 mg/L in the east to more than 7000 mg/L in the west. The most obvious feature from the figure is the groundwater salinity values in the Hundred of Stirling which are in excess of 7000 mg/L.

Unfortunately there are no salinity monitoring wells located in the southern part of the PWA where the water table is rising. Given that the rise in the water table is probably a result of land clearance then it would be expected that groundwater salinity is also increasing in this area.

Salinity Trends

The most notable increase in groundwater salinity is occurring in Sub-area 7, the Hundred of Stirling. Groundwater sampled from a number of wells in this area show salinity increasing at a rate of more than 100 mg/L annually. There are a number of factors that contribute to this increase, the main causes are considered to be:

- in the Hundred of Stirling extraction exceeds vertical recharge. Evidence for this is the substantial increase in groundwater salinity in the last 25 years and a long term decline in the water table. The decline in the water table indicates that a proportion of throughflow is also used. Groundwater is not moving fast enough to remove salts from the area. This is compounded by a high concentration of irrigation activity in the area. This ultimately results in an increase in the groundwater salinity caused by continuous recycling of the groundwater. Water use figures are based only on the crop water requirement and do not include irrigation losses. Flood irrigation methods are probably extracting many times the crop water use figure.

- lucerne, the major crop grown in the Hundred of Stirling, is a high water use crop. As water is drawn up through the root system salt not taken up by the plant accumulates in the root zone. The relatively high water use of lucerne results in a substantial salt load remaining in the soil profile. When irrigation water of a higher salinity is applied to the plant it must draw up more water to survive. This in turn leaves a higher salt load in the soil profile. It is this process that eventually reduces the crop yield of the plant. The salt that has accumulated in the soil profile then percolates back down into the aquifer during subsequent irrigation applications or from rainfall recharge. There is therefore a continuous cycle increasing the groundwater salinity.

Studies have shown that in the Hundred of Stirling lucerne seed and dry matter crop yields decrease when the salinity of irrigation water exceeds 7000 mg/L (DENR, 1997). As the salinity in some parts of the sub-area already exceed 7000 mg/L, in the short term corresponding reductions in crop yields should be expected. In the long-term there are very few crops that can be grown economically with a groundwater salinity in excess of 7000 mg/L TDS. The alternatives therefore given the current rate of salinity increase are limited.

CONFINED AQUIFER

Water Level Trends

There are three confined aquifer water level monitoring wells in the Tatiara PWA. Hydrographs of the wells are presented in Appendix B. The hydrograph from the observation well in the Hundred of Shaugh (SHG006) shows a long term increase in the potentiometric surface of approximately 2.5 cm/yr. The increase in the potentiometric surface is probably related to an increase in overburden pressure resulting from a rise in the water table in the unconfined aquifer rather than an increase in vertical recharge. The change in overburden pressure would also explain the decline in the potentiometric head in the confined aquifer as observed in the hydrograph located in the Hundred of Wirrega. The well (WRG025) is located in the mid-western portion of the Hundred. In this area the water level in the unconfined aquifer is declining.

There is only one well utilising groundwater from the confined aquifer but it has only been operational for the past year and therefore can not yet have had an impact on groundwater levels.

Observation well TAT027 located in the Hundred of Tatiara shows no long-term change in groundwater level.

Salinity Distribution

The two wells sampled for groundwater salinity WRG025 and TAT027 are programmed to be sampled every three years as part of the Border Zone observation network. Observation well WRG025 was sampled only in 1993. The salinity of the sample was measured at 1227 mg/L TDS. Observation well TAT027 has been sampled twice, in 1993 and 1996. Salinity was measured at 1233 mg/L and 1250 mg/L respectively.

WATER DEMAND

UNCONFINED AQUIFER

Historical Demand

The historical and current estimated crop water use, and allocation, for each sub-area as supplied by the Department for Water Resources – Policy Division are shown on Tables 1 and 2 respectively. The data is broken down into irrigation use and combined industrial and recreational use.

The allocation volumes vary slightly from season to season. The changes are due to changes in crop area ratios and increases in individual water licences following successful legal appeals (L. Schmidt, *pers. com.*). In 1997 in Sub-area 7 (Hundred of Stirling) the annual allocation was voluntarily reduced from 31 250 ML to 20 310 ML. This is a net reduction in total allocation of 35% and was implemented at the request of the local community. Crop area ratios for lucerne were also changed as part of the 35% reduction. The new crop area ratios for lucerne seed are presented in Appendix A.

The water use figures in Table 2 for Sub-area 7, the Hundred of Stirling (1997/98 and 1998/99) have not been corrected to the new crop area ratio system. DWR are in the process of altering the database to accommodate for the new CARs. They therefore do not reflect the decline in water use associated with the increase in crop area ratio. Water use should be approximately 17-18,000 ML for Sub-area 7. Figures calculated on the new crop area ratio system are not available.

Theoretically under the old CAR system an irrigator with a 100 Ha IE licence could irrigate 120 Ha of lucerne seed (ie. a CAR of 1.2 for lucerne seed). Under the new system the 100 ha IE has been reduced by 35%. Therefore a 100 ha IE licence would be decreased from 100 ha IE to 65 Ha IE. The new ratio for a 13 week irrigation period between November and March is 1.9. The irrigator can therefore irrigate an area of 123.5 ha of lucerne seed.

In 1998/99 irrigation season 50 out of the 60 irrigators that planted lucerne seed used the 1.9 Crop Area Ratio.

The water usage volume is estimated from seasonal returns supplied by the water licensees. The estimation of the volume relies on the veracity of the water user and the irrigated crop water requirement method. In both instances, therefore, the figures should be considered only as an approximation. The volume extracted from the aquifer, especially using flood irrigation methods, will be significantly higher than the irrigated crop water use value.

Table 1 *Tatiara PWA annual groundwater allocations*

Sub-areas	Irrigation Season (in ML)															
	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Part Zone 7A																
Irrigation	6070	6070	6070	6070	6136	6136	6206	6446	6455	6455	6455	6550	6550	6564	6699	6564
Industrial and Recreational	320	320	320	320	320	320	320	320	320	320	503	510	510	510	510	510
Sub-area Total	**6390**	**6390**	**6390**	**6390**	**6457**	**6457**	**6526**	**6766**	**6776**	**6776**	**6959**	**7060**	**7060**	**7075**	**7209**	**7075**
Zone 8A																
Irrigation	1659	1659	1659	1659	2228	2228	3496	3597	3722	2454	3722	3820	2552	2639	4039	5041
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	-	16	16	16	16	16
Sub-area Total	**1659**	**1659**	**1659**	**1659**	**2228**	**2228**	**3496**	**3597**	**3722**	**2454**	**3722**	**3836**	**2568**	**2654**	**4055**	**5056**
Part Zone 9A																
Irrigation	1686	1686	1686	1686	1686	1686	1686	1686	1686	1686	1686	1686	1686	1686	3330	3330
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-area Total	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**1686**	**3330**	**3330**
Sub-area 2																
Irrigation	28994	28994	28994	28994	29225	29494	29494	29519	29519	29519	30717	30618	30618	30882	31606	31519
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	119	394	394	130	115	101
Sub-area Total	**28994**	**28994**	**28994**	**28994**	**29225**	**29494**	**29494**	**29519**	**29519**	**29519**	**30836**	**31011**	**31011**	**31012**	**31721**	**31620**
Sub-area 3																
Irrigation	10225	10225	10225	10225	10352	10352	10352	10352	10352	10352	10583	10583	10583	10583	10583	10583
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-area Total	**10225**	**10225**	**10225**	**10225**	**10352**	**10352**	**10352**	**10352**	**10352**	**10352**	**10583**	**10583**	**10583**	**10583**	**10583**	**10583**
Sub-area 5																
Irrigation	2951	3341	3341	3386	3386	3386	3616	3616	3847	3847	3886	4057	4098	4097	4097	4098
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	29	29	29	29	29	29
Sub-area Total	**2951**	**3341**	**3341**	**3386**	**3386**	**3386**	**3616**	**3616**	**3847**	**3847**	**3916**	**4086**	**4127**	**4126**	**4126**	**4127**
Sub-area 6																
Irrigation	5341	5341	5341	5341	5870	5870	5986	7147	7147	7147	7147	6621	6621	6621	6646	6646
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-area Total	**5341**	**5341**	**5341**	**5341**	**5870**	**5870**	**5986**	**7147**	**7147**	**7147**	**7147**	**6621**	**6621**	**6621**	**6646**	**6646**
Sub-area 7																
Irrigation	30528	30528	30528	30528	31060	31223	31511	31511	31519	31519	31711	32554	31931	31932	23535	20733
Industrial and Recreational	165	165	165	165	165	165	165	165	165	165	171	178	178	178	178	181
Sub-area Total	**30693**	**30693**	**30693**	**30693**	**31224**	**31388**	**31676**	**31676**	**31684**	**31684**	**31882**	**32732**	**32109**	**32110**	**23713**	**20914**
Annual Total	**87940**	**88330**	**88330**	**88375**	**90427**	**90860**	**92832**	**94359**	**94733**	**93465**	**96731**	**97615**	**95765**	**95866**	**91384**	**89351**

Table 2 *Tatiara PWA annual groundwater usage*

Sub-areas	**Irrigation Season (in ML)**															
	83/84	**84/85**	**85/86**	**86/87**	**87/88**	**88/89**	**89/90**	**90/91**	**91/92**	**92/93**	**93/94**	**94/95**	**95/96**	**96/97**	**97/98**	**98/99**
Part Zone 7A																
Irrigation	4477	2820	3458	3631	4243	3728	3022	2755	2170	2500	2386	2788	2601	2193	2908	2679
Industrial and Recreational	320	320	320	320	320	304	320	320	127	0	0	0	0	0	0	0
Sub-area Total	**4797**	**3140**	**3778**	**3951**	**4564**	**4031**	**3343**	**3076**	**2297**	**2500**	**2386**	**2788**	**2601**	**2193**	**2908**	**2679**
Zone 8A																
Irrigation	0	0	140	86	356	603	627	665	496	323	420	470	493	454	373	795
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
Sub-area Total	**0**	**0**	**140**	**86**	**356**	**603**	**627**	**665**	**496**	**323**	**420**	**470**	**493**	**454**	**373**	**795**
Part Zone 9A																
Irrigation	0	0	1098	446	446	441	441	441	441	441	441	441	441	441	937	1646
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-area Total	**0**	**0**	**1098**	**446**	**446**	**441**	**441**	**441**	**441**	**441**	**441**	**441**	**441**	**441**	**937**	**1646**
Sub-area 2																
Irrigation	19384	20299	21657	21047	20813	19969	20113	19806	21013	20029	18440	19773	19062	16927	19322	19991
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
Sub-area Total	**19384**	**20299**	**21657**	**21047**	**20813**	**19969**	**20113**	**19806**	**21013**	**20029**	**18440**	**19773**	**19062**	**16927**	**19322**	**19991**
Sub-area 3																
Irrigation	5296	5168	5561	5386	6138	5962	6561	6709	6701	5785	6145	7554	7308	6292	6092	6049
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-area Total	**5296**	**5168**	**5561**	**5386**	**6138**	**5962**	**6561**	**6709**	**6701**	**5785**	**6145**	**7554**	**7308**	**6292**	**6092**	**6049**
Sub-area 5																
Irrigation	0	350	1829	1432	1556	1711	1323	1359	1175	1178	1225	1078	1041	1500	1500	1968
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
Sub-area Total	**0**	**350**	**1829**	**1432**	**1556**	**1711**	**1323**	**1359**	**1175**	**1178**	**1225**	**1078**	**1041**	**1500**	**1500**	**1968**
Sub-area 6																
Irrigation	1154	733	753	1058	1209	1469	1993	1951	2883	3100	3328	4194	4462	4044	4803	4648
Industrial and Recreational	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-area Total	**1154**	**733**	**753**	**1058**	**1209**	**1469**	**1993**	**1951**	**2883**	**3100**	**3328**	**4194**	**4462**	**4044**	**4803**	**4648**
Sub-area 7																
Irrigation	23622	23236	24828	24038	24647	24259	23856	22133	26745	26120	24298	27372	24380	24454	24674	25667
Industrial and Recreational	152	152	152	152	152	157	165	164	165	152	152	152	144	0	0	0
Sub-area Total	**23774**	**23388**	**24980**	**24190**	**24799**	**24416**	**24021**	**22297**	**26909**	**26272**	**24450**	**27524**	**24524**	**24454**	**24673***	**25667***
Annual Total	**54406**	**53078**	**59795**	**57596**	**59881**	**58601**	**58421**	**56304**	**61915**	**59628**	**56835**	**63821**	**59932**	**56305**	**60609**	**63442**

* includes old CAR for lucerne seed of 1.2

Table 3 *Tatiara PWA current PAVs, vertical recharge, allocation and usage (all in ML)*

Sub-area	PAV	Vertical Recharge	Allocation (1998/99)	Use (1998/99)	% of Used Allocation	Available Allocation
Part Zone 7A	7500	6000	7075	2679	38%	Closed
Zone 8A	7700	7720	5056	795	16%	Available
Part Zone 9A	4840	4840	3330	1646	49%	Available
Sub-area 2	28 120	[1]26 500	31 620	19 991	63%	Closed
Sub-area 3	10 000	15 040	10 583	6049	57%	Closed
Sub-area 5	4200	4200	4127	1968	48%	Closed
Sub-area 6	7400	7440	6646	4648	70%	Closed
Sub-area 7	20 310	19 260	20 914	[2]25 667	123%	Closed
Total	90 070	91 000	89 351	63 443	71%	

1. includes point source recharge component.
2. includes old CAR for lucerne seed of 1.2

Table 4 *Stock Use Tatiara PWA 1996/97*

Sub-area	Estimate Stock Water Use ML	Approximate Stock Numbers			
		Sheep	Dairy Cattle	Meat Cattle	Pigs
Part Zone 7A	250	66 520	625	3050	3880
Zone 8A	280	78 100	5	4870	270
Part Zone 9A	170	33 850	—	5145	—
Sub-area 2	590	162 420	1120	8670	2130
Sub-area 3	340	68 350	—	10 060	—
Sub-area 5	215	46 260	15	240	140
Sub-area 6	170	35 000	40	4330	305
Sub-area 7	285	70 000	—	6500	225
Total	2300	560 500	1805	45 025	6950

Current Demand

The total annual groundwater allocation for the 1998/1999 irrigation season for the Tatiara PWA was 89351 ML. Total groundwater usage for the PWA is estimated to be 63442 ML which represents approximately 71% of the total allocation. Table 3 is a break down of the PAVs, estimated rainfall recharge, 1998/99 allocation and water use figures on a sub-area basis. Vertical recharge figures are from Stadter and Love (1987) and Stadter *et al.*, (1995).

In Sub-area 2, 2300 ML are included in the vertical recharge calculation as a contribution from preferred flow path recharge (ie. runaway holes).

Estimated stock water use and the corresponding approximate stock numbers for the 1996/97 season are shown in Table 4. The data were obtained from the Australian Bureau of Statistics Hobart. Daily stock consumption figures were based on data from the NSW Department of Agriculture and are given in Appendix C. The stock use estimates are to the nearest 5 ML. Total annual stock use for the PWA is estimated to be 2300 ML.

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.

There are five town water supply wells located west of Bordertown. Combined water use from the wells between 1991/1992 and 1998/1999 ranged from 545 to 621 ML/yr. The use for 1998/1999 was 621 ML, which is approximately 0.5% of the total allocation for the PWA. Keith township receives its water from the Murray River. Total water usage for Keith township was 347 ML during the 1998/1999 season.

