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

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by

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PRIMARY INDUSTRIES AND RESOURCES
SOUTH AUSTRALIA

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

Michael Cobb and Keith Brown

EXECUTIVE SUMMARY

In the development of a Water Allocation Plan for the Padthaway PWA, the South East Catchment Water Management Board (SECWMB) appointed groundwater consultants Water Search Pty Ltd. and the Department for Water Resources SA (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 Padthaway PWA and where applicable makes recommendations for its future management.

The Padthaway Prescribed Wells Area (PWA) is located approximately 300 km south-east of Adelaide and covers an area of ~700 km^2. The PWA can be divided by topography into a low-lying interdunal flat to the west and a remnant dune ridge that rises above the flat by ~60 metres to the east. The two terrains are separated by the NW–SE Kanawinka Fault, which runs through the middle of the PWA.

The main water resource is the regionally unconfined aquifer. On the flat, groundwater flows through two sub-aquifers of the unconfined aquifer system: the Padthaway Formation sub-aquifer which is present only on the flat, and the underlying Bridgewater Formation sub-aquifer. The sub-aquifers are hydraulically connected in the main irrigation area. The Padthaway Formation sub-aquifer is the dominant of the two aquifers, is particularly transmissive and generates high well yields. In the range, the Bridgewater Formation sub-aquifer is the main source of groundwater. Poor cementation of the sediments, in some areas, in the Formation limits its potential as an aquifer.

The confined aquifer is generally absent, or thin (less than 2.5 m), over much of the Padthaway PWA and is not utilised as a water resource.

The area was proclaimed in 1976 following concern that increased irrigation activity may lower the water table. The original water licences were issued on the basis of established irrigation activity and proposed development. Therefore no Permissible Annual Volume (PAV) was established for the area.

There were originally five water management sub-areas in the Padthaway PWA, but they were never formally recognised. Because the sub-areas were until recently unofficial, the DWR database can only supply allocation and water use figures for the whole of the PWA. Sub-areas 1, 2A, 2B and 3 are situated on the flat. Sub-area 4 is the highlands area lying north-east of the Kanawinka Fault. Sub-areas 2A and 2B are located immediately south-west of the Fault and are collectively known as the Intensely Irrigated Area. Viticulture is the main crop type in these sub-areas. Four management sub-areas have now been formerly adopted for the PWA. Sub-area 2A and Sub-area 2B have been combined as one.

The total allocation for the Padthaway PWA for the 1998/1999 season was 35 084 ML. Water use for the same period was estimated to be 24 944 ML. The accuracy of this figure is debatable. The water use figure is not the actual volume extracted but rather an estimate of crop water usage. The danger is that the current water use for the PWA can increase by ~40% before reaching the permissible water allocation limit. It is presumed the outstanding, unused allocations, are in areas outside

the main irrigation areas of Sub-areas 2A and 2B, but there are no figures to confirm this.

In the Padthaway PWA there are currently 42 observation wells in the water level monitoring network. 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 81. Generally the networks are adequate; it is recommended to increase the number of water level observation wells in the central part of Sub-area 2B.

Water levels on the flat have generally remained stable over the monitoring period, which commenced in the early 1970s. However, salinity in the Intensely Irrigated Area is rising at a rate of between 5 and 18 mg/L annually. The current levels of salinity are at or approaching the limits for established viticulture, any further increases which the monitoring data indicates, may seriously affect this industry. Groundwater recycling of irrigation water is considered the cause of this increase.

In the Range, water levels are rising on average between two and twelve cm/yr. Hydrographs show the greatest rise in the water table has occurred since the early 1980s. It is attributed to clearance of native vegetation by early European settlers, and the failure of lucerne crops in the mid-1970s. Associated with the rising water table is an increase in groundwater salinity.

Various options to mitigate the rising salinity trend in Sub-area 2B have been identified by the community. Most of these require obtaining water from an external source. In the long-term the only true way to address the rising groundwater salinity (and therefore manage the resource in a sustainable manner) in the main irrigation area would be to reduce water use.

The present level of water use in Sub-area 2B is estimated to be more than twice the recharge by rainfall for the area.

In the Padthaway 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.

The Morambro Creek recharge project is an option that has been considered by the Padthaway vignerons to mitigate the increasing groundwater salinity trends in Sub-area 2B. Assessment of this option concluded that if it were to proceed it would be unlikely to have any major detrimental effect on the water quality of the aquifer. The minor concerns with this option were identified as possible iron bacteria contamination and suspended solids in the flow system. Water logging or a rising water table are unlikely scenarios given the aquifer characteristics of the sub-aquifers beneath the flat. There would have to be, however, an evaluation of the environmental downstream impacts of taking surface water flows from the Creek.

As the confined aquifer is generally absent over most of the Padthaway PWA, there is little likelihood that use of the aquifer resource could impact on the unconfined aquifer. Similarly there is little possibility extraction from the unconfined aquifer would have any impact on the confined aquifer.

It is unlikely that there would be cross zone boundary impacts given the hydraulic properties (high storage values) of the unconfined aquifer in the PWA.

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) is 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 Padthaway 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 (ie. the confined aquifer or any relevant surface 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 undertaken 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

The South East region of South Australia provides a large percentage of the State's income mainly through primary industries (eg. forestry, stock, viticulture, cereal crops and aquaculture). 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 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 and stock use, and for supplying municipal water to a number of towns located in the area.

The South East region is generally of low relief. Topography slopes gently upwards away from the coast, broken only by a series of low lying remnant cemented sand dune ridges that run sub-parallel to the existing coastline. 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 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. 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 upper, unconfined aquifer is the most extensively used of the two aquifers. However, the recent introduction of water management policies which effectively caps its 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 from the latter part of the Tertiary Period through to the Quaternary, and incorporates the Gambier Limestone, Coomandook, Bridgewater, and Padthaway Formations.

The confined aquifer consists of non-calcareous quartz sands, interbedded with dark brown carbonaceous clays. Together these units make up the Dilwyn Formation. Deposition 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 does not have the same lateral extent as the unconfined aquifer; it is very thin or absent in much of the northern margins of the South East. For example, there is generally no confined aquifer in the Padthaway PWA.

Lateral flow, for both the unconfined and confined aquifer systems, is from the topographic high of the Dundas Plateau in western Victoria. From there, the groundwater flows radially westward and southward to the coast, and northwards to the Murray River. The velocity the groundwater flows through each aquifer varies depending on local hydrogeological characteristics. 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. 1). The north-northwesterly trending Kanawinka Fault has a pronounced lineament and is downthrown to the south-west. The west-northwesterly trending Tautwarp 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 evaporation increases from about 1400 mm in the south to about 1800 mm in the north. Precipitation exceeds potential evaporation usually from May to September. Potential for recharge to the upper unconfined aquifer exists during this period.

Groundwater Management Areas

The water resources of the South East region are managed by the South East Catchment Water Management Board established under the *Water Resources Act 1997*. 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. 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.

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 the same as those of the unconfined aquifer (ie. the extent of the Padthaway PWA).

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 recharge 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, 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 under estimates water use from the aquifer.

HYDROGEOLOGY OF THE PADTHAWAY PWA

GEOGRAPHICAL SETTING

The Padthaway PWA covers an area of approximately 700 km^2 and includes the Hundreds of Glen Roy, Parsons and the north-eastern half of Marcollat. The eastern boundary of the PWA is formed along the Hundred line of Glen Roy and Parsons. The northern boundary is located along the top of the Hundreds of Marcollat and Parsons, while the southern boundary is the bottom of the Hundred of Glen Roy. The western boundary trends NW-SE, and generally follows the foot of Harpers Range, the first sand ridge west of the Kanawinka Fault (Fig. 1).

RAINFALL

The climate in the Padthaway PWA is typical of the South East; hot, dry summers and cool wet winters. The average annual rainfall (1977 to present) from the Padthaway Southcorp Wines gauging station situated just north-west of Padthaway township is 518 mm. The annual potential evapotranspiration is approximately 1600 mm (Stadter et al. 1995).

GEOMORPHOLOGY

The Padthaway PWA comprises two discrete land-forms separated by the NW-SE trending Kanawinka Fault. To the south-west of the Fault, is a low-lying interdunal flat. The width of the flat is approximately ten kilometres and slopes gently downwards to the north-west. Northeast of the Fault a remnant dunal ridge rises to about 50 to 60 metres above the flat, forming part of the Naracoorte Ranges.

SURFACE WATER FLOWS

Morambro Creek is an ephemeral watercourse that flows into the PWA in its south-eastern corner. From there, it meanders across the southern part of the interdunal flat before discharging into Cockatoo Lake. From Cockatoo Lake the water flows via man-made drains north-west along the base of the Harper Range to Nyroca. A cutting through the Range then enables the water to join the Marcollat watercourse. The catchment area for the Creek is approximately 1200 km^2 (Foale and Smith, 1991) and extends across the border into Victoria.

Annual flow in the Morambro Creek is highly variable. It is common for no flow to occur in the Creek for more than two or three years. However, in an average year the flow generated from the Creek is approximately 4270 ML and it contributes approximately 30% of the average annual flow to the Marcollat watercourse (B.C. Tonkins and Associates, 1997). Therefore the downstream impacts taking surface flow from the Creek need to be evaluated.

LOCAL HYDROSTRATIGRAPHY

Unconfined Aquifer

In the Padthaway PWA, groundwater is extracted from two sub-aquifers which form part of the regional unconfined aquifer. These sub-aquifers occur within the Padthaway Formation and the Bridgewater Formation respectively. A schematic east-west cross section through the Padthaway PWA highlighting the main geological units is shown in Figure 2.

Interdunal Flat Aquifers

The Padthaway Formation sub-aquifer occurs only beneath the interdunal flat and generally ranges in thickness from six to fourteen metres. The formation consists mainly of an off-white, well-cemented fine-grained limestone. A well developed secondary porosity has resulted in a highly transmissive aquifer. Harris (1972) gave ranges in transmissivity of between 1100 and 11 000 m^2/day. Depth to water generally ranges between two and six metres. This is the most used sub-aquifer in the PWA.

Underlying the Padthaway Formation sub-aquifer is the Bridgewater Formation sub-aquifer. Beneath the flat, the Bridgewater Formation is approximately 20 metres thick. It is made up of an orange to yellow calcareous sandstone and is moderately to well cemented.

In the main irrigation area (between Grub Road and the main highway) the two sub-aquifers are hydraulically connected and have a similar groundwater salinity and aquifer characteristics. To the west of the main irrigation area there is a confining unit separating the two sub-aquifers. The water quality is better in the Bridgewater Formation, but the permeability (and well yields) of this sub-aquifer is significantly lower (Brown, 1998a). Transmissivity ranges from 320 to 2400 m^2/day (Harris, 1972). The majority of wells located on the flat are uncased or have shallow surface casing. Most wells penetrate both sub-aquifers and are therefore not separated.

Below the Padthaway and Bridgewater Formations are the Coomandook and Ettrick Formations. Both Formations may contain good quantities of good quality groundwater, but they are restricted in their use as a water source due to fine grain size and poor consolidation.

Naracoorte Range Aquifers

The Bridgewater Formation sub-aquifer forms the main aquifer in the Naracoorte Range. Most of the wells are completed in the base of the Bridgewater Formation (and possibly the top of the Gambier Limestone) as it is better cemented than the top section of the formation. Average well yields are approximately 30 L/sec but they can be highly variable (Brown, 1998b). The quality of the groundwater from the aquifer is better than its equivalent on the flat, but the Formation is not as consolidated and can produce fine sand when pumped. The depth to water is greater than on the flat and reflects a steepening of topography away from the Kanawinka Fault.

Confined Aquifer

The Dilwyn Formation aquifer (the confined aquifer) is generally thin or absent in the Padthaway PWA. Exploratory drilling undertaken by the DWR located the aquifer beneath the flat and its thickness ranges from 1 to 2.5 m (Brown, 1998a). Bore logs from a well located in the Range, approximately two kilometres north-east of Padthaway township, gives a Dilwyn Formation thickness of more than nine metres, but in nearby wells it is absent. The aquifer potential of the confined aquifer is generally unknown in the Padthaway PWA. There are no wells using the confined aquifer in the Padthaway PWA.

GROUNDWATER MANAGEMENT APPROACH

HISTORY

Following initial concerns from irrigators in the late 1960s that increased irrigation would result in falling water levels, and an assessment by Harris (1970) who commented on the potential impacts from increasing groundwater salinity, restrictions on the withdrawal of groundwater from the Padthaway area were applied in 1975. The area was subsequently proclaimed in 1976, immediately following the introduction of the *Water Resources Act 1976*.

Water licences for the PWA were issued on the basis of established irrigation activity, or on proposed development. As such, there was no assessment of sustainable water use in the Padthaway PWA and therefore PAVs were never determined.

In 1983 the current usage rates were considered sustainable but there was a fear that if the total water allocation were fully utilised it would cause serious salinity problems in the main irrigation area. Subsequently in 1983/84, allocations were restricted to the highest usage between 1975 and the 1982/83 irrigation season.

The original water licences were expressed in lucerne equivalents but this was changed in 1992 to pasture irrigation equivalents (IE system), (DENR, 1997). To implement the change from lucerne equivalents to IEs there was an increase in allocation so no licensee was adversely affected by the change. The current irrigation equivalents and crop area ratios (after Desmier, 1992) are attached in Appendix A.

MANAGEMENT ZONES

Unconfined Aquifer

The Padthaway PWA until recently was divided into five sub-areas but they were never formally adopted (Fig. 3). Sub-area 1 covers an area in the west of the PWA where land use is mainly pasture for livestock (sheep and cattle) but various vegetable and pasture crops are also grown (Watkins, 1997). Sub-area 2 is sub-divided into Sub-areas 2A and 2B and together they are commonly referred to as the Intensely Irrigated Area. Situated south of Padthaway township, Sub-area 2A forms a thin, 1 to 2 km wide strip lying between the main highway and Grub Road. Grape vines are the dominant crop type in this sub-area (Fig. 3). Sub-area 2B forms a 2 to 3 km wide strip north of Padthaway township. Crop types are more varied than Sub-area 2A; they include vines, vegetables, clover and pasture. Sub-area 3 is a 2 to 3 km wide strip located immediately west of Sub-area 2A and pasture for livestock is the main crop grown. Sub-area 4 is the area east to north-east of the Kanawinka Fault (ie. the main highway). The main crop type is pasture for livestock, however approximately 20% of the Sub-area is under native vegetation.

Four management sub-areas have now been officially adopted with Sub-areas 2A and 2B united as one.

Confined Aquifer

Boundaries are yet to be established for the confined aquifer in the South East region. For this assessment the boundaries were assumed to be the same as those of the unconfined aquifer.

THE MONITORING NETWORK

UNCONFINED AQUIFER

Current Monitoring Network

The Department for Water Resources and its predecessors have undertaken monitoring of the water resources in the Padthaway PWA since 1970 when a water level monitoring network was

established. Salinity monitoring began slightly later in 1978. A number of wells are also regularly sampled and analysed for major ion chemistry.
The current water level and salinity monitoring network are shown on Figure 4.

Water Level Monitoring Network

The water level monitoring network in the Padthaway PWA has been in operation for more than 30 years. Over this period, the network has been constantly upgraded and enlarged to meet the agricultural expansion in the PWA. There are currently 42 wells monitored for water level in the Padthaway PWA. These wells are measured quarterly (March, June, September and December) by the Department for Water Resources.

While the network is acceptable it could be improved by the addition of two to three observation wells in both Sub-areas 2B and 4. There are few observation wells in the central part of Sub-area 2B and monitoring for long-term water level changes is essential. In Sub-area 4, the lack of data points is evident when constructing the water table contours for the PWA. This, however, is a relatively minor issue.

Salinity Monitoring Network

There are two groundwater salinity monitoring networks operating in the Padthaway PWA, the Padthaway Monitoring Network and the Padthaway Irrigation Network. The main network is the Padthaway Monitoring Network and is sampled by the DWR. There are currently 28 wells in the network. Sampling frequency is the same as for the water level monitoring network.

The second network, the Padthaway Irrigation Network, monitors privately owned irrigation wells. They are either sampled by the irrigators themselves or by the DWR, but on an irregular basis. There are currently 53 wells in the private network.

The salinity monitoring network is of a high standard. The use of the Padthaway Irrigation Network to augment the main network ensures public involvement and increases the data points, especially in the main irrigation area. It must be pointed out that a fair proportion of the private network wells are already sampled by DWR.

CONFINED AQUIFER

There are no monitoring wells, water level or salinity, in the confined aquifer in the Padthaway PWA.

CURRENT STATUS OF THE WATER RESOURCES

UNCONFINED AQUIFER

Groundwater Flow

The water table elevation zones for the unconfined aquifer are shown on Figure 5. Groundwater flow is generally in a south-westerly direction east of the Kanawinka Fault. On the interdunal flat the flow direction changes to a north-westerly direction consistent with the slope of the ground surface.

The hydraulic gradient is relatively steep up-gradient of the Kanawinka Fault. This steep gradient has previously been inferred as reflecting a lower hydraulic conductivity in the Bridgewater Formation aquifer. While the Formation undoubtably has a lower hydraulic conductivity than the sub-aquifers on the flat, the steepening gradient could also be a change in the flow dynamics related to the Fault. On the flat the hydraulic gradient is much lower reflecting the high transmissivity of the Padthaway and Bridgewater Formation sub-aquifers.

Water Level Trends

Long term water level trends from hydrographs located in the Padthaway PWA are shown on Figure 6. Only wells with more than five years data were included in the study. Long-term water level trends from bore hydrographs located in Sub-area 4 show a general rise in the water table of between two and twelve cm/yr. A number of the wells (eg. Par36 and Par44 in Appendix B) show a higher rising trend beginning in the mid- to late 1980s. The rise in the water table is considered an outcome of the clearance of native vegetation and the failure of lucerne crops in the mid-1970s.

In the other sub-areas (1, 2A, 2B and 3) there has been no significant long-term change in the water table elevation. While there has been no overall long-term change in water level, many of the wells on the flat show a sinusoidal nature. Various authors (Cobb, 1992; Watkins, 1997) have commented that this trend can be related to rainfall patterns.

Salinity Distribution

The salinity distribution for the Padthaway PWA is shown on Figure 7. Generally, the salinity of groundwater in the Range is lower than on the flat. In Sub-area 4, the salinity ranges between ~930 and ~2065 mg/L. On the flat, the salinity ranges from 895 to 6370 mg/L TDS. Salinity on the flat rises westward towards the Harper Range.

Salinity Trends

Associated with the rise in groundwater levels in Sub-area 4 is an increase in groundwater salinity as shown on Figure 8. Generally the groundwater salinity in this area is increasing by between 5 and 17 mg/L annually. This is a result of higher rates of recharge, reflected in the rising water table, flushing salts stored in the soil profile and the unsaturated zone into the aquifer.