In Sub-area Part Zone 7A the PAV is 7500 ML/yr. This is the total allocation for the whole of Zone 7A. The PAV should be ~6000 ML, but this figure will have to be verified by hydrogeological assessment.

In Sub-area 3, the Hundred of Willalooka, the PAV was set at 10000 ML/yr even though the rainfall recharge rate was calculated to be 15040 ML. It was not increased because there was evidence that suggested salinity stratification is occurring in the unconfined aquifer in this area (Stadter and Love, 1987). Here poor quality groundwater at the top of the aquifer (>8000 mg/L) is separated from better quality water at depth by a marl in the Padthaway Formation. Increased groundwater extraction would exacerbate downward leakage of this more saline water hence following discussion with the community it was agreed to adopt a lower figure as a conservative approach.

Future Demand

In two sub-areas (Zone 8A and Part Zone 9A) allocations have not reached the PAV limit. Only Zone 8A has been included in the pro-rata roll out however because there were sufficient applications at the time of determination to take allocation up to the PAV threshold in part Zone 9A. Existing allocations, stock and domestic use, expected plantation expansion and the environment were considered as part of the pro-rata rollout assessment for Zone 8A (Table 5).

Most of Zone 8A is used only for sheep grazing. There is some evidence to suggest water use is increasing in the area but it is still only around 16% of the allocation.

The remaining sub-areas all have significant percentages of allocation unused (Table 3). This is particularly concerning in Sub-area 3, the Hundred of Willalooka. Declining water levels and increasing groundwater salinity would suggest current levels of extraction are not sustainable.

Whilst stock numbers will change with seasons and market conditions such changes will have only a small effect on the relative magnitude of groundwater use.

SA Water believe that Bordertown's water use has stabilised and forecast a maximum annual usage over the next five years at 700 ML.

CONFINED AQUIFER

Historical Demand

The confined aquifer has not been previously utilised in this PWA.

Current Demand

There is only one known well that extracts water from the confined aquifer. Unfortunately water allocation and water use figures are not available for the confined aquifer.

Future Demand

The proposed PAVs for the confined aquifer for both South Australia and Victoria are presented in Table 6. The management zones are shown on Figure 13.

As the depth to the confined aquifer is an economically an expensive exercise when compared to the relatively shallow depths of the unconfined aquifer there is little likelihood that there will be any future demand for the aquifer. Wells in this area are known to produce fine sand therefore it is unlikely that the confined aquifer will be actively targetted in the immediate future.

WATER BALANCE

UNCONFINED AQUIFER

A water balance has been determined for each sub-area in the Tatiara PWA. The figures are based on a water balance undertaken by Stadter and Love (1987). The main differences from the earlier budget are that changes in storage and the adjustments to sub-areas as a result of the inclusion of the Border Zones have been taken into account (Table 7). Lateral inflow and outflow calculations were estimated using flow-net analysis.

Annual rainfall recharge to Sub-area Part Zone 7A has been taken as 6000 ML/yr. The method used to estimate rainfall recharge was to assess the relationship between seasonal changes in groundwater level (measured from hydrographs) and an assumed specific yield of 0.1. Each sub-area was classified into recharge zones according to soil type, morphology and hydrogeological condition. These recharge zones were further subdivided to reflect depth characteristics of soil types, depth to water and vegetation cover.

Groundwater use figures are for the 1998/1999 irrigation season (these are not the total allocation figures). Where applicable they include the total irrigation use, industrial and recreational use for each sub-area.

Table 5 *Pro-Rata determination for Sub-areas in the Tatiara PWA*

Zone	Adopted 1996 PAV (ML)	Existing Allocation (ML)	Stock Use (ML)	Dom. Use (ML)	Town Use (ML)	Forrestry Commitment (ML)	Environmental Commitment (ML)[1]	Volume Available for Pro-Rata Allocation (ML)
Zone 8A	7700	6120	198	92	0	0	0	1290

1. No part of the adopted PAV has been taken for environmental requirements

Table 6 *Proposed PAVs for the TCSA in South Australia and Victoria*

South Australian Management Areas	Proposed PAV (ML/yr)	Victorian Management Areas	Proposed PAV (ML/yr)
1A	9 200	1B	14 400
2A	2 900	2B	5 100
3A	1 900	3B	1 100
4A	690	4B	300
5A	550	5B	550
6A	350	6B	350
7A	350	7B	350
8A	340	8B	340
9A	570	9B	630
10A	320	10B	560
11A	0	11B	0
Copeville	940	Dartmoor	18 600
Karoonda	1 500	Goroke	2 200
Keith	2 500	Kaniva	1 000
Kingston	24 972	Little Desert	1 100
Lameroo	1 200	Nhill	1 200
Millicent	12 000		
Mindarie	780		
Monbulla	4 300		
Naracoorte	3 900		
Wirrega	960		

1. For the proposed PAVs where the volume is less than 1000 ML, the PAV has been rounded upwards to the nearest 10 ML.
2. For the proposed PAVs where the volume is greater than 1000 ML, the PAV has been rounded upwards to the nearest 100 ML.
3. The northern parts of Zones 11A and 11B contain saline groundwater with a salinity greater than 3000 mg/L. The determined volumes for the areas where the TDS is less than 3000 mg/L are insignificant (less than 100 ML).

Table 7 *Water Balance for Tatiara PWA*

	Sub-area								
Inputs	**Pt Zone 7A**	**Zone 8A**	**Pt Zone 9A**	**Sub-Area 2**	**Sub-Area 3**	**Sub-Area 5**	**Sub-Area 6**	**Sub-Area 7**	**Totals**
Groundwater Inflow	8830	3650	3560	11 980	28 040	14 590	12130	25 040	
Rainfall Recharge	6000	7720	4840	26 500	15 040	4200	7440	19 260	
Total In									198 820
Outputs	**Pt Zone 7A**	**Zone 8A**	**Pt Zone 9A**	**Sub-Area 2**	**Sub-Area 3**	**Sub-Area 5**	**Sub-Area 6**	**Sub-Area 7**	**Totals**
Groundwater Outflow	9830	16 545	14 610	31 680	36 525	9590	5190	7440	
Groundwater Use (1998/99)	2680	795	1645	19 990	6050	1970	4650	18 000[1]	
Total Out									186 190

1. Estimation based on changes to CAR system.

The water budget would suggest that the Tatiara PWA is approximately in balance (Table 7). However it does not take into account the ~1 m reduction in water levels in the north-west portion of the PWA. If it were included, the water budget would not balance. There are a number of possible explanations for this discrepancy but it is probably a result of the previously highlighted underestimation in groundwater usage.

The decline in groundwater levels in Sub-area 7 would suggest that groundwater extraction is exceeding vertical recharge. The affect this is having on the groundwater resource, particularly the deterioration in groundwater quality in the sub-area, is well documented. Its potential effects down-gradient of the densely irrigated areas are also noted.

CONFINED AQUIFER

As previously discussed the proposed PAVs for the management zones for the confined aquifer are presented in Table 6.

POTENTIAL IMPACTS THE USE OR TAKING OF WATER FROM ONE RESOURCE MAY HAVE ON ANOTHER RESOURCE

The potential detrimental impacts taking, or using, water from one resource may have on the quantity or quality of water of another resource in the Tatiara PWA were considered in the following situations:

- the impact of using surface water to artificially replenish the groundwater system.
- the impact taking groundwater from the unconfined aquifer may have on the confined aquifer.
- the impact taking groundwater from the confined aquifer may have on the unconfined aquifer.

In all three scenarios consideration was also given to the impacts extraction may have across management boundaries.

THE IMPACT OF USING SURFACE WATER TO ARTIFICIALLY REPLENISH THE GROUNDWATER SYSTEM

The unconfined aquifer receives most of its recharge via diffuse percolation of rainfall through the soil profile and unsaturated zone. However, during high rainfall events surface water in the form of run-off also enters the aquifer directly. In the Tatiara PWA, Poochers Swamp and Mundulla Swamp are the two main areas that naturally recharge the unconfined aquifer. There are also a number of smaller sites that also recharge the aquifer. Some of these occur naturally such as sinkholes whilst others are man-made drainage wells. The main purpose of the man-made wells is to relieve surface flooding. Distinguishing between what is naturally occurring and man-made can be somewhat arbitrary.

Herczeg *et al.*, (1997) undertook a study of point source recharge at a number of sites in the South East region. One of the selected sites was Poochers Swamp. Results from their study showed that recharge to the unconfined aquifer was only detectable on a local scale (less than 500 m) and that groundwater mounds arising from point source recharge dissipate within 2–4 months after the cessation of rainfall. They also showed that even though the salinity of the surface water entering into the aquifer is very low, it does not however affect the regional groundwater salinity.

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 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.

It is concluded therefore that the addition of surface water to artificially replenish the groundwater system would have only minimal effects on groundwater levels and salinity in the unconfined aquifer.

THE IMPACT TAKING OR USING GROUNDWATER FROM THE UNCONFINED AQUIFER MAY HAVE ON THE CONFINED AQUIFER AND ADJACENT PWAs

The aquitard which separates the unconfined and confined aquifers in the Tatiara PWA is generally more than 20 metres thick and has a very low vertical permeability. While the potential for recharge exists (ie. the head in the unconfined is higher than the head in the confined aquifer) 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.

There are only a few examples in the South East region where the extraction from the unconfined aquifer has impacted across management boundaries. One such example may exist in the Tatiara PWA. In Sub-area 7, the Hundred of Stirling, long-term water level decline of more than 5 cm/yr have been occurring over a large portion of the sub-area. However a similar decline is also being experienced in the northern portion of Sub-area 3, the Hundred of Willalooka and the north-western part of Sub-area 2, in the Hundred of Wirrega. Whether this is due to an expansion of a drawdown cone emanating from the Hundred of Stirling or whether the long-term decline in the remaining Hundreds is a local phenomenon has not been ascertained.

In the long-term, a decline in groundwater quality is expected down-gradient of the densely irrigated area in Sub-area 7. This would occur outside the Tatiara PWA with the largest impact expected in the eastern portion of the Hundred of Laffer and possibly in the Tintinara-Coonalpyn moratorium area.

THE IMPACT TAKING OR USING GROUNDWATER FROM THE CONFINED AQUIFER MAY HAVE ON THE 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 impact on the unconfined aquifer.

If groundwater were to be taken from the confined aquifer then the only foreseeable way it could effect the unconfined aquifer would be if the water from the confined aquifer were added to the unconfined aquifer. In this scenario, there may be a volumetric effect, due to the increased quantity of water applied to the unconfined aquifer, and possibly a quality effect due to the addition of salts. As the groundwater in the confined aquifer generally has a lower salinity than the unconfined aquifer, the addition of an extra salt load is a minor issue. The application of an additional supply of water is unlikely to have any long-term effect on the unconfined aquifer in the Tatiara PWA, given the minimal response witnessed during point source recharge from surface recharge events.

CONCLUSIONS

An unconfined aquifer water balance calculated for the Tatiara PWA would suggest that the area is approximately in balance if it were not for a significant decline in water levels in the densely irrigated western portion of the PWA.

Groundwater salinity monitoring since the mid-1970s indicates a significant increase in groundwater salinity in Sub-area 7, the Hundred of Stirling. Groundwater recycling due to overuse is believed to be the main cause of the salinity increase in this area. In the eastern highlands the water table is rising slightly, as is the groundwater salinity. Increased recharge following land clearance is considered to be responsible for these trends.

In Sub-area 7, the Hundred of Stirling the PAV was voluntarily cut by 35% at the beginning of the 1997/98 irrigation season. At this time the crop area ratio was changed for lucerne seed to compensate for the reduction.

Generally the water level and salinity monitoring networks are adequate for the Tatiara PWA.

The potential impacts of using one water resource would have on another were considered only minor in the Tatiara PWA. However there are potential down-gradient impacts from the densely irrigated area in the western portion of the PWA.

RECOMMENDATIONS

The following recommendations are made:

- obtain accurate water extraction figures particularly in relation to flood irrigation practices.
- increase the unconfined aquifer salinity monitoring network in the southern portion of the PWA,
- increase the unconfined aquifer water level monitoring network in Sub-area Part Zone 9A,
- a study to assess potential salinity increases in the eastern highlands area,
- if the confined aquifer is to be targetted for future use then the confined aquifer network should also be increased.

REFERENCES

Department of Environment and Natural Resources, 1997. *Tatiara Prescribed Wells Area draft groundwater management plan. Adelaide, South Australia.*

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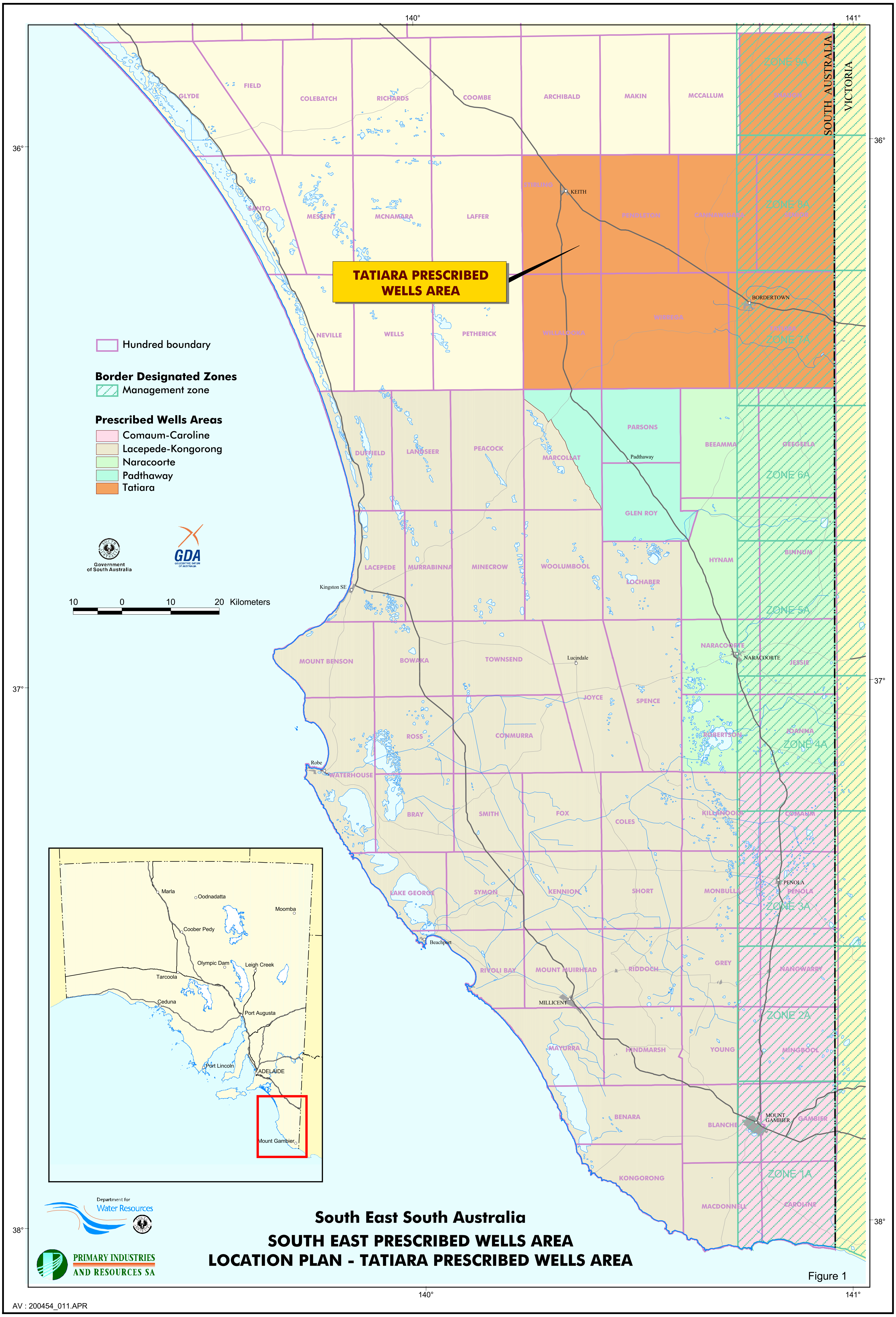
Stadter, F., Bradley, J., DeSilva, J., Foley, G., Robinson, M., 1995. *Five year technical review 1991–1995 Border (Groundwater Agreement) Act, 1985.*

Stadter. F., Love, A., 1987. Tatiara Proclaimed Region groundwater assessment. *Department of Mines and Energy South Australia. Report Book 87/87.*

Stadter, M.H., 1984. Keith-Willalooka-Bordertown irrigation area investigation. Progress report No. 2. *Department of Mines and Energy South Australia. Report Book No. 84/29.*

Figures



TATIARA PRESCRIBED WELLS AREA
Hundred boundary
Border Designated Zones
Management zone
Prescribed Wells Areas
Comaum-Caroline
Lacepede-Kongorong
Naracoorte
Padthaway
Tatiara
Government of South Australia
GDA
10 0 10 20 Kilometers
140°
141°
36°
37°
38°
SOUTH AUSTRALIA
VICTORIA
GLYDE
FIELD
COLEBATCH
RICHARDS
COOMBE
ARCHIBALD
MAKIN
MCCALLUM
SHAUGH
ZONE 9A
SANTO
MESSENT
MCNAMARA
LAFFER
STIRLING
KEITH
PENDLETON
CANNAWIGARA
ZONE 8A
SENIOR
BORDERTOWN
NEVILLE
WELLS
PETHERICK
WILLALOOKA
WIRREGA
TATIARA
ZONE 7A
DUFFIELD
LANDSEER
PEACOCK
MARCOLLAT
PARSONS
Padthaway
BEEAMMA
GEEGEELA
ZONE 6A
GLEN ROY
LACEPEDE
MURRABINNA
MINECROW
WOOLUMBOOL
LOCHABER
HYNAM
BINNUM
Kingston SE
ZONE 5A
MOUNT BENSON
BOWAKA
TOWNSEND
Lucindale
NARACOORTE
JESSIE
JOYCE
SPENCE
ROSS
CONMURRA
ROBERTSON
JOANNA
ZONE 4A
Robe
WATERHOUSE
BRAY
SMITH
FOX
COLES
KILLANOOLA
COMAUM
LAKE GEORGE
SYMON
KENNION
SHORT
MONBULLA
PENOLA
ZONE 3A
Beachport
RIVOLI BAY
MOUNT MUIRHEAD
RIDDOCH
GREY
NANGWARRY
MILLICENT
ZONE 2A
MAYURRA
HINDMARSH
YOUNG
MINGBOOL
BENARA
BLANCHE
MOUNT GAMBIER
GAMBIER
ZONE 1A
KONGORONG
MACDONNELL
CAROLINE
Marla
Oodnadatta
Moomba
Coober Pedy
Olympic Dam
Leigh Creek
Tarcoola
Ceduna
Port Augusta
Port Lincoln
ADELAIDE
Mount Gambier
Department for Water Resources
PRIMARY INDUSTRIES AND RESOURCES SA
South East South Australia
SOUTH EAST PRESCRIBED WELLS AREA
LOCATION PLAN - TATIARA PRESCRIBED WELLS AREA
Figure 1
AV : 200454_011.APR

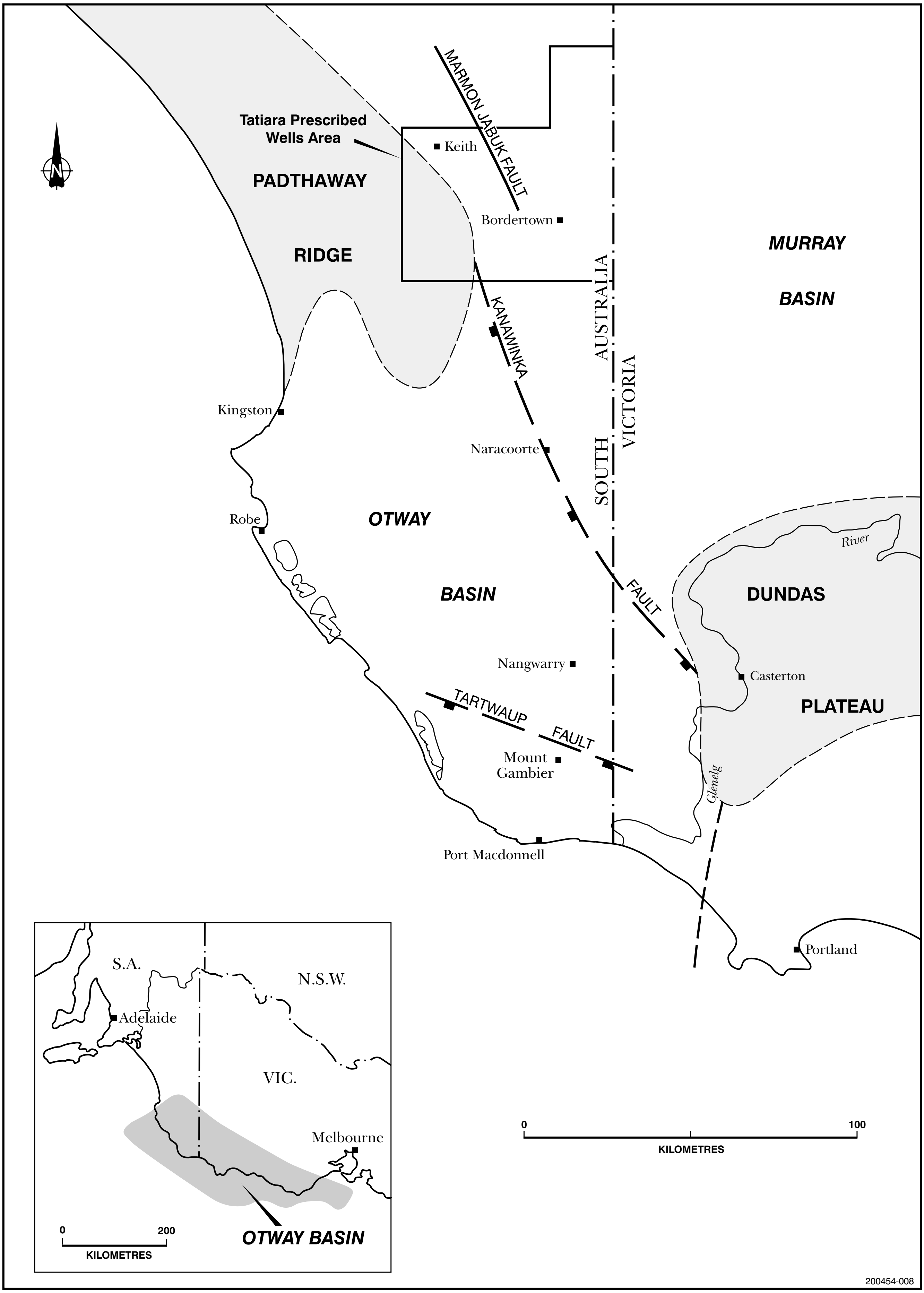


Figure 2 *Geological provinces in the South East Region.*

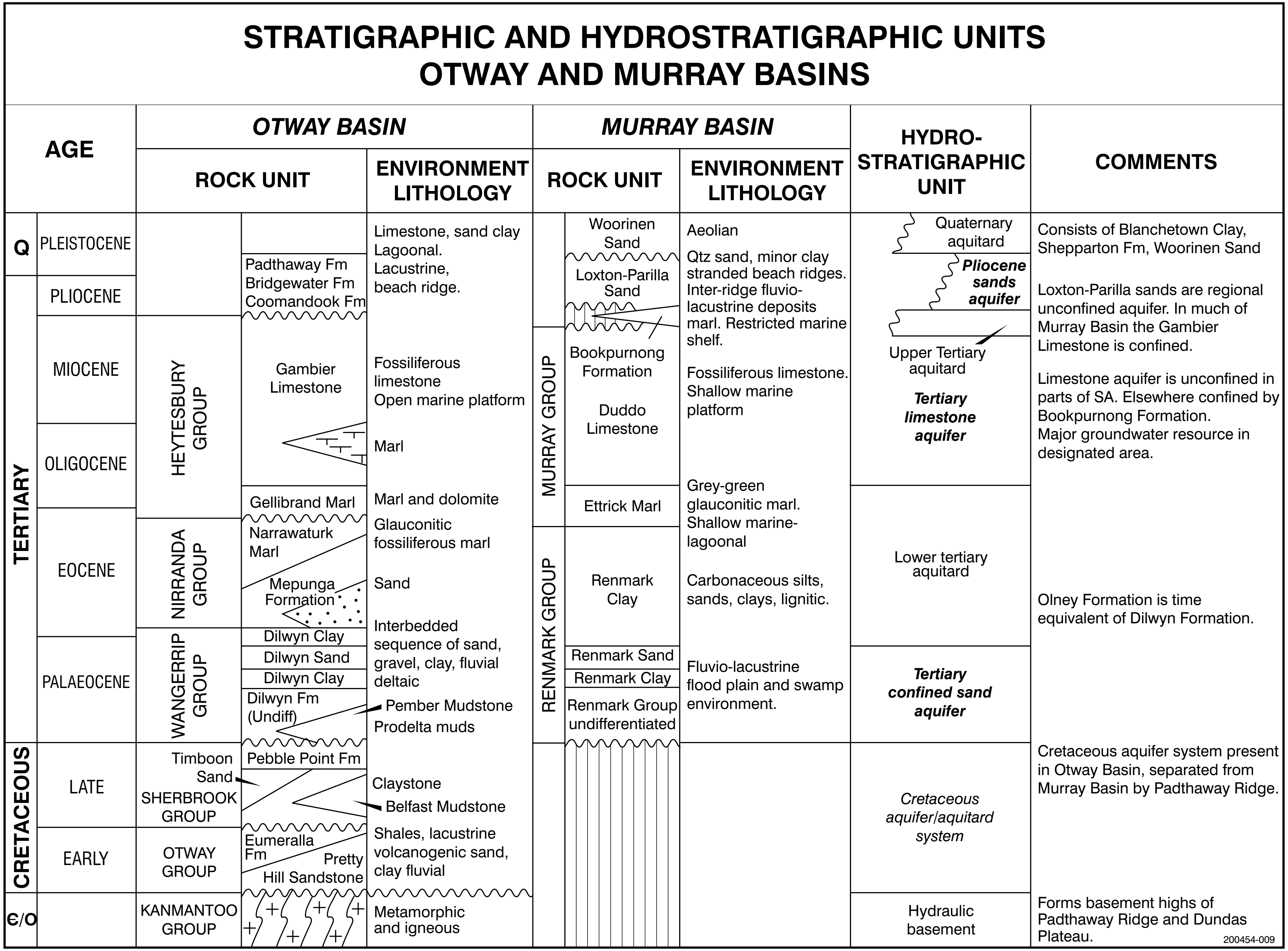
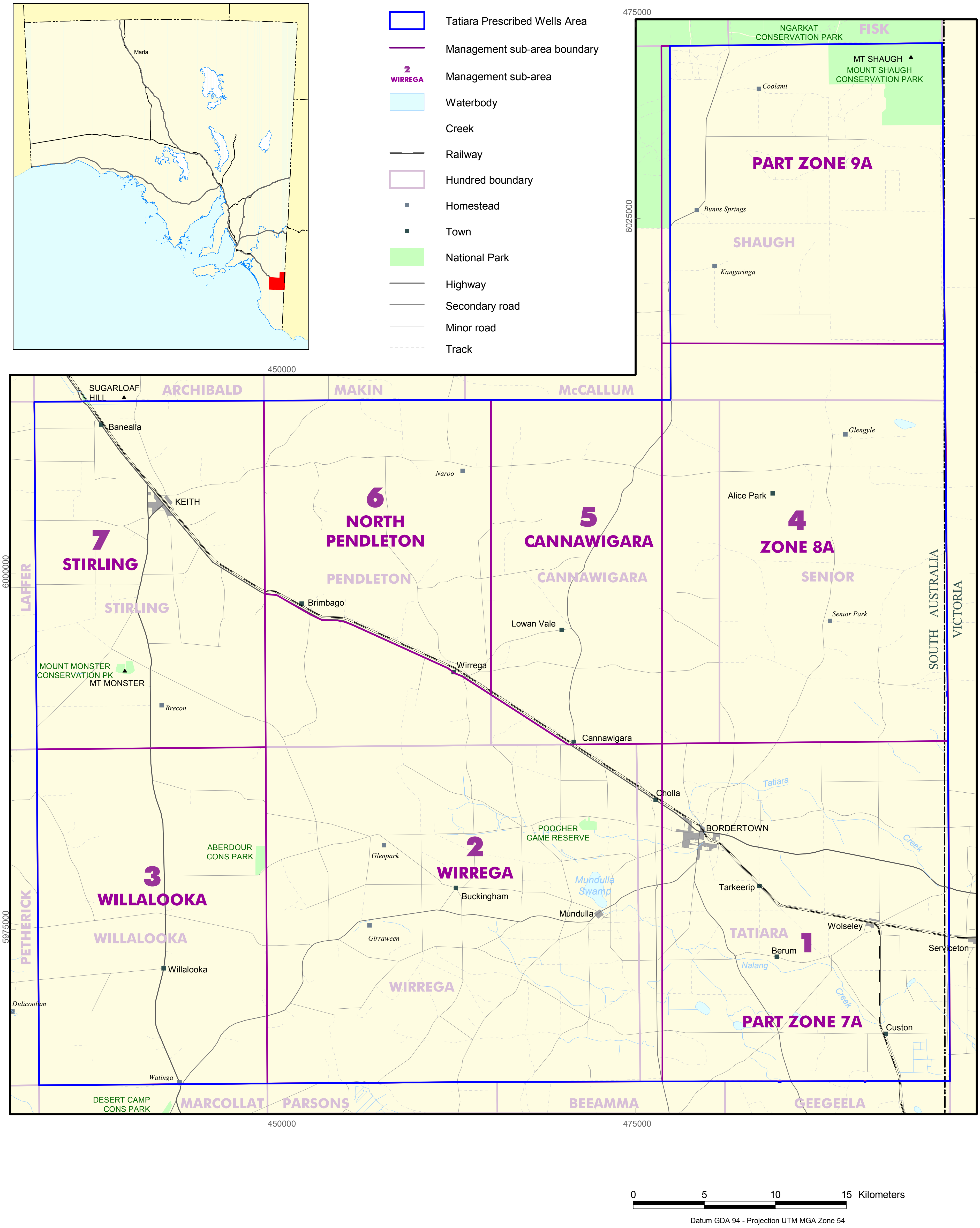