There are currently no new management strategies to address the increasing groundwater water levels and rising salinity in Sub-area 4. The rising water table could be advantageous, however, in that an increase in the hydraulic gradient would potentially increase the groundwater flow through the intensely irrigated area (see Option 4 – Interception channel) aiding salt removal.

Further research is required into assessing the impacts of increasing groundwater salinity in Sub-area 4, specifically identifying salt accession mechanisms to the aquifer.

Observation wells in Sub-area 1 show a falling groundwater salinity trend of between 10 and 50 mg/L annually (Fig. 8). This is attributed to a lowering of the water table related to the establishment of the drainage system in the western margin and to an increase in lateral flow of lower salinity groundwater from the east flushing what was formerly an evaporative discharge area for the aquifer.

In Sub-areas 2A, 2B and 3 the groundwater salinity is rising. The recycling of irrigation water in the main irrigation area is considered to be the main cause for this increase. However there may also be a contribution laterally in the future of salt from the Ranges to the east. Salinity is rising, on average, between 5 and 18 mg/L annually.

The groundwater salinity is generally considered to be well within the accepted limits for livestock use. Of more concern is the effect the rising salinity will have on crop yields. For example, the optimum groundwater salinity for grape vines is ~550 mg/L TDS. At a groundwater salinity level of ~1500 mg/L the vines will have a reduced productivity of about 25%, at ~ 2500 mg/L the yield will reduce to 50% of its optimum (Ayers, 1977). The effect of rising groundwater salinity is most notable in the eastern half of Sub-area 2B.

In an effort to address the salinity issue in the Intensely Irrigated Area, a number of management options were proposed to slow the current rate of increase (Appendix C). These are:

1. Sourcing less saline water from the Naracoorte Ranges,
2. Pumping from deeper parts of the unconfined aquifer,
3. Artificial Recharge (Morambro Creek),
4. Interception channel,
5. Improved irrigation efficiency,
6. Reduction in water allocation.

An investigation into the feasibility of Option 1, sourcing less saline water from the Naracoorte Ranges, was undertaken by Brown (1998b). The conclusions of the study were that the Range was potentially a good source of groundwater, but inherent problems related to the aquifer properties (ie. poor consolidation), would make it difficult to accurately predict individual well performance. There was also concern what the impact would be if a large number of wells were located in the area.

Option 2 was also assessed during a drilling program in 1996/1997 (Brown, 1998a). Results from this study concluded that in the Intensely Irrigated Area, there was no better quality groundwater in the deeper parts of the aquifer.

The merits of Option 3 are discussed further on under the impact of using surface water to artificially replenish the groundwater system section.

Option 4 entails constructing a drainage channel directly west of the Intensely Irrigated Area. The effect of the drain would be to increase the hydraulic gradient by lowering the water table. The increased throughflow would then ultimately remove the more saline groundwater. Further technical assessment is required into the feasibility of this option.

Implementation of Option 5, improving irrigation efficiency would result in a reduction in groundwater extraction in the main irrigation areas. To a certain extent Option 5 has already been put into practice by irrigators in the main irrigation area. Most have improved their irrigation efficiency by changing to dripper systems and by employing techniques to reduce evapotranspiration.

Option 6 is the most drastic and for obvious reasons the least favoured by the community. To ensure the long-term sustainability of the resource however this option has the most merit.

CONFINED AQUIFER

There are no monitoring wells in the Padthaway PWA, therefore the current status of the resource is unknown.

WATER DEMAND

UNCONFINED AQUIFER

Historical Demand

The historical and current estimated crop water use as supplied by the Department for Water Resources – Policy Division are shown on Table 1. The data only goes back as far as the 1985/1986 irrigation season (see DENR, 1997 for water allocations that pre-date this period). The allocation and use volumes used by Watkins, (1997) and DENR, (1997) do not, however, appear to be the same as those provided for this report. The reason for these discrepancies need clarification, time constraints prevented follow-up of this matter.

As part of the project brief for this study, water allocation and usage were to be broken down into management sub-areas. However, in the case of the Padthaway PWA, the data could not be provided in the required format.

Table 1 *Padthaway PWA groundwater allocation and usage*

Year	Purpose	Allocation (ML)	Usage (ML)
1985/1986	Irrigation	27314	24921
1986/1987	Irrigation	27314	24476
1987/1988	Irrigation	27932	23179
1988/1989	Irrigation	28113	21707
1989/1990	Irrigation	29282	21472
1990/1991	Irrigation	29498	24891
1991/1992	Irrigation	29675	24016
1992/1993	Irrigation	30211	20367
1993/1994	Irrigation	30222	21351
1994/1995	Irrigation	35010	22440
	Industrial and Recreation	14	0
1995/1996	Irrigation	35010	23600
	Industrial and Recreation	14	0
1996/1997	Irrigation	35069	23766
	Industrial and Recreation	14	0
1997/1998	Irrigation	37268	24164
	Industrial and Recreation	14	0
1998/1999	Irrigation	35019	24944
	Industrial and Recreation	65	0

The water usage volume is estimated from seasonal returns supplied by the water users. 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 a rough calculation. Even though the figures are considered unreliable the total water use appears to have increased gradually over the last seven irrigation seasons.

Current Demand

Currently the total groundwater allocation in the Padthaway PWA is 35 084 ML. Total ground-water usage for the area is estimated to be 24 944 ML which represents approximately 71% of the total allocation. There are only three categories of water use in the Padthaway PWA; they are irrigation, industrial and recreational. Neither industrial nor recreational water users have used any of their allocation to the end of the 1998/1999 season.

Stock information for the 1996/97 irrigation season in the Padthaway PWA are shown in Table 2. The data was obtained from the Australian Bureau of Statistics, Hobart. Daily stock consumption figures were based on data supplied by the NSW Department of Agriculture. The stock use estimates are to the nearest 5 ML. Unfortunately it was not possible to assess individual sub-areas for the Padthaway PWA, therefore the data is presented by Hundreds. Total annual stock use for the PWA is estimated to be 500 ML.

Domestic water use is considered to be relatively small as rainwater tanks are prominent in the area. Water use from two town water supply wells located just east of Padthaway township between 1991/1992 and 1998/1999 generally ranges from 9 to 15 ML. The exception was in 1994/1995 when 61 ML was used. The current use for 1998/1999 was 11.6 ML, which is less than 0.05% of the total allocation for the PWA.

Future Demand

There is the potential to increase present water use by approximately 40% before the groundwater allocation threshold is reached. However, the total water use varies markedly on an individual sub-area basis. It is probable that most of the unused allocation is outside the Intensely Irrigated Area. Before any useful assessment of the potential future demand for the Padthaway PWA can be carried out, the total groundwater allocation and water usage for each sub-area needs to be calculated.

CONFINED AQUIFER

This is not applicable to the Padthaway PWA.

WATER BALANCE

UNCONFINED AQUIFER

As the allocation and water use data were not available on a sub-area basis, it was not possible to undertake a water balance for each of the sub-areas. Deriving a water balance for the whole PWA would be erroneous. For example, it would disguise what is occurring in the intensely irrigated area. The most recent water balance based on individual sub-areas was carried out by Watkins, (1997) and results are shown in Table 3. They are based on the 1994/1995 irrigation season. The estimated water usage for both Sub-area 2A and Sub-area 2B is approximately twice the rainfall recharge to the area.

Table 2 *Stock Numbers and Estimated Water Use Padthaway PWA 1996/97*

Hundred	**Estimated Ground-water Use (ML)**	**Approximate Stock Numbers**			
		Sheep	Dairy Cattle	Meat Cattle	Pigs
Parsons	140	36 150	6	2750	—
Glen Roy	185	47 380	—	3860	—
Pt. Marcollat	175	29 270	—	6150	—
Total	500	112 800	6	12 760	—

Lateral inflow and outflow calculations were estimated by flownet analysis using an assumed transmissivity of 750 m^2/day in the Range for the Bridgewater Formation sub-aquifer and 1000 m^2/day on the flat. A transmissivity of 10000 m^2/day was assigned to the Padthaway Formation sub-aquifer.

The rainfall recharge rates beneath cleared agricultural land (open pasture) for each sub-area were estimated by the Department for Water Resources as detailed in Table 4. The study was conducted in 1994. 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 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. The upper and lower limits were determined from various seasonal hydrograph responses (low hydrograph response was equated to low recharge).

The lower limits were used in Watkins (1997) water balance calculation. To be consistent with the approach used for the other PWAs, that is the PAV is calculated using the estimated rainfall recharge to an area, the recommended PAV for each sub-area would be the rainfall recharge values in Table 3.

CONFINED AQUIFER

No calculations of sustainability were undertaken for the confined aquifer as it is not utilised in the Padthaway PWA.

Historical Demand

Not applicable.

Current Demand

Not applicable.

Future Demand

Not applicable.

Table 3 *Water Balance for Padthaway PWA (after Watkins, 1997)*

Inputs (ML/a)	Sub-area 1	Sub-area 2A	Sub-area 2B	Sub-area 3	Sub-area 4	Totals
Groundwater inflow	23315	9423	13307	8170	27051	81267
Rainfall Recharge	15774	3510	2450	2900	6678	31312
Total In						**112579**
Outputs (ML/a)						
Groundwater outflow	27325	6168	8170	8701	27409	77773
Crop Use	8320	6850	6000	1430	900	23500
Storage	0	0	735	0	7950	8685
Total Out						**109958**

Table 4 *Sub-Area Recharge Rates*

Recharge Rate (mm/a)	Sub-area 1	Sub-area 2A	Sub-area 2B	Sub-area 3	Sub-area 4
Lower Limit	66	90	50	58	21
Upper Limit	90	105	62	66	35

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 Padthaway 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.