***Figure 3** Stratigraphic and hydrostratigraphic units of the Otway and Murray Basins.*



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AV3: 200454-012

Tatiara Prescribed Wells Area

GROUNDWATER SUB-AREAS IN THE TATIARA PWA

GDA

Government of South Australia

Figure 4

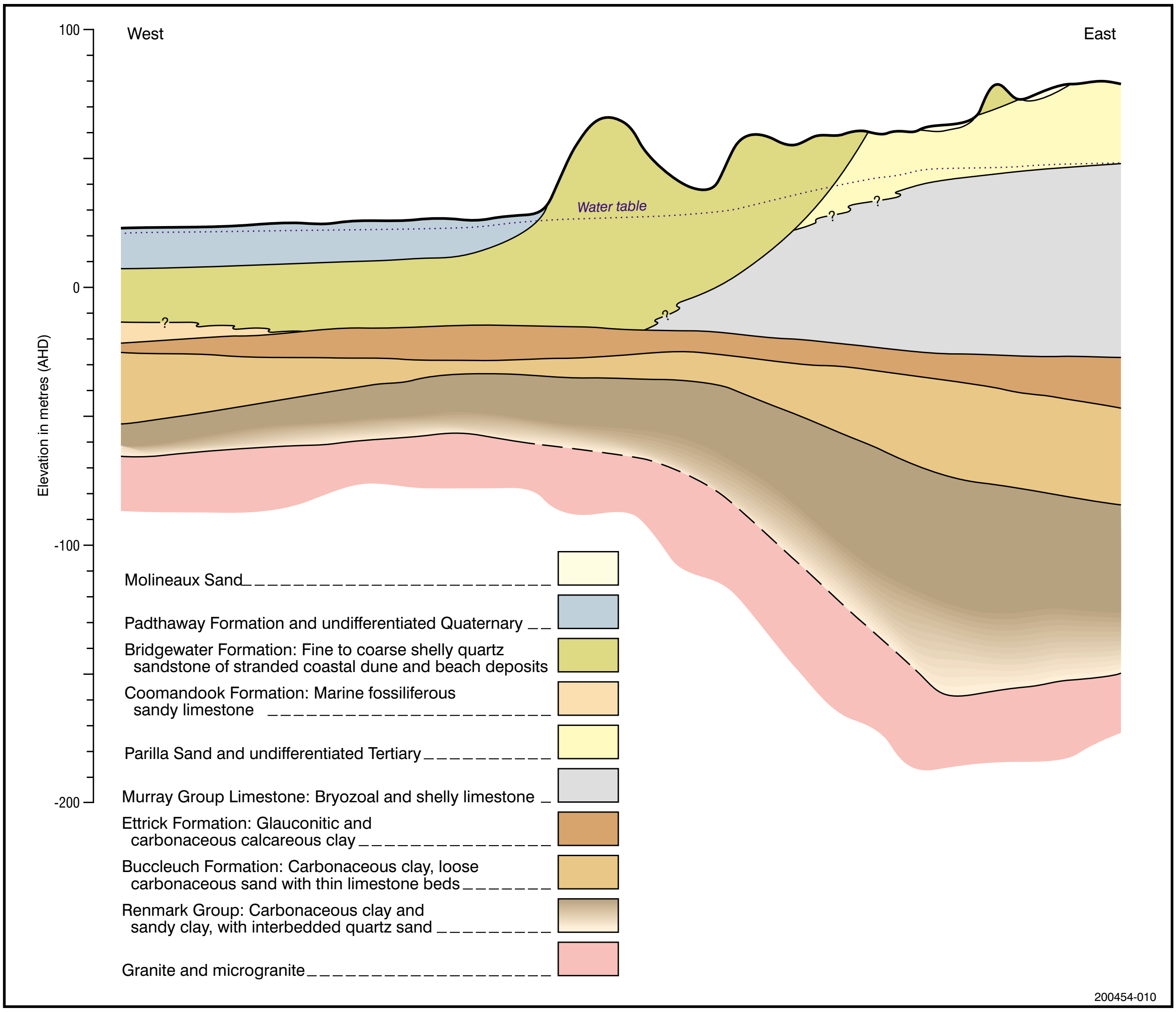
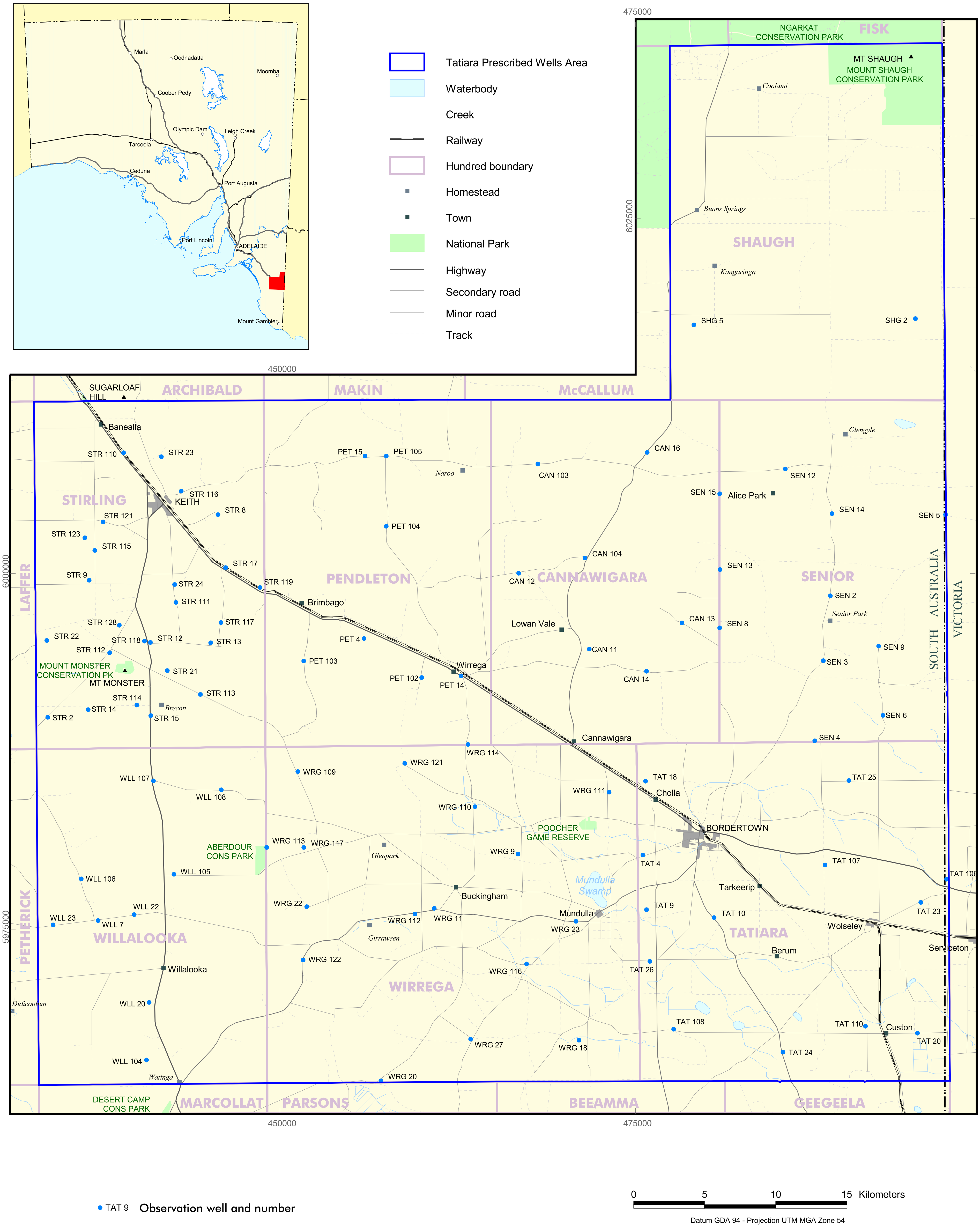


Figure 5 *Schematic east-west geological cross section of the Tatiara PWA.*



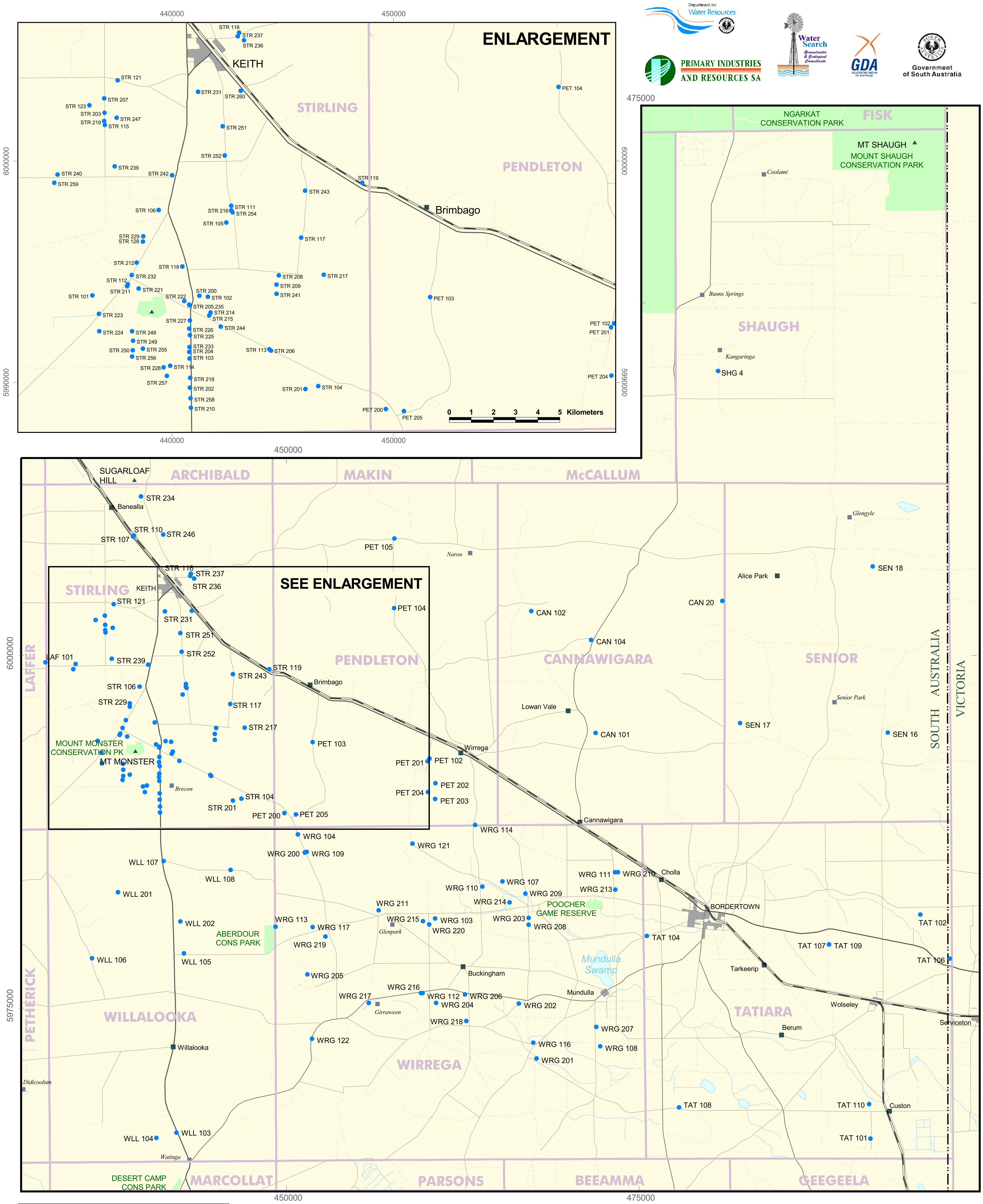
TATIARA PRESCRIBED WELLS AREA

LOCATION OF CURRENT WATER LEVEL MONITORING WELLS JUNE2000

AV3: 200454-013

Figure 6

ORIGINALLY AV3: 200164-002



• TAT 108 Observation well number

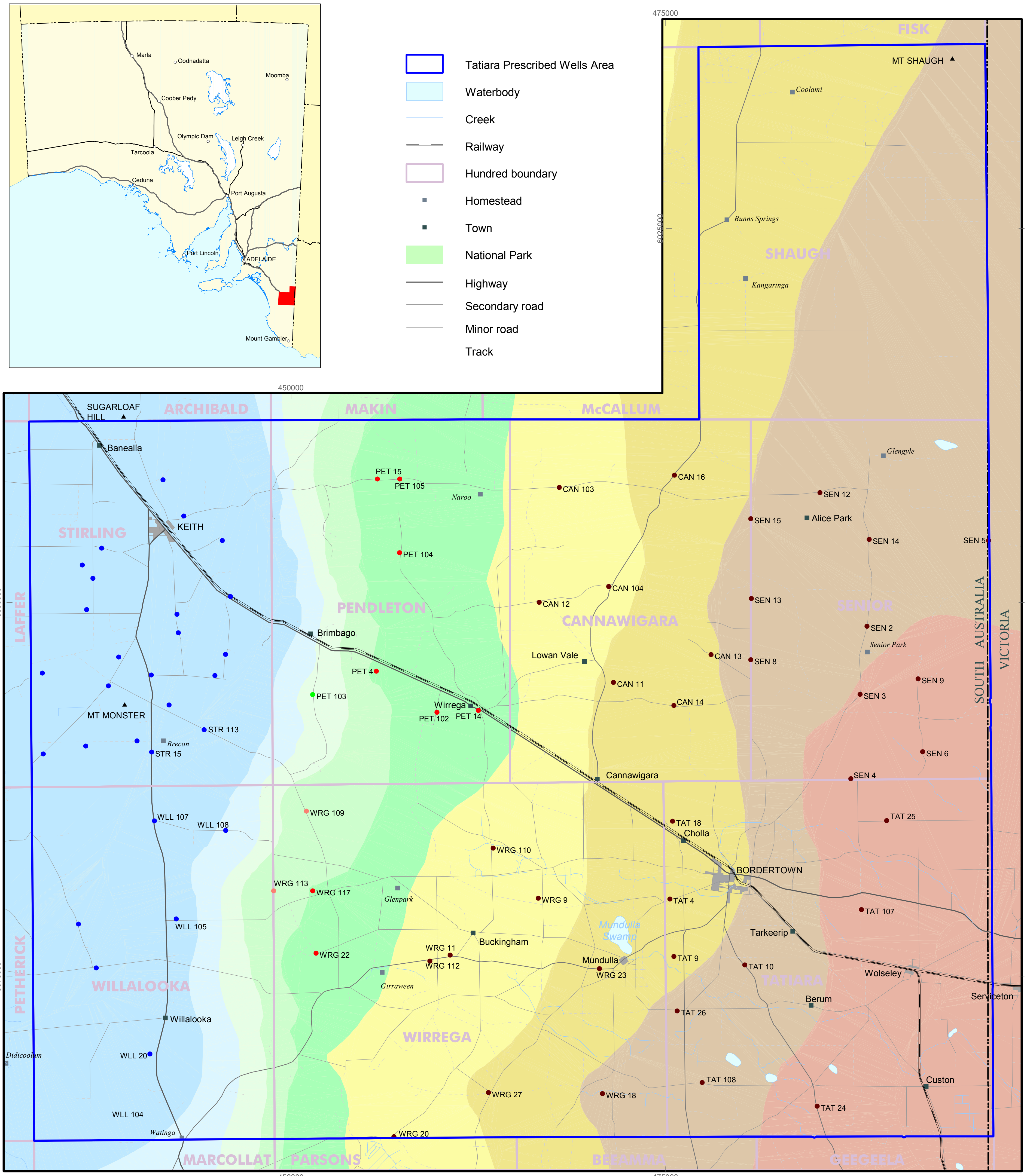
Figure 7

TATIARA PRESCRIBED WELLS AREA

LOCATION OF CURRENT SALINITY OBSERVATION WELLS JUNE 2000

AV3: 200454-014

AV3: 200164-003



Water table elevation - m (AHD)	
●	20 - 30
●	30 - 35
●	35 - 40
●	40 - 45
●	45 - 50
●	50 - 70

Water table elevation -m (AHD)
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70

0 5 10 15 Kilometers

Datum GDA 94 - Projection UTM MGA Zone 54

Water Search

Department for Water Resources

PRIMARY INDUSTRIES AND RESOURCES SA

AV3: 200454-015

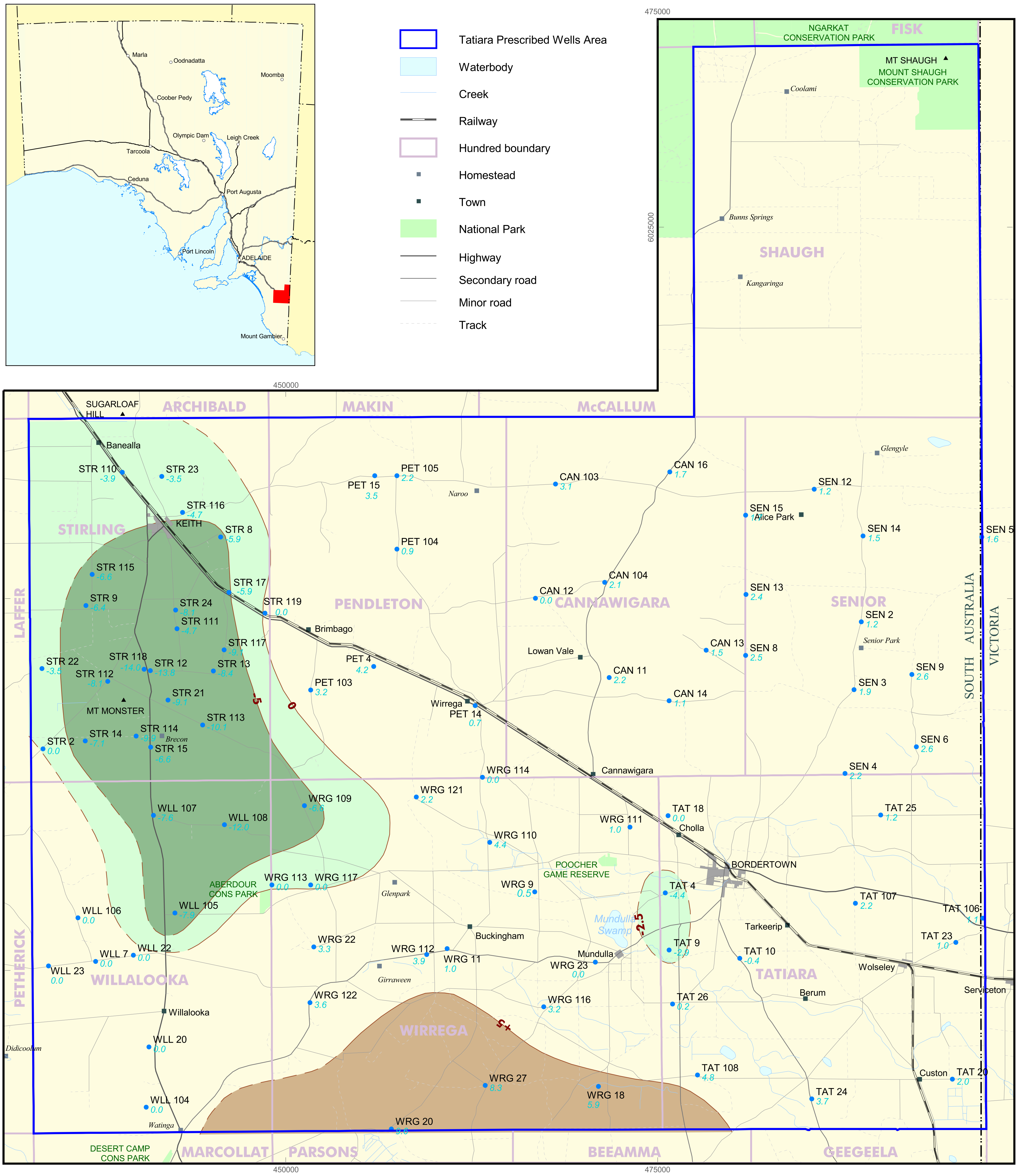
Tatiara Prescribed Wells Area

GENERALISED WATER TABLE ELEVATION ZONES IN THE UNCONFINED AQUIFER

GDA

Government of South Australia

Figure 8



Groundwater level trends (cm/year)

Rising

- Greater than +5
- 0 to +5

Declining

- 0 to -5
- Greater than -5

- Groundwater level trend contour in metres per year (cm/year)
- SEN 4 Observation well and number
- 2.2 Annual groundwater level trend (cm/year)

0 5 10 15 Kilometers

Datum GDA 94 - Projection UTM MGA Zone 54

Water Search Groundwater & Geological Consultants

Department of Water Resources

PRIMARY INDUSTRIES AND RESOURCES SA

AV3: 200454-016

TATIARA PRESCRIBED WELLS AREA

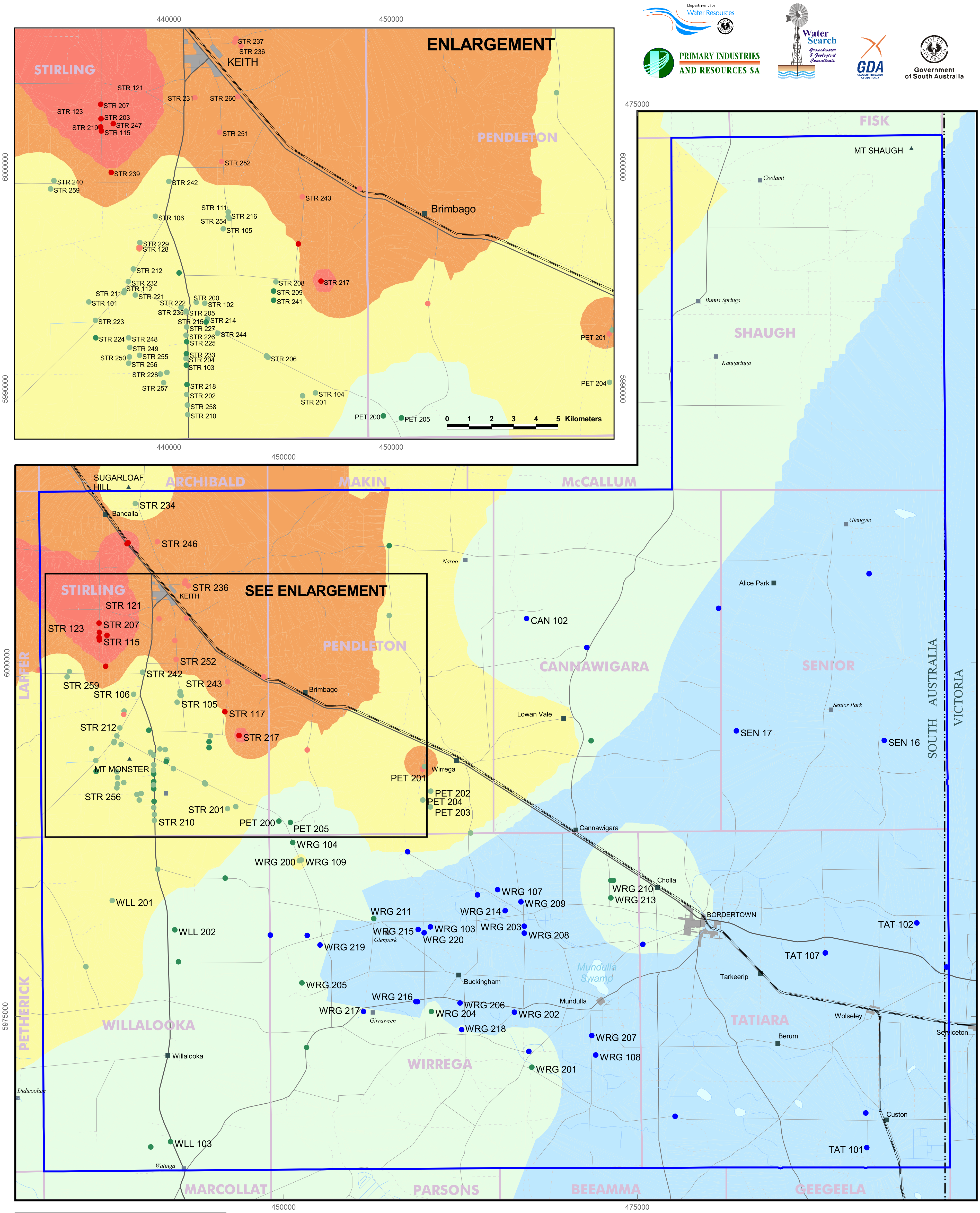
WATER LEVEL TRENDS IN THE UNCONFINED AQUIFER AT END OF 1998-1999 IRRIGATION SEASON

GDA

Government of South Australia

Figure 9

ORIGINALLY AV3: 200164-005



Salinity (mg/L)

- 0 - 2000
- 2000 - 3000
- 3000 - 5000
- 5000 - 7000
- 7000 - 10000

Salinity zones (mg/L)

- 0 - 2000
- 2000 - 3000
- 3000 - 5000
- 5000 - 7000
- 7000 - 10000

0 5 10 15 Kilometers

Datum GDA 94 - Projection UTM MGA Zone 54

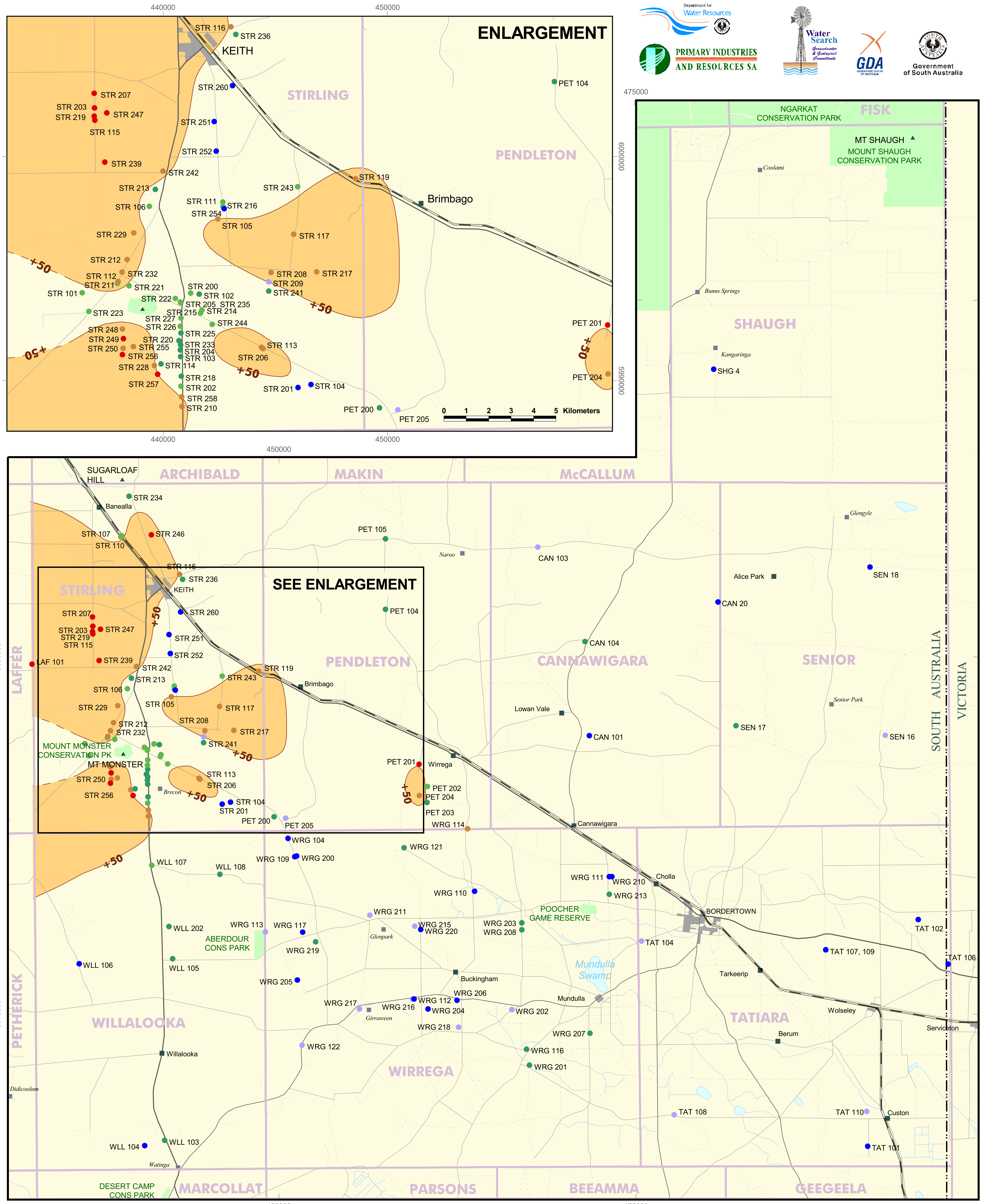
Figure 10

Tatiara Prescribed Wells Area

GENERALISED SALINITY DISTRIBUTION IN THE UNCONFINED AQUIFER

AV3: 200454-017

Originally AV3: 200164-006



Annual salinity trends (mg/L)

Decreasing
- -50 to 0

Increasing
- 0 to 10
- 10 to 30
- 30 to 50
- 50 to 100
- Greater than 100

Annual salinity trend contour - mg/L (calculated from linear regression of all available data at end of 1998-1999 irrigation season)