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

Recharge to the unconfined aquifer via a preferential flow path, such as a runaway hole or a discharge well, is not uncommon in the South East region. Surface flow into these holes usually aid flood mitigation during seasonally high levels of rainfall.

In the Padthaway PWA, it has been proposed to divert approximately 3000 ML annually of the Morambro Creek flow into the unconfined aquifer. A natural storage basin situated immediately north-east of the Kanawinka Fault would be modified to store the water. The water would then be piped along a main pipeline and then distributed to individual properties on the flat.

The proposed site for the storage basin is in an area with a rising water table. Leakage from the storage basin may contribute additional water locally to the water table around the holding basin, but as the size of the basin is relatively small, it is considered a minor consequence.

The other more serious potential impact could be from water logging, or a rising water table, on the flat as a result of applying additional water. Results from numerical groundwater flow modelling undertaken by Armstrong and Stadter (1998) showed that this would be unlikely.

As part of their feasibility study, B.C. Tonkins and Associates (1997), sampled for total dissolved solids, nitrogen, phosphorus, iron, iron bacteria and suspended solids. They concluded that the water quality in Morambro Creek meets guidelines for aquifer recharge, with the exception of high iron levels. The high iron content, they concluded, may lead to iron bacteria problems. They reported suspended solids may also be an issue in some circumstances.

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

As there is little or no confined aquifer at this locality such a scenario is considered most unlikely. There are only a few examples in the South East region where the extraction from the unconfined aquifer has impacted across management boundaries. For example in the north-western portion of the Tatiara PWA a decline in water levels in the area may be impacting across sub-area boundaries. There may also be a potential impact for irrigators down-gradient of high salinity areas as salts are transported out of the PWA.

The water budget indicates that the Padthaway PWA is approximately in balance and there is no indication of declining water levels. There is the possibility, however, that groundwater of a higher salinity will eventually flow down-gradient out of the intensely irrigated area and into Sub-area 3. However the salinity in Sub-area 3 is generally already higher than that of Sub-areas 2A and 2B. In the Padthaway PWA therefore this scenario is currently not a major issue.

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

For the same reasons as outlined above this scenario is considered most unlikely.

Hypothetically, however, if at a future date investigations found a confined aquifer in the Padthaway PWA and groundwater were to be taken from it then the only foreseeable way it could affect 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.

In the unlikely event the confined aquifer was found in the Padthaway PWA then there may be across zone impacts.

CONCLUSIONS

If a water resource is to be managed at a sustainable level there has to be a balance between output (natural discharge and extraction) and input (recharge). In the Intensely Irrigated Area (Sub-areas 2A and 2B), a long-term increase in groundwater salinity has impacted on grape yields. At current levels of water use the resource is not sustainable. Based on the estimated water use figures, there is the threat that water use may increase by a further 40% before the allocation limit is reached.

The Padthaway area was proclaimed more than 25 years ago and the community are generally well aware the impact increasing groundwater salinity is having in the Intensely Irrigated Area. And to their credit they have introduced ways in an attempt to arrest the present rate of salinity increase. A number of recent options to mitigate the rising salinity trend have been identified. Most of these require obtaining water from an external source. The most recent proposal is to import River Murray water via a mains pipeline from the Keith area. However, to truly address the rising salinity, there would have to be a concerted effort to reduce water use in the main irrigation area.

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

In the Padthaway PWA, the only scenario where the using of one water resource could potentially impact on another resource is using surface flow from the Morambro Creek to artificially recharge the unconfined aquifer.

The Morambro Creek recharge project is an option that has been considered by the Padthaway vignerons to mitigate the increasing groundwater salinity in Sub-area 2B. There are minor concerns with iron bacteria contamination and suspended solids in the flow system. Water logging or a rising water table, are unlikely scenarios given the aquifer properties of the sub-aquifers beneath the flat.

As the confined aquifer is generally absent over most of the Padthaway PWA, or at best very thin, there is little likelihood that its limited water resources could have any significant impact on the resources of the unconfined aquifer. Similarly utilising the water resources of the unconfined aquifer is unlikely to impact on the confined aquifer.

RECOMMENDATIONS

The following recommendations are made:

- consider further management options to reduce groundwater salinity in the Intensely Irrigated Area,
- obtain accurate water extraction figures,
- investigate salt accession mechanisms in Sub-area 4,
- to be consistent with the methodology of using rainfall recharge to calculate PAVs, the PAVs for the Padthaway PWA on a sub-area basis are the rainfall recharge figures as calculated in Table 3 should be adopted,
- to ensure proper management of the resource the Department for Water Resources database should be improved so that water allocation and water use data can be obtained on an individual sub-area basis,
- continued monitoring at present levels, possibly increasing the number of water level observation wells in the central part of Sub-area 2B and possibly Sub-area 4.

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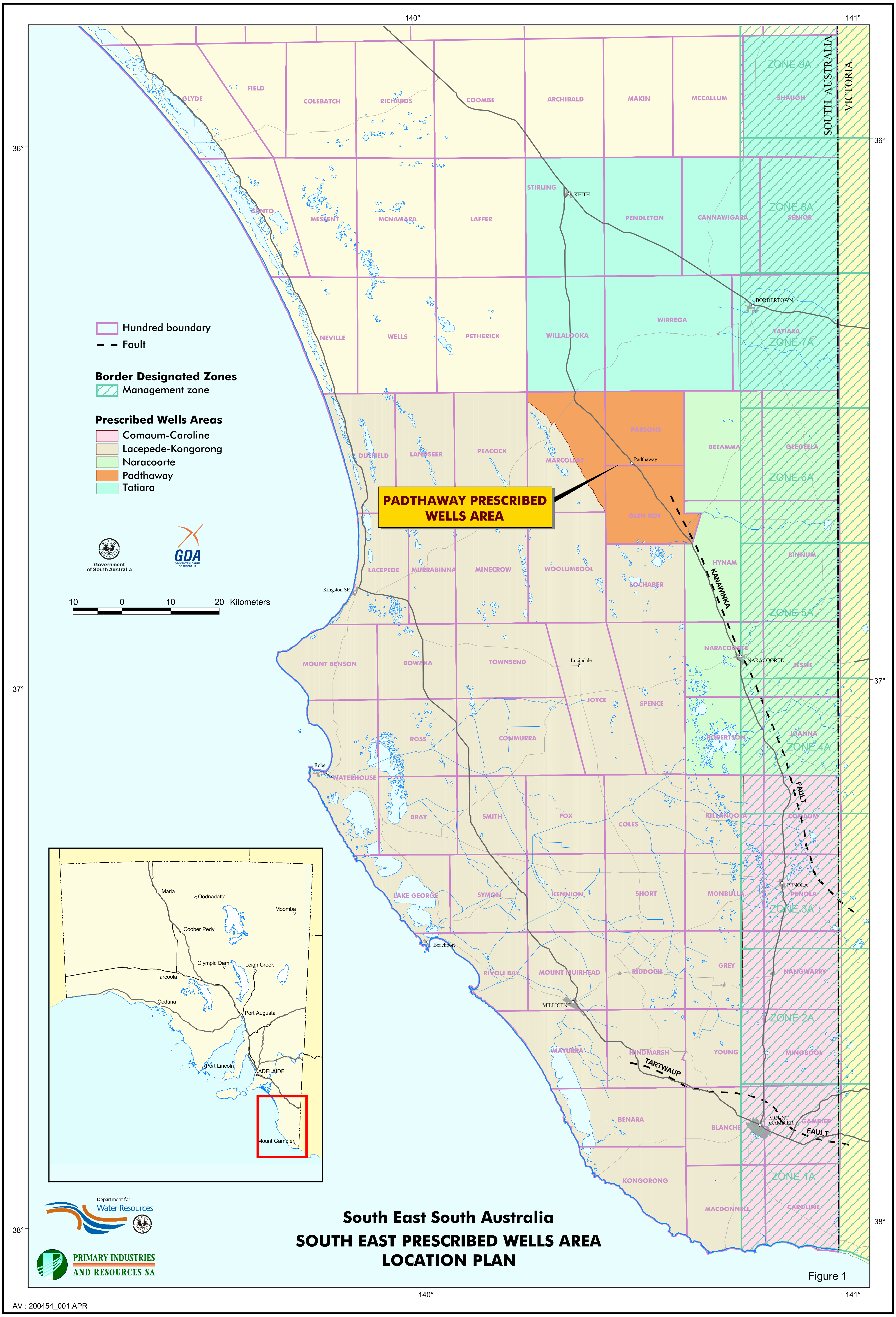
Figures