Salinity increase greater than 50mg/L per year

SHG 4 Observation well number

0 5 10 15 Kilometers

Datum GDA 94 - Projection UTM MGA Zone 54

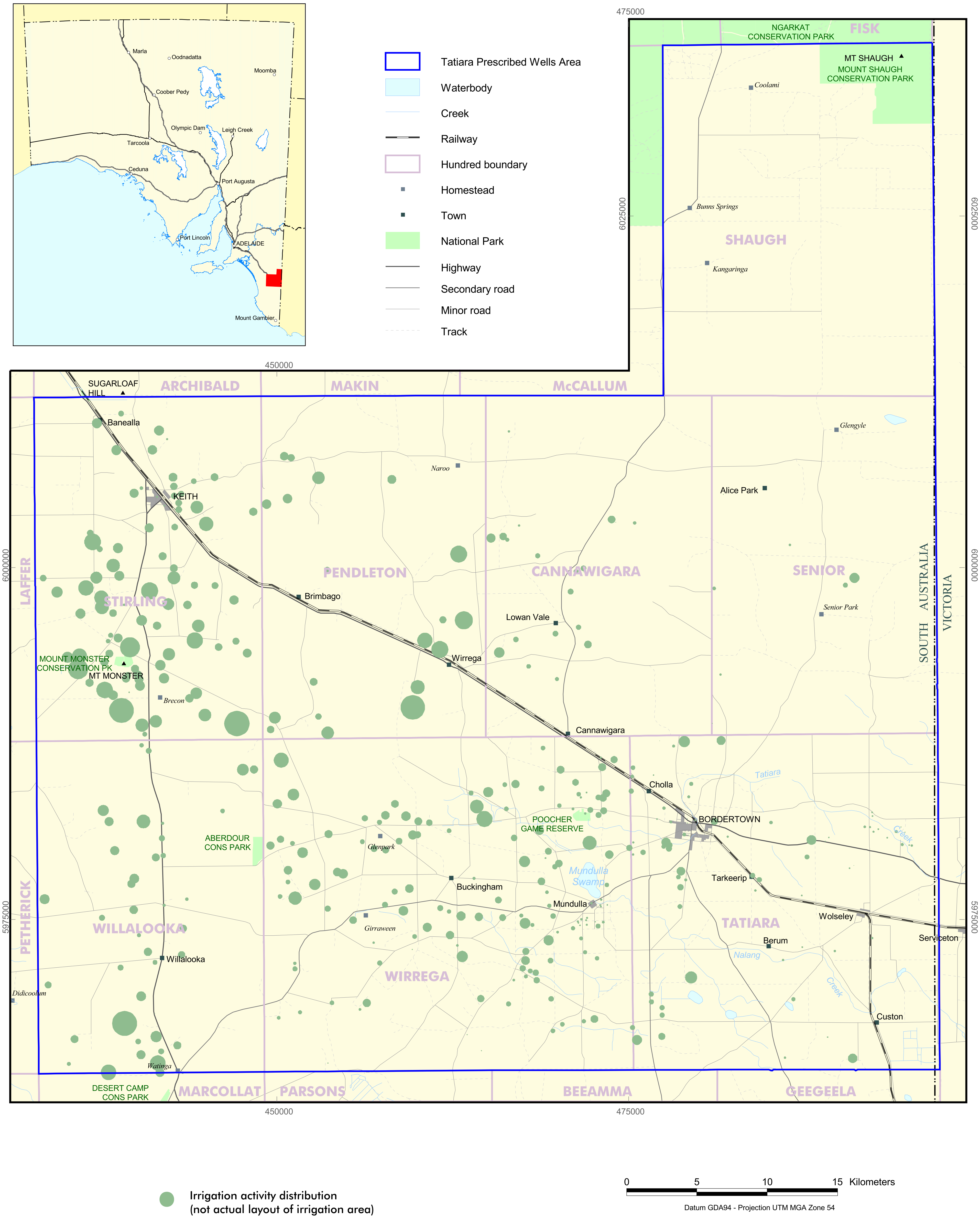
Figure 11

TATIARA PRESCRIBED WELLS AREA

SALINITY TRENDS IN THE UNCONFINED AQUIFER AT END OF 1998-1999 IRRIGATION SEASON

AV3: 200454-018

ORIGINALLY AV3: 200164-007



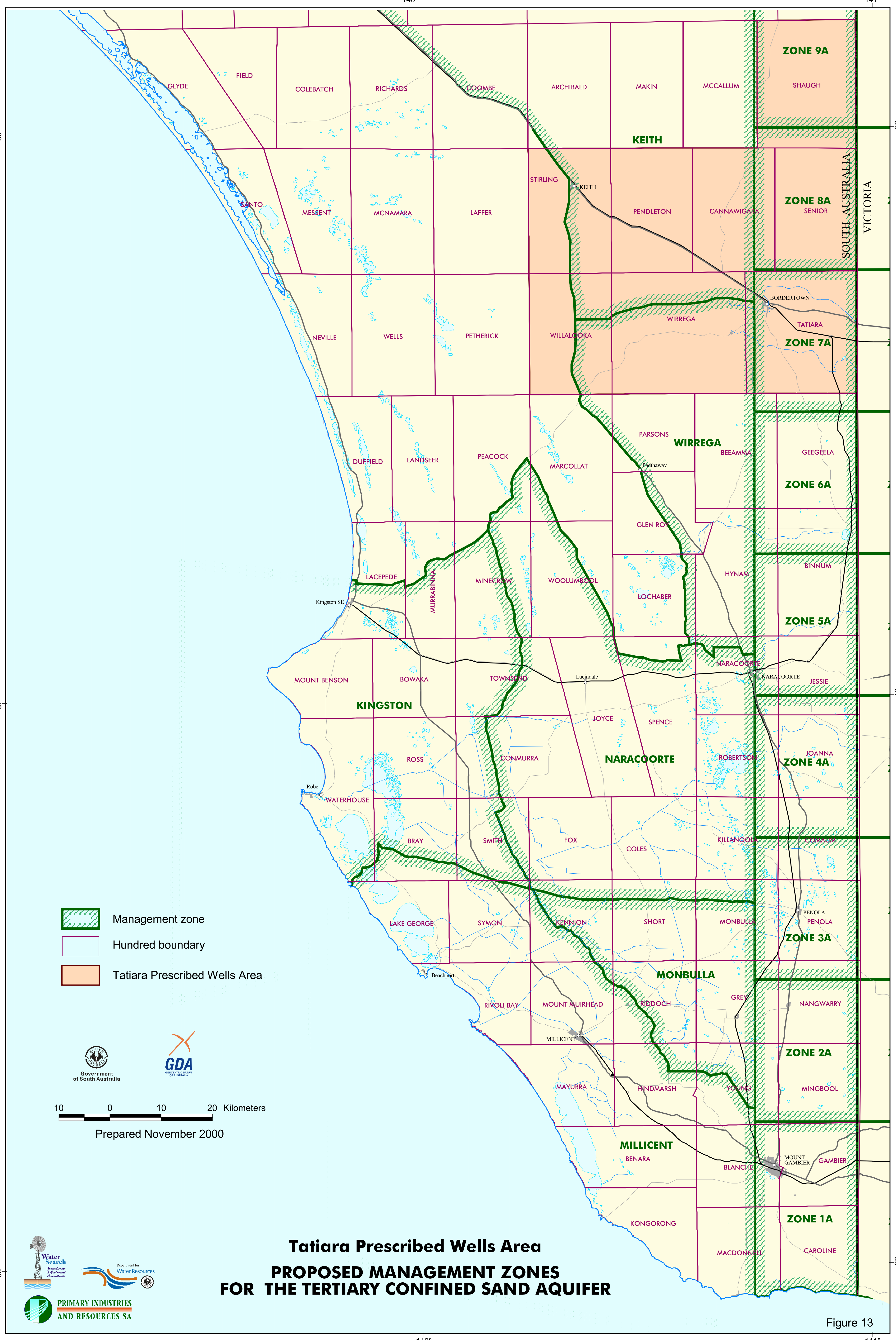
AV3: 200454-019

TATIARA PRESCRIBED WELLS AREA

IRRIGATION ACTIVITY DISTRIBUTION FOR 1998-1999 IRRIGATION SEASON

Figure 12

ORIGINALLY AV3: 200164-008



Tatiara Prescribed Wells Area

PROPOSED MANAGEMENT ZONES FOR THE TERTIARY CONFINED SAND AQUIFER

Figure 13

AV : 200454_058

Appendix A

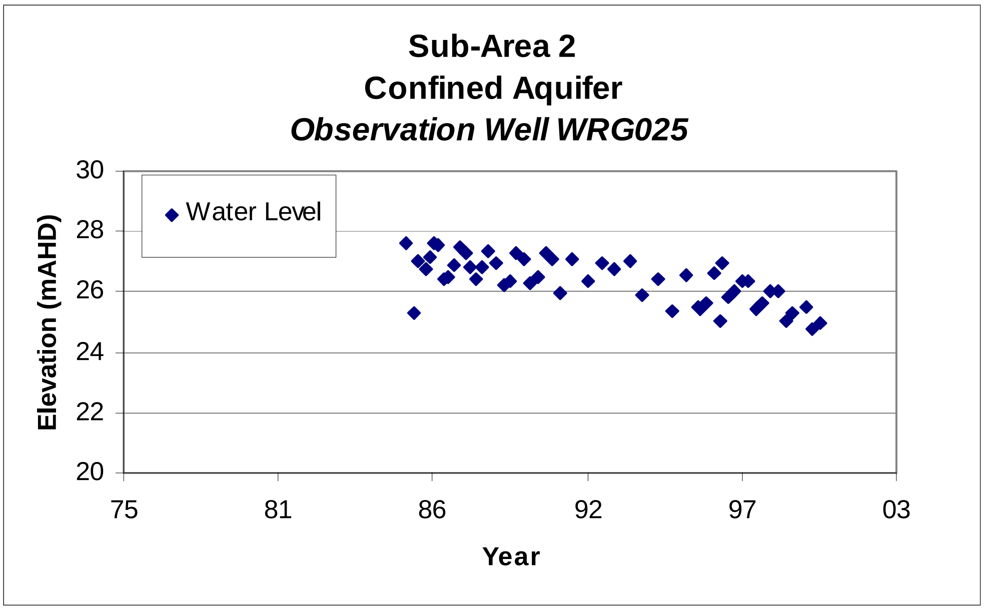
Estimated irrigation requirements and crop area ratios

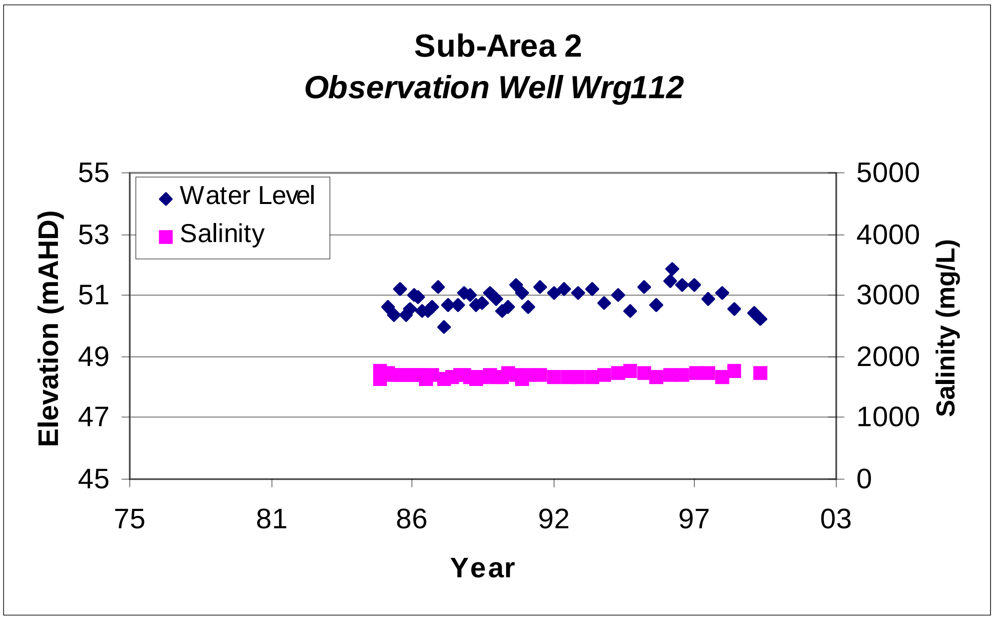
for the Tatiara Prescribed Wells Area

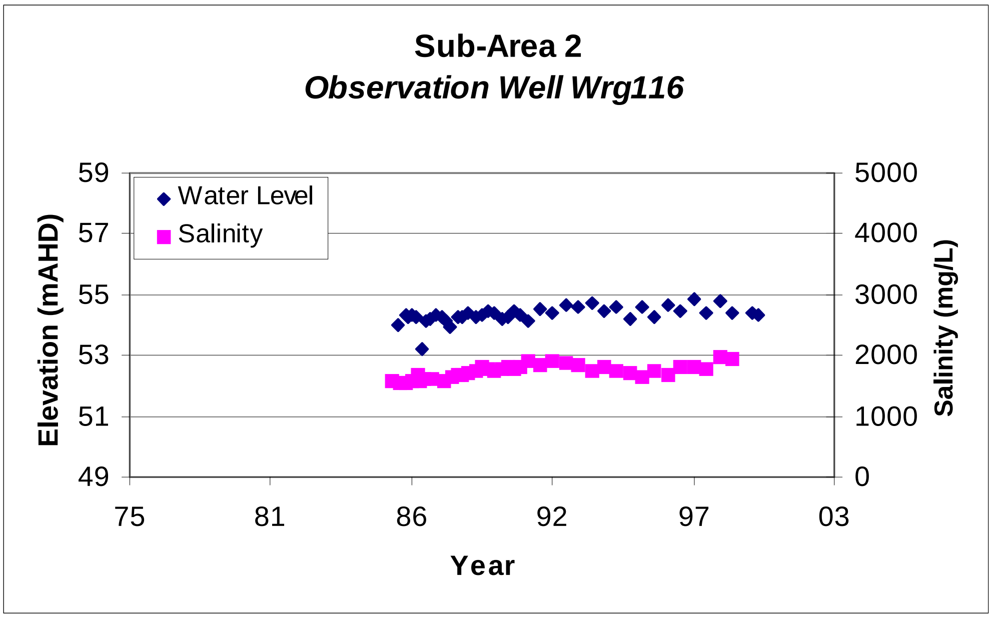
Crop Area	Irrigation Requirement (mm)	Crop Ratio
Reference crop	634	1.0
Annual clover seed	263	2.4
Canola seed	73	8.7
Cereals	136	4.7
Chinese cabbage seed	73	8.7
Citrus	272	2.3
Coriander seed	73	8.7
Fenugreek seed	73	8.7
Field Beans/Lupins/Peas/Vetch	101	6.3
Garlic	122	5.2
Gladiolus	436	1.5
Grass seed	405	1.6
Haifa seed	394	1.6
Linseed	73	8.7
Kale seed	141	4.2
Lucerne hay	551	1.2
Lucerne ‘full’ seed or fodder		1.1
Lucerne seed (13) + autumn fodder		1.5
Lucerne spring fodder + seed		1.3
Lucerne seed (16)		1.6
Lucerne seed (13)		1.9
Maize	290	2.2
Medic seed	120	5.3
Mustard seed	73	8.7
Onions	343	1.8
Pasture	601	1.1
Pasture starter, finisher	100	6.3
Perrenial clover seed	394	1.6
Potatoes	365	1.7
Pumpkins	345	1.8
Primrose	73	8.7
Proteas	70	9.0
Radish seed	124	5.1
Sainfoin seed	515	1.2
Sorghum/Millet	374	1.7
Spring lucerne		4.3
Spring and autumn lucerne		2.8
Starter or finisher lucerne		6.3
Sunflower	345	1.8
Turf areas	634	1.0
Vines	282	2.2
Winter crop then Sorgham/Millet	407	1.6