South East South Australia
SOUTH EAST PRESCRIBED WELLS AREA LOCATION PLAN

Figure 1

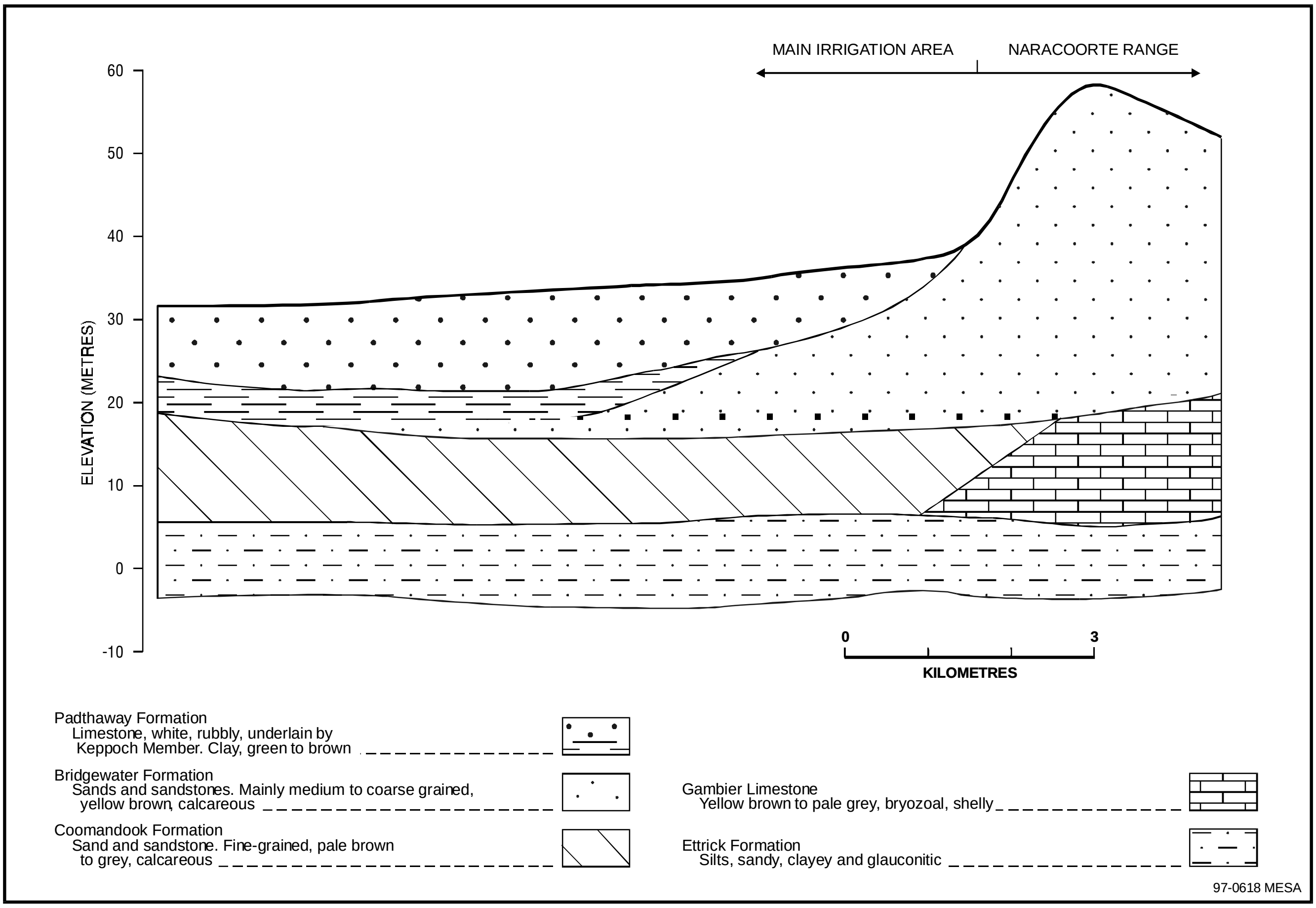
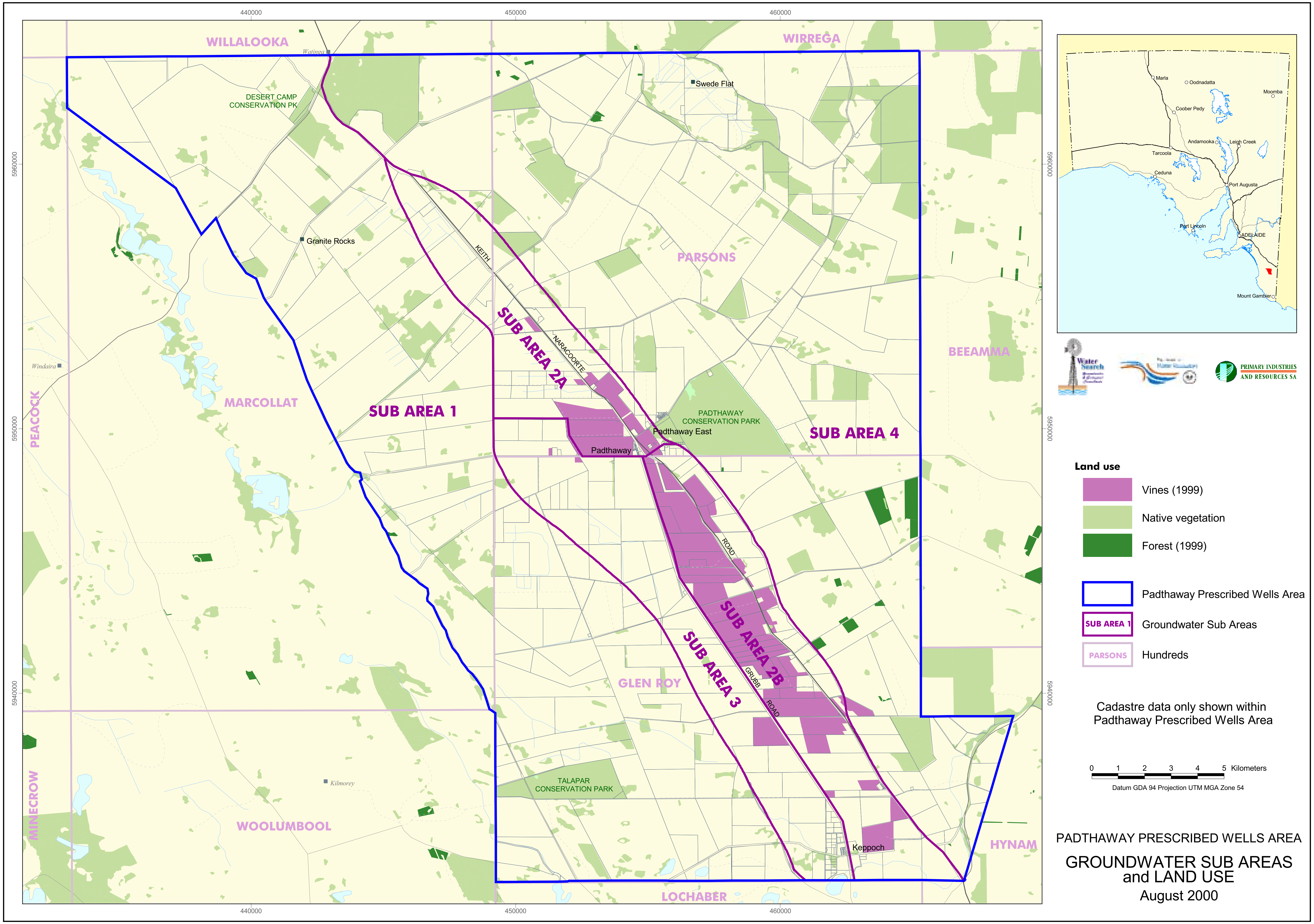


***Fig. 2** Schematic east - west geological cross section.*



PADTHAWAY PRESCRIBED WELLS AREA

GROUNDWATER SUB AREAS and LAND USE

August 2000

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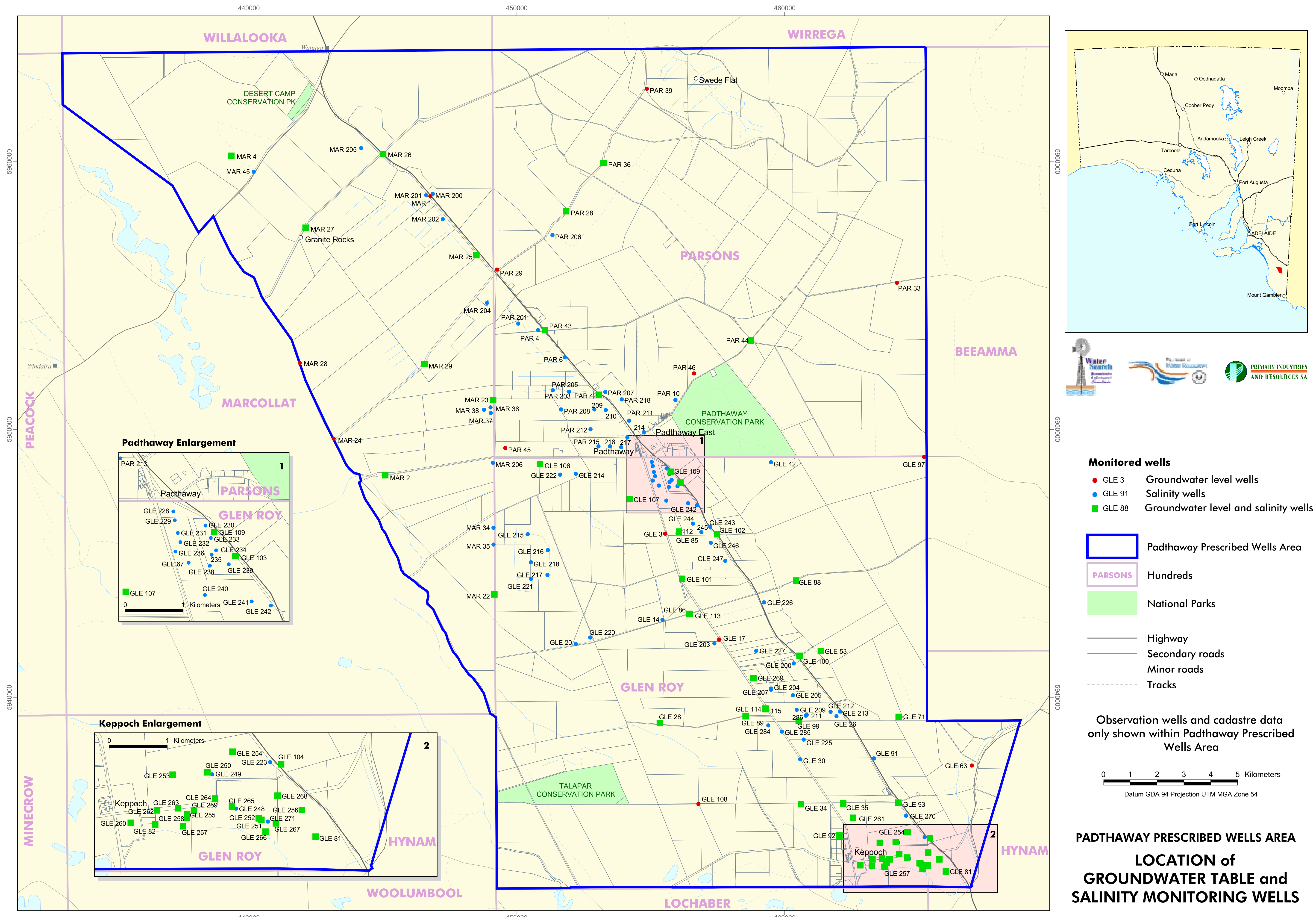
Figure 3



PADTHAWAY PRESCRIBED WELLS AREA

LOCATION of GROUNDWATER TABLE and SALINITY MONITORING WELLS

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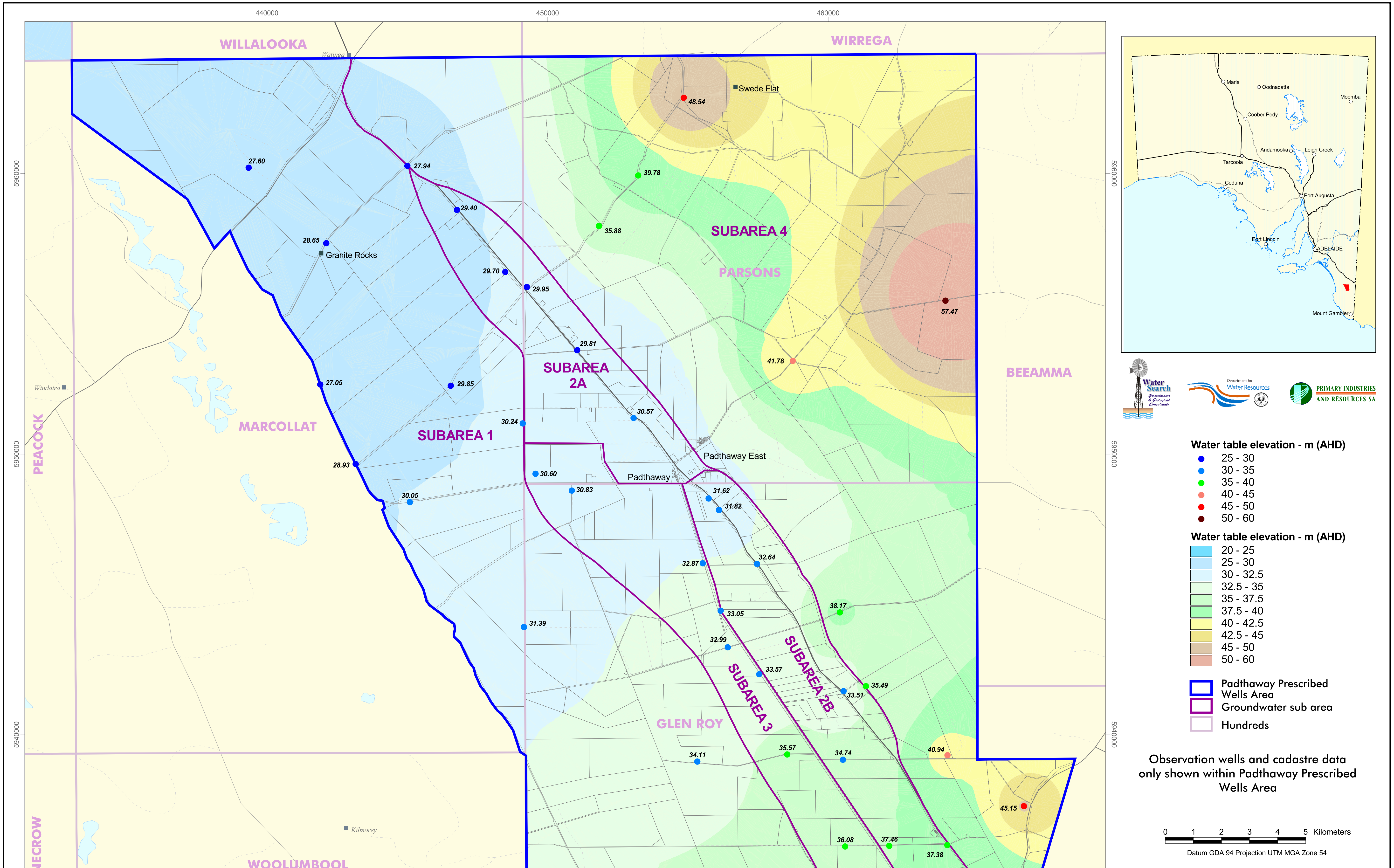
Figure 4



PADTHAWAY PRESCRIBED WELLS AREA

UNCONFINED AQUIFER WATER TABLE ELEVATION ZONES AUGUST 2000

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Figure 5

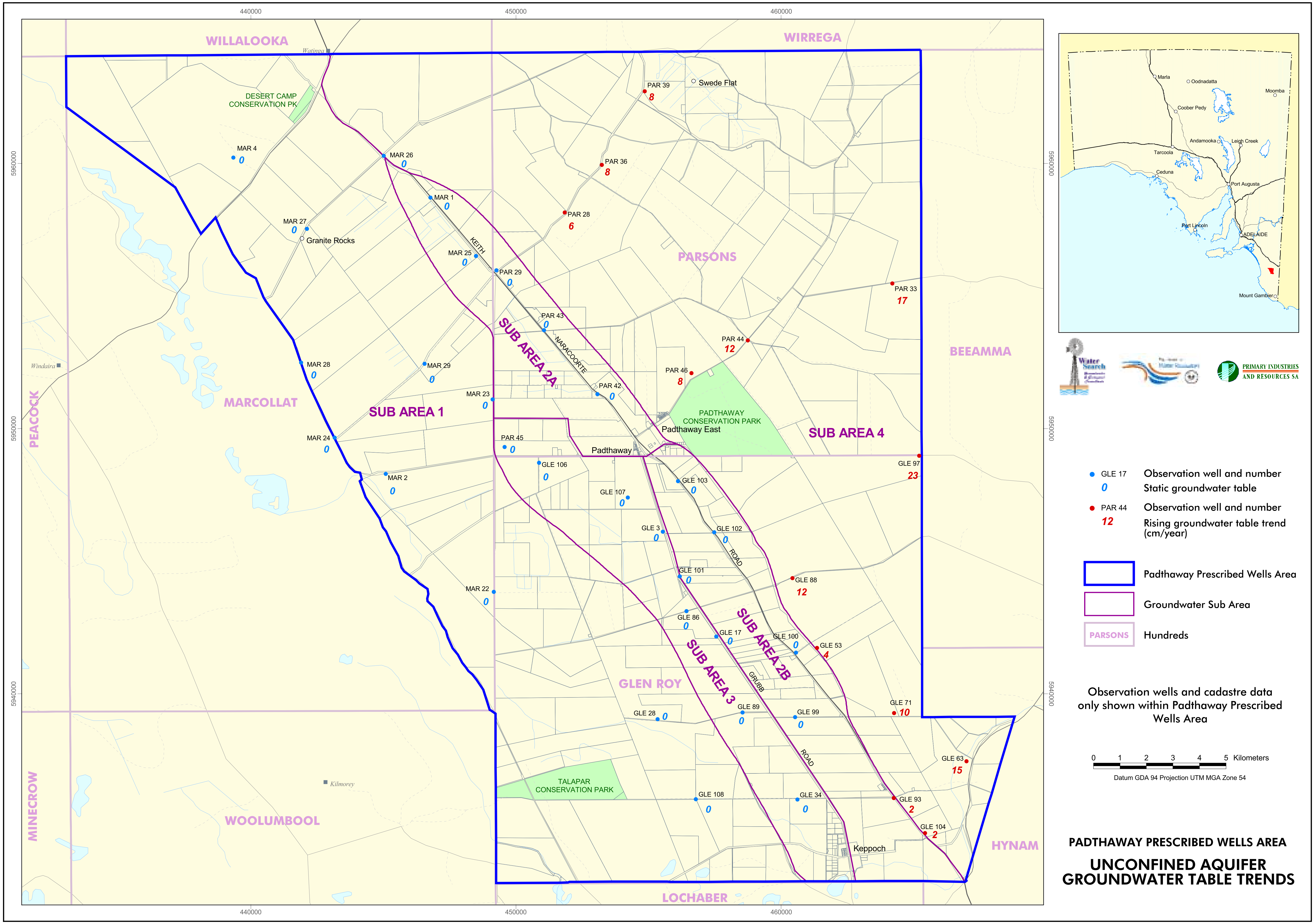

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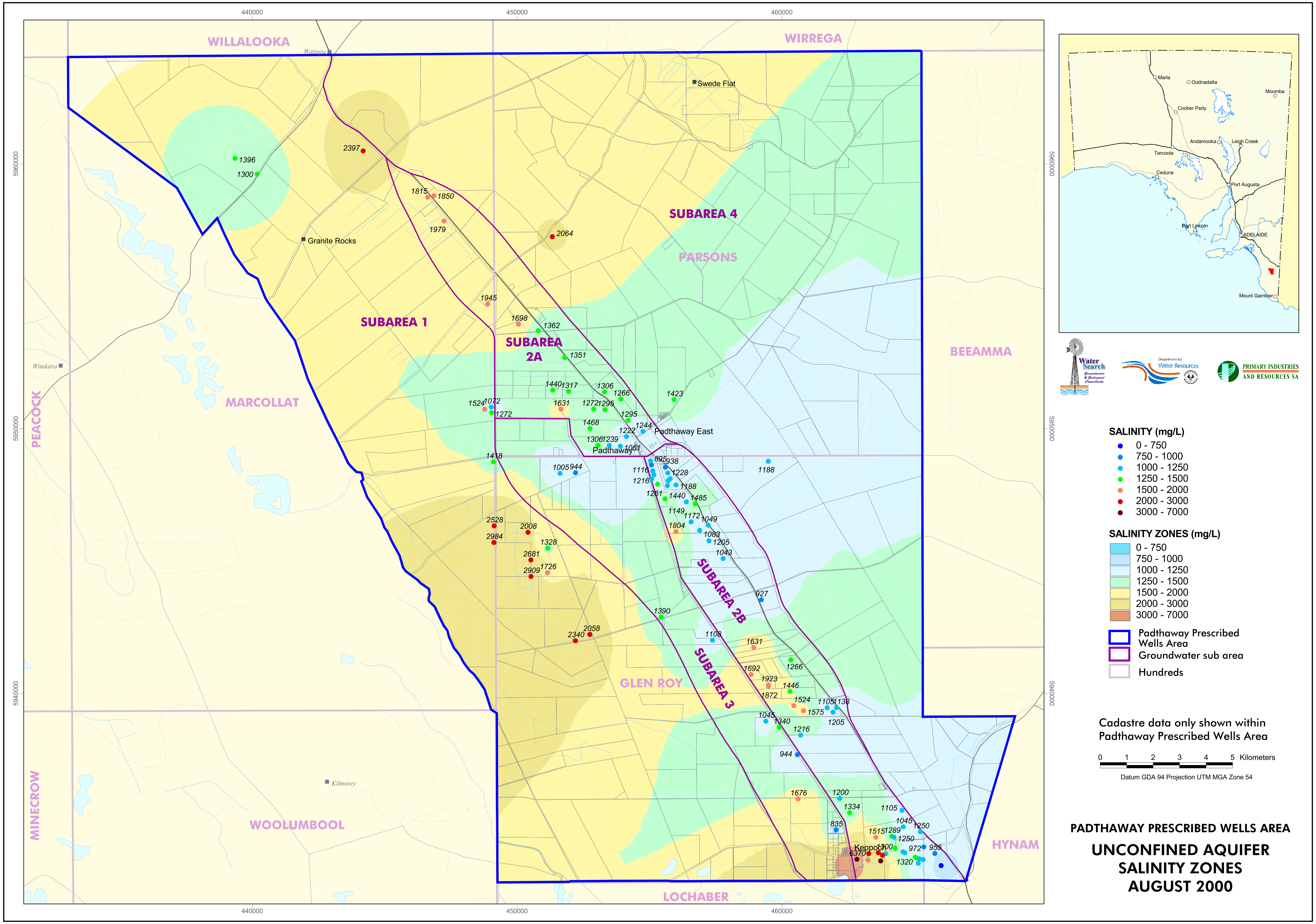
Figure 6



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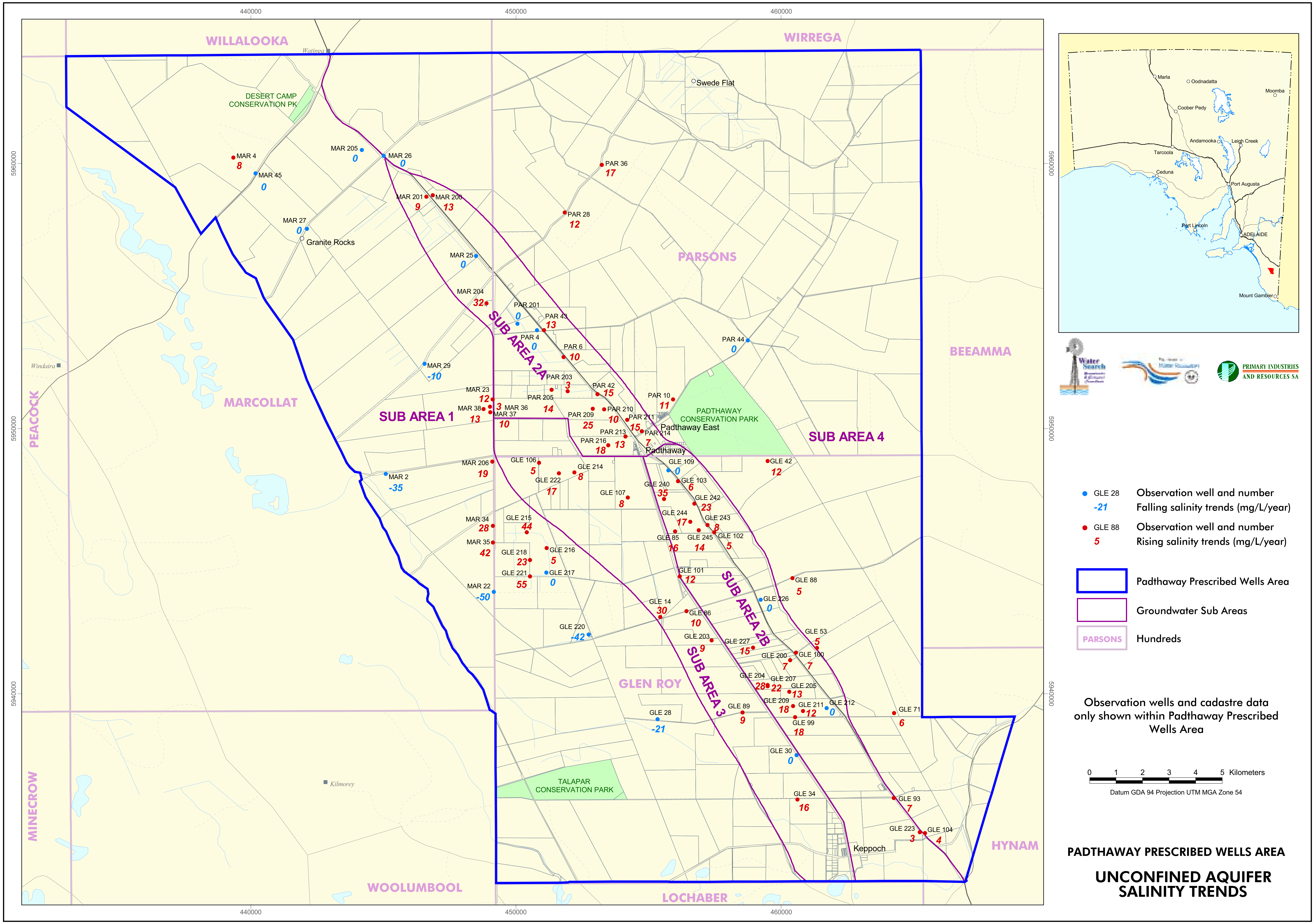