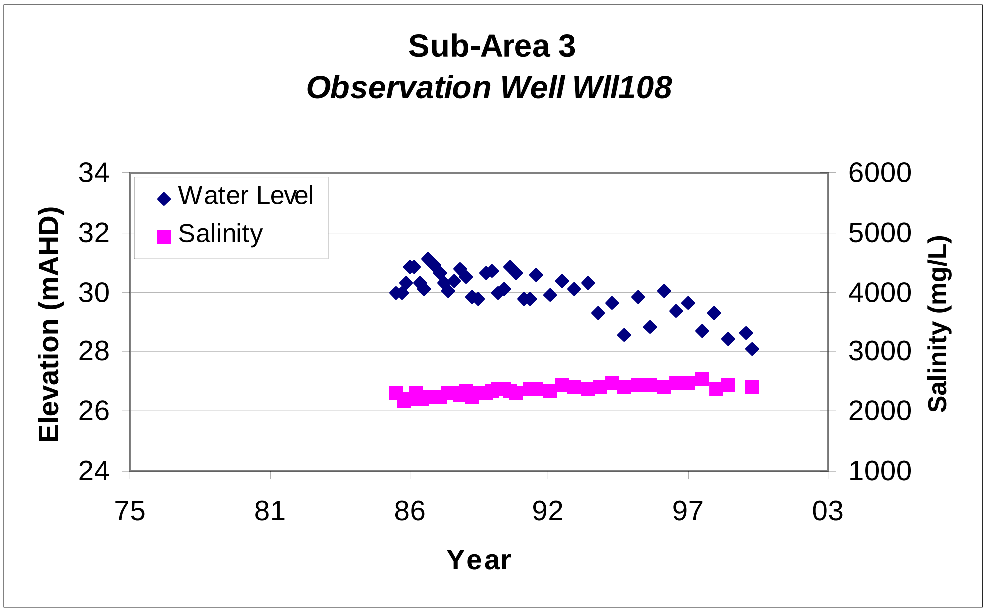
Appendix B

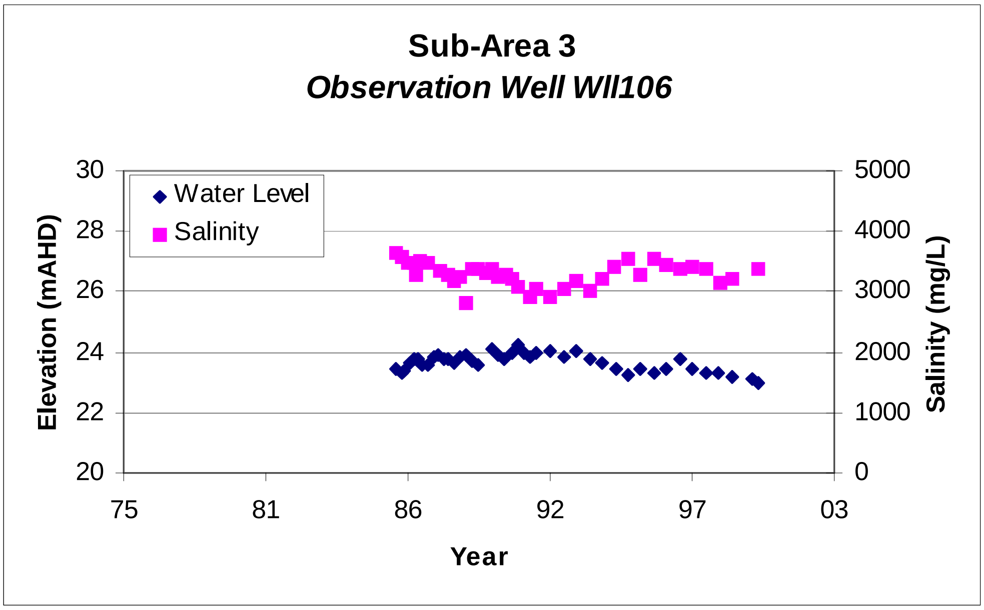
Bore hydrographs and salinity graphs


Sub-Area 2
Confined Aquifer
Observation Well WRG025
Water Level
Elevation (mAHD)
30
28
26
24
22
20
75
81
86
92
97
03
Year


Sub-Area 2
Observation Well Wrg112
Water Level
Salinity
Elevation (mAHD)
55
53
51
49
47
45
Salinity (mg/L)
5000
4000
3000
2000
1000
0
75
81
86
92
97
03
Year


Sub-Area 2
Observation Well Wrg116
Water Level
Salinity
Elevation (mAHD)
59
57
55
53
51
49
Salinity (mg/L)
5000
4000
3000
2000
1000
0
75
81
86
92
97
03
Year


Sub-Area 3
Observation Well WII108
Water Level
Salinity
Elevation (mAHD)
34
32
30
28
26
24
6000
5000
4000
3000
2000
1000
Salinity (mg/L)
75
81
86
92
97
03
Year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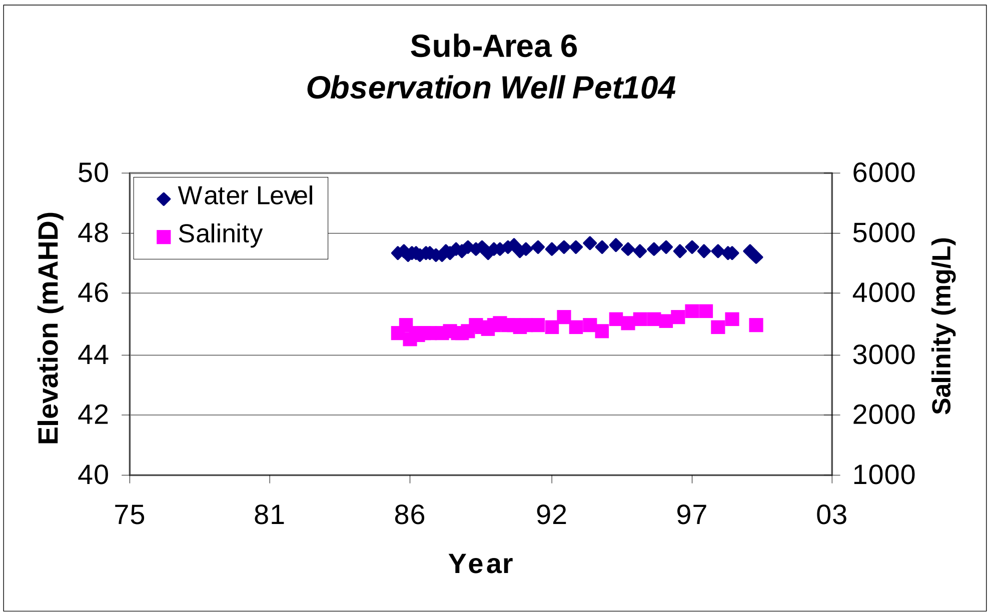
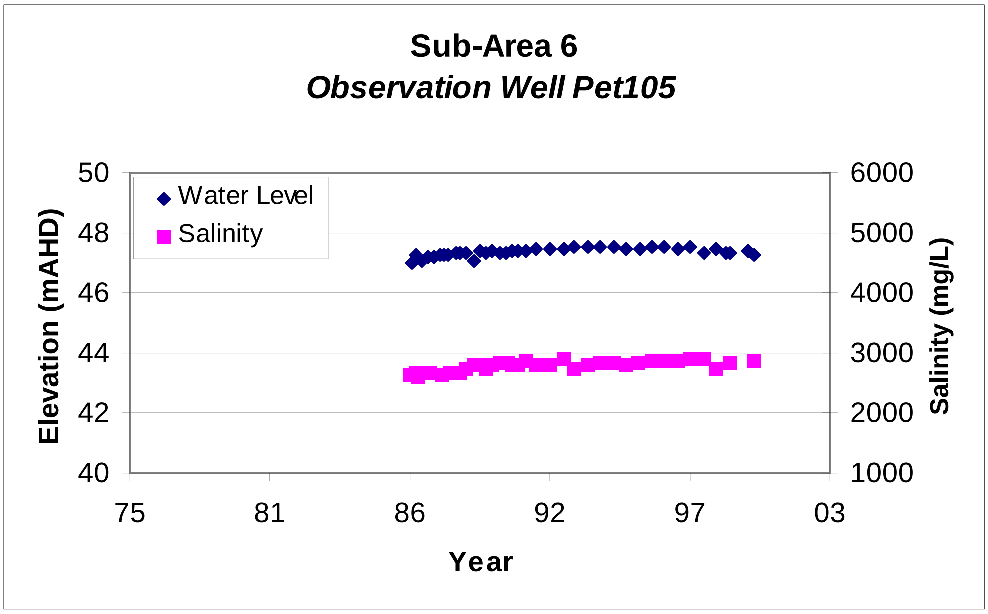
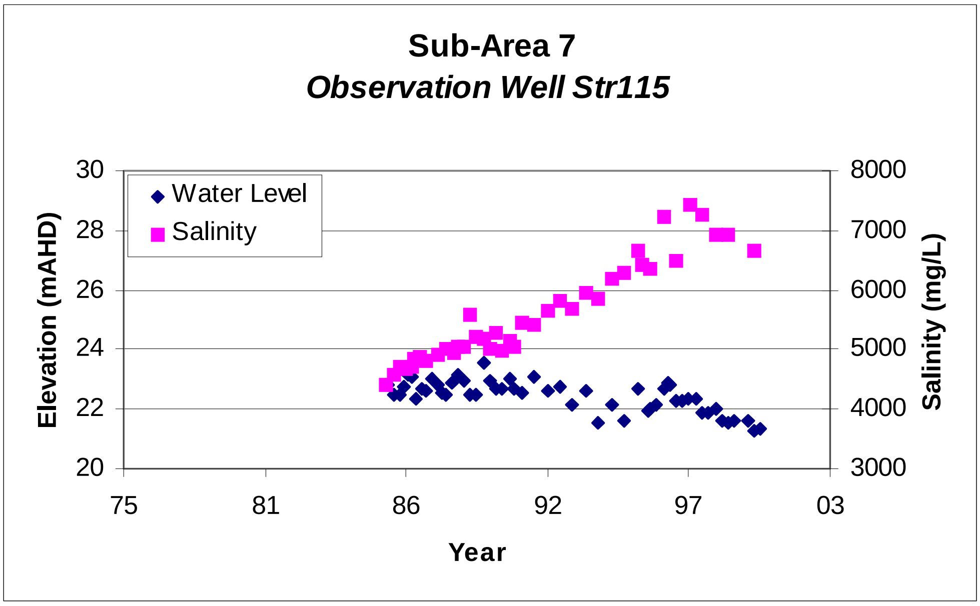
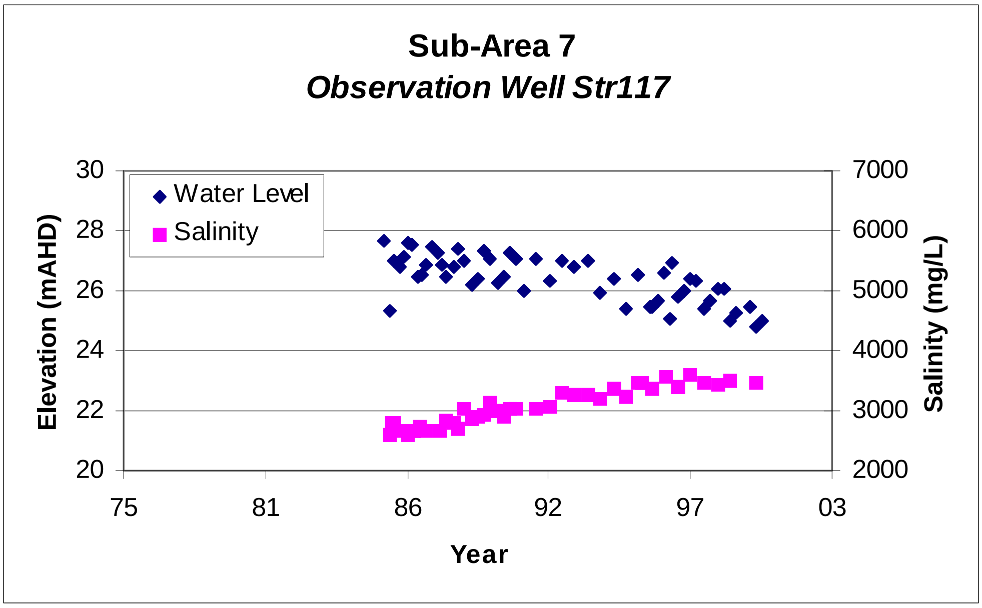
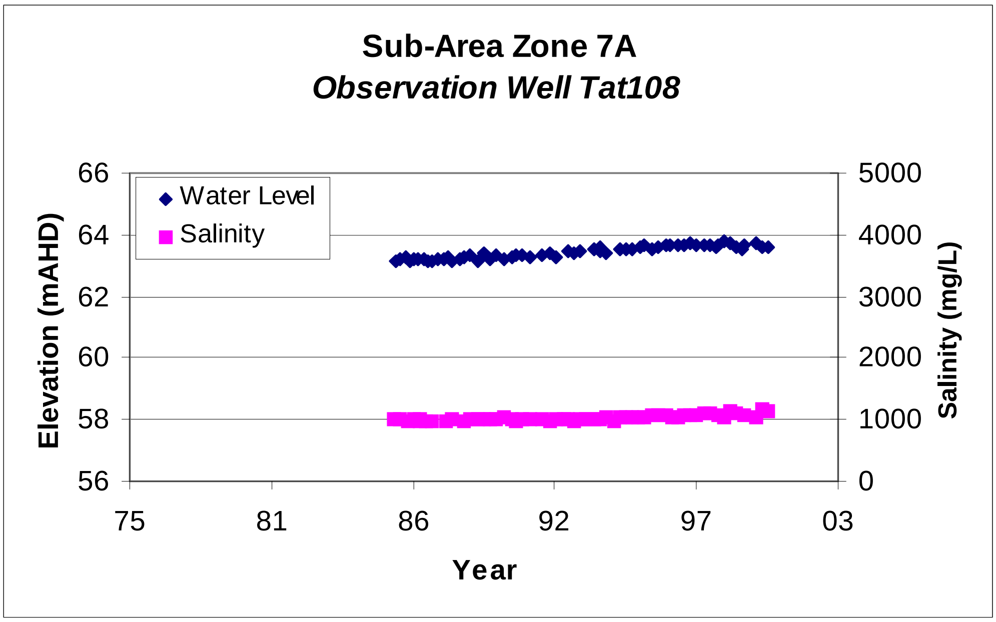
Observation Well WII106
Water Level
Salinity
Elevation (mAHD)
30
28
26
24
22
20
5000
4000
3000
2000
1000
0
Salinity (mg/L)
75
81
86
92
97
03
Year

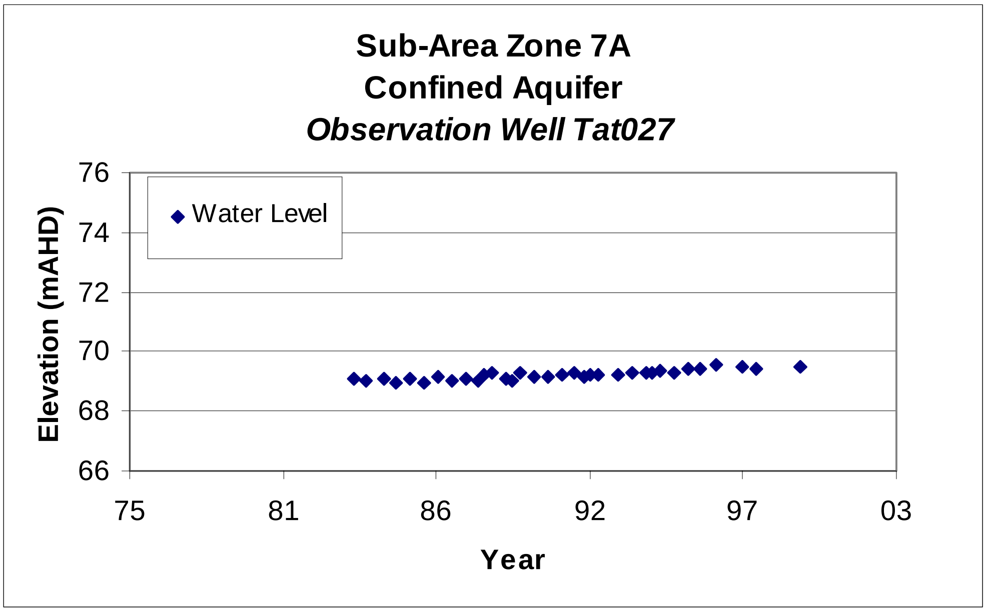

Sub-Area 6
Observation Well Pet104
Water Level
Salinity
Elevation (mAHD)
50
48
46
44
42
40
6000
5000
4000
3000
2000
1000
Salinity (mg/L)
75
81
86
92
97
03
Year