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Figure 8

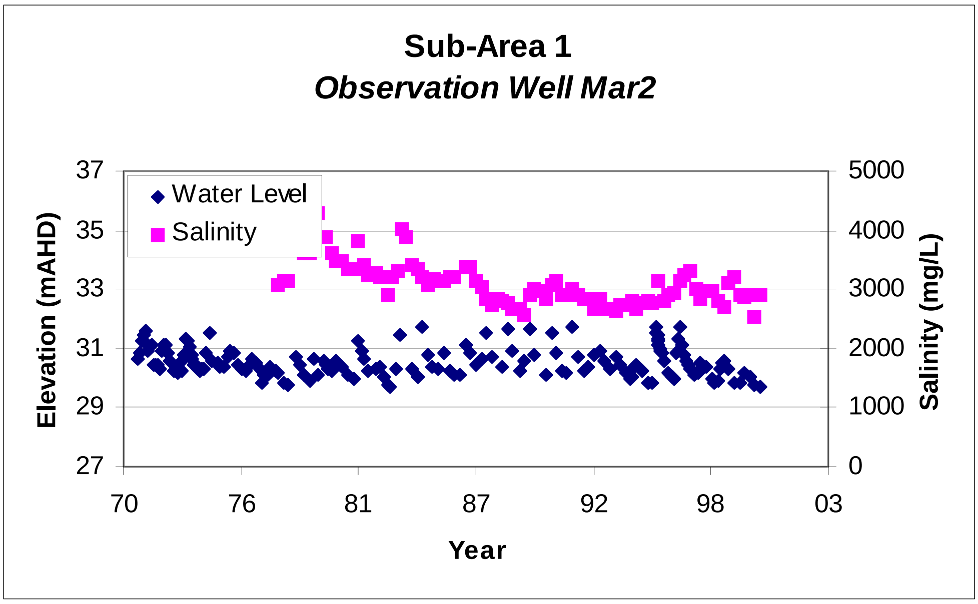
Appendix A

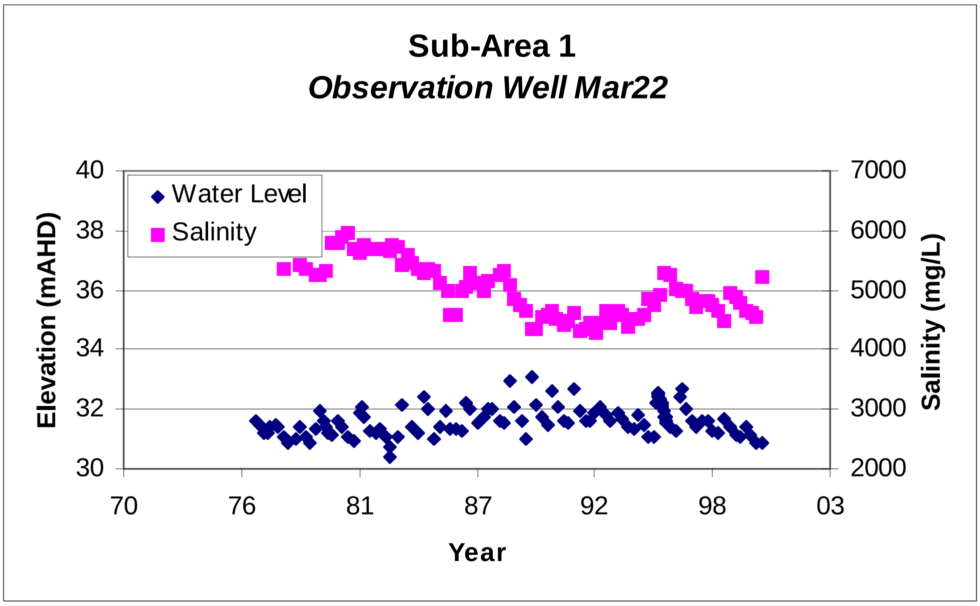
Estimated irrigation requirements and crop area ratios for the Padthaway Prescribed Wells Area

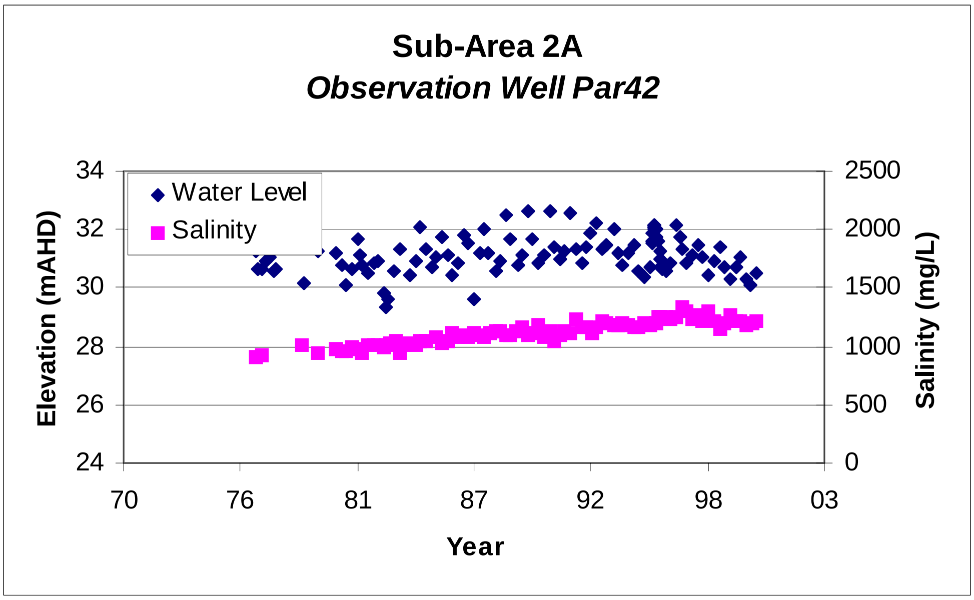
Crop Area	Irrigation Requirement (mm)	Crop Ratio
Reference crop	592	1.0
Apples	556	1.1
Annual clover seed	205	2.9
Beans Faba/Field	142	4.2
Cabbage winter sown	80	7.4
Canola Seed	141	4.2
Carrots summer sown	143	4.1
Cauliflower winter sown	80	7.4
Cereals	145	4.1
Chinese cabbage seed	141	4.2
Cocksfoot seed	305	1.9
Coriander seed	196	3.0
Fescue seed	216	2.7
Garlic	194	3.0
Kale seed	141	4.2
Linseed	132	4.5
Lucerne hay	549	1.1
Lucerne seed	440	1.3
Medic seed	241	2.5
Mustard seed	141	4.2
Onions	460	1.3
Pasture	592	1.0
Pasture starter, finisher	80	7.4
Perennial clover seed	371	1.6
Phalaris seed	305	1.9
Potatoes	458	1.3
Radish seed	141	4.2
Strawberries	454	1.3
Sub clover seed	242	2.4
Summer fodder	331	1.8
Sunflower	366	1.6
Sweet corn	340	1.7
Vetch seed	239	2.5
Vines	219	2.7

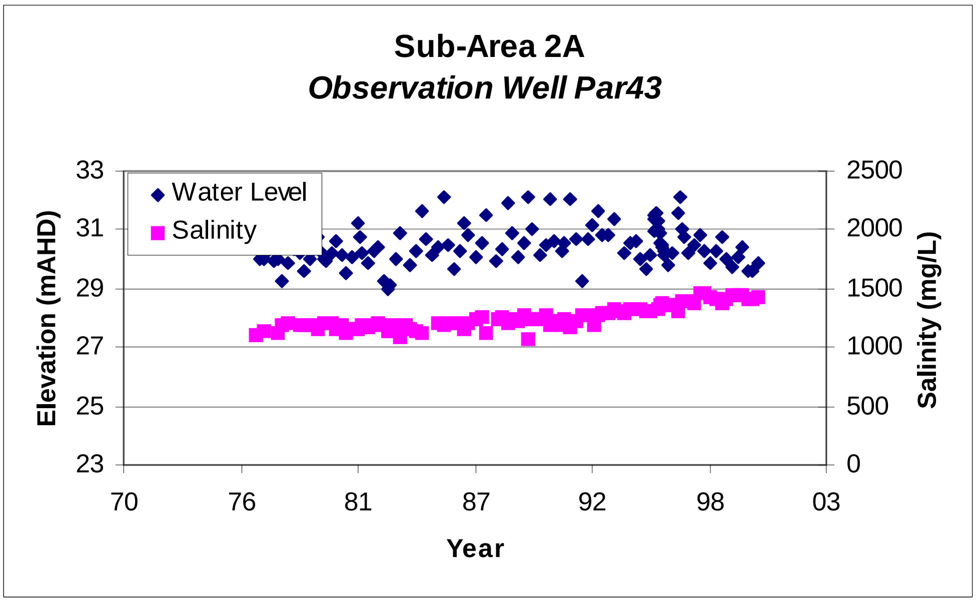
Appendix B

Bore Hydrographs and Salinity Graphs


Sub-Area 1
Observation Well Mar2
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
Year
37
35
33
31
29
27
5000
4000
3000
2000
1000
0
70
76
81
87
92
98
03


Sub-Area 1
Observation Well Mar22
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
Year
40
38
36
34
32
30
7000
6000
5000
4000
3000
2000
70
76
81
87
92
98
03


Sub-Area 2A
Observation Well Par42
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
34
32
30
28
26
24
2500
2000
1500
1000
500
0
70
76
81
87
92
98
03
Year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Observation Well Par43
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
33
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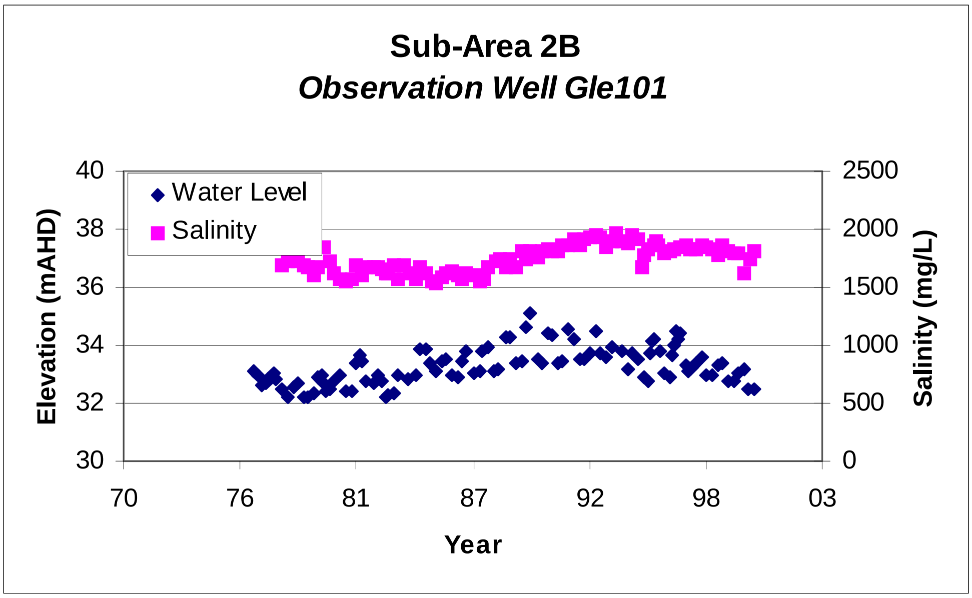