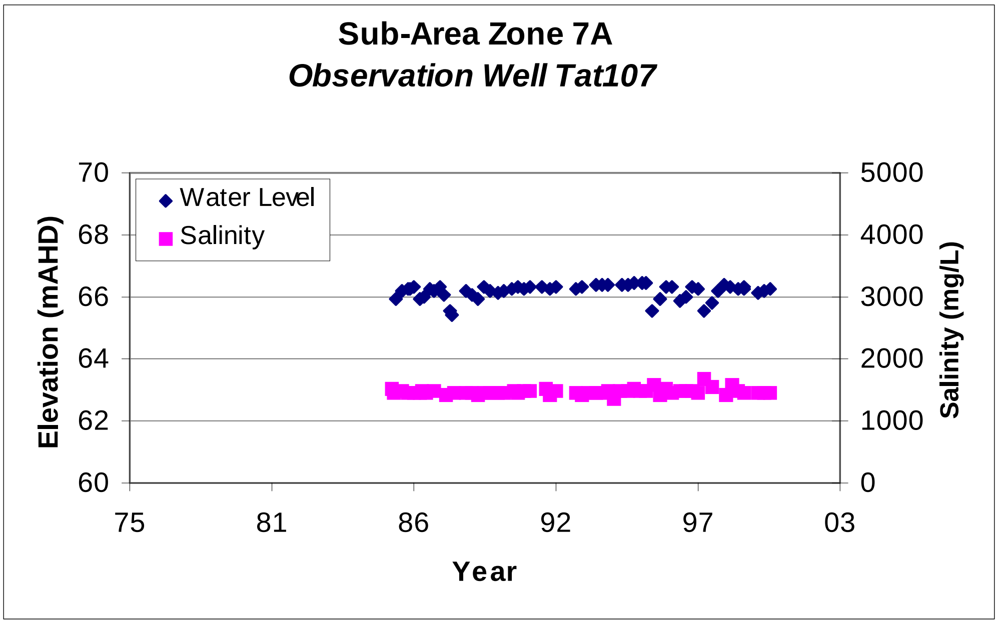

Sub-Area 6
Observation Well Pet105
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
50
48
46
44
42
40
6000
5000
4000
3000
2000
1000
75
81
86
92
97
03
Year

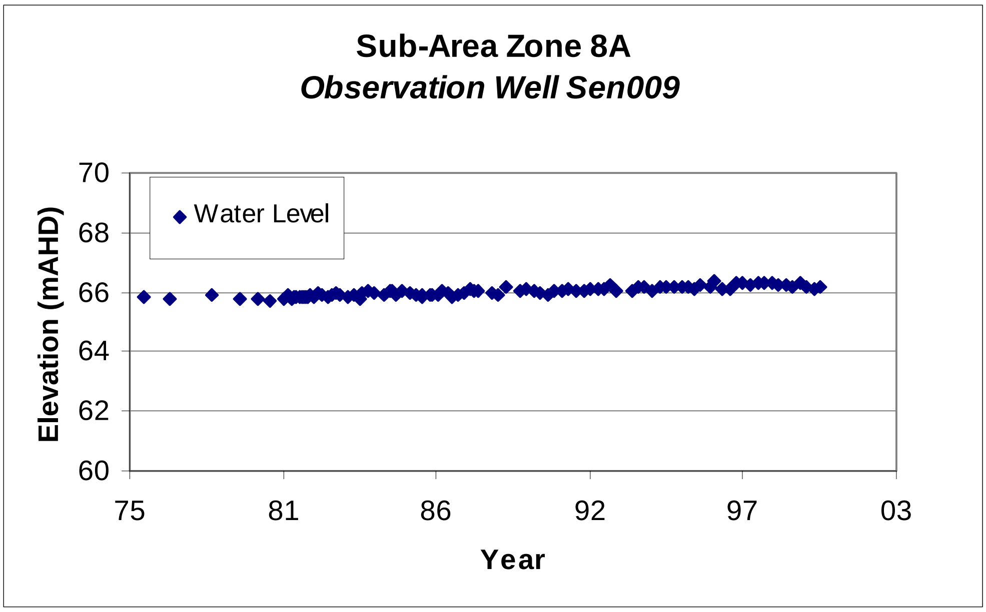

Sub-Area 7
Observation Well Str115
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
30
28
26
24
22
20
8000
7000
6000
5000
4000
3000
75
81
86
92
97
03
Year

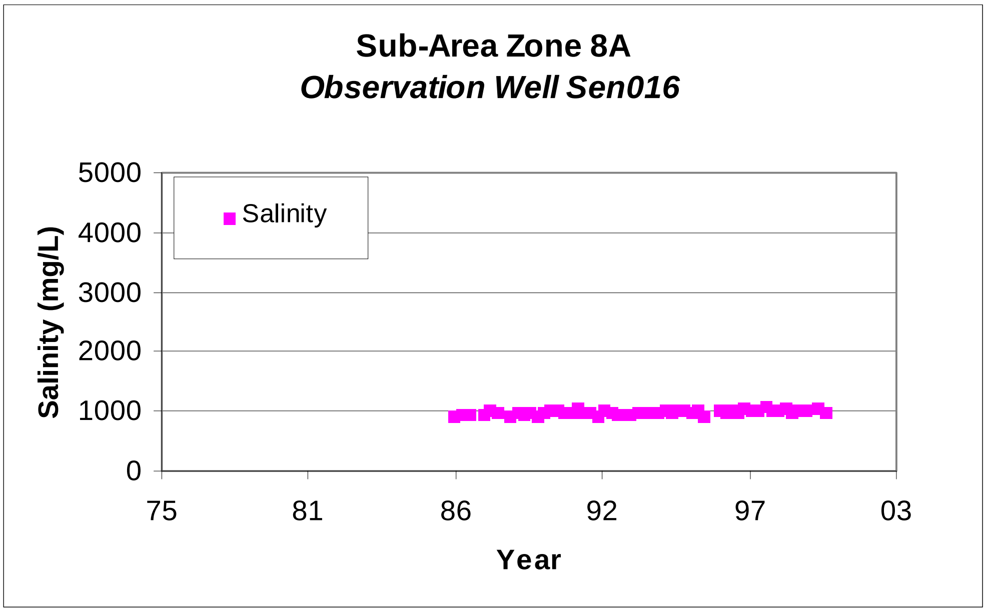

Sub-Area 7
Observation Well Str117
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
30
28
26
24
22
20
7000
6000
5000
4000
3000
2000
75
81
86
92
97
03
Year

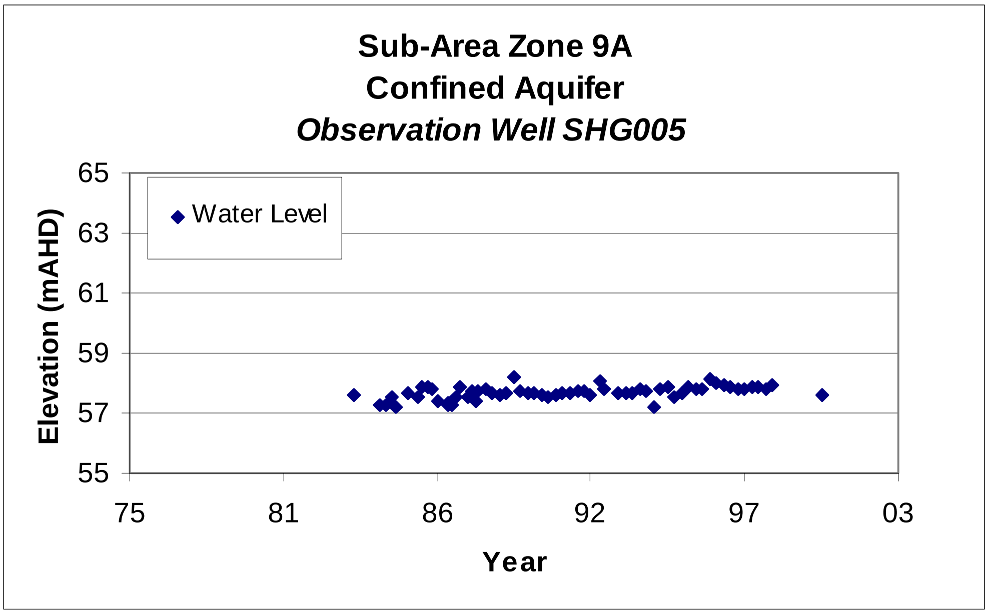

Sub-Area Zone 7A
Observation Well Tat108
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
66
64
62
60
58
56
5000
4000
3000
2000
1000
0
75
81
86
92
97
03
Year

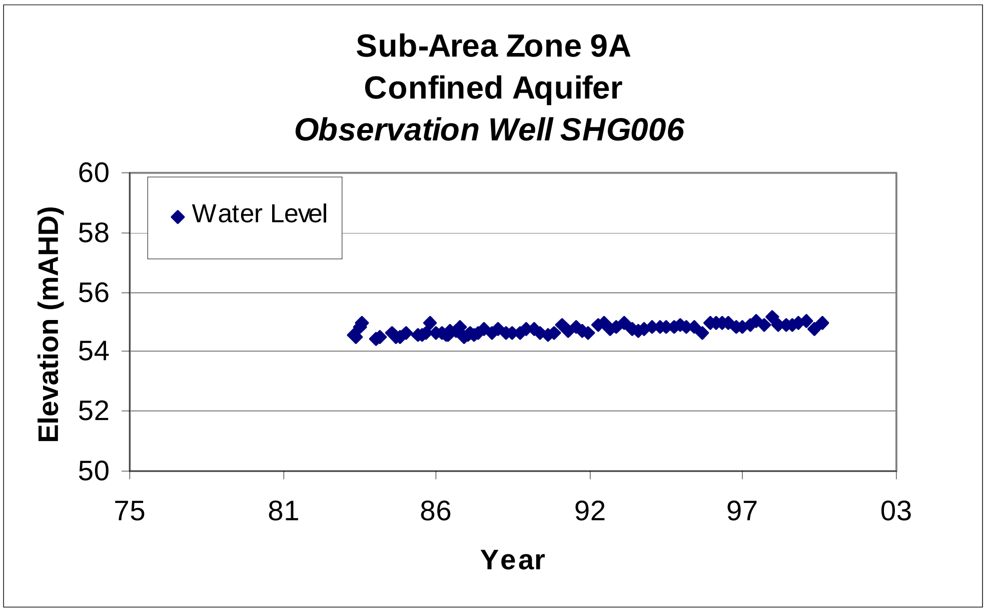

Sub-Area Zone 7A
Confined Aquifer
Observation Well Tat027
Water Level
Elevation (mAHD)
76
74
72
70
68
66
75
81
86
92
97
03
Year

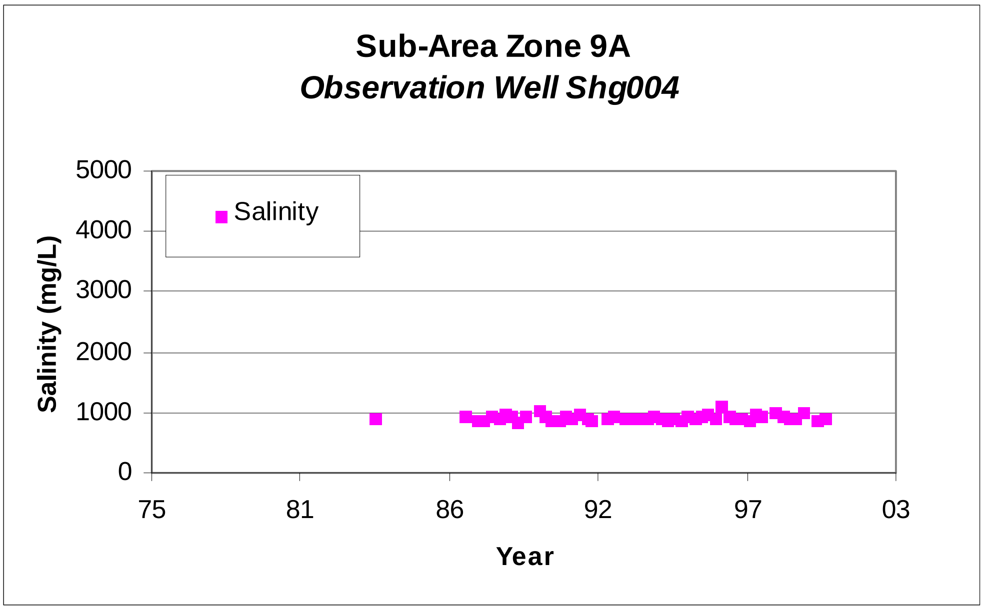

Sub-Area Zone 7A
Observation Well Tat107
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
70
68
66
64
62
60
5000
4000
3000
2000
1000
0
75
81
86
92
97
03
Year


Sub-Area Zone 8A
Observation Well Sen009
Water Level
Elevation (mAHD)
70
68
66
64
62
60
75
81
86
92
97
03
Year


Sub-Area Zone 8A
Observation Well Sen016
Salinity
Salinity (mg/L)
5000
4000
3000
2000
1000
0
75
81
86
92
97
03
Year


Sub-Area Zone 9A
Confined Aquifer
Observation Well SHG005
Water Level
Elevation (mAHD)
65
63
61
59
57
55
75
81
86
92
97
03
Year


Sub-Area Zone 9A
Confined Aquifer
Observation Well SHG006
Water Level
Elevation (mAHD)
60
58
56
54
52
50
75
81
86
92
97
03
Year


Sub-Area Zone 9A
Observation Well Shg004
Salinity
Salinity (mg/L)
5000
4000
3000
2000
1000
0
75
81
86
92
97
03
Year

Appendix C

Stock Water Use Consumption Figures

STOCK WATER USE CONSUMPTION FIGURES

Sheep (dry pasture)	7 Litres/Head
Sheep (irrigated pasture)	4 Litres/Head
Lambs (dry pasture)	2.5 Litres/Head
Lambs (irrigated pasture)	1 Litres/Head
Beef Cattle	45 Litres/Head
Calves	23 Litres/Head
Dairy Cattle (in lactation)	68 Litres/Head
Dairy Cattle (dry)	45 Litres/Head
Horses (working)	55 Litres/Head
Horses (grazing)	36 Litres/Head
Sows	23 Litres/Head
Pigs	11 Litres/Head
Poultry (100)	3.2 Litres/Head
Turkeys (100)	5.5 Litres/Head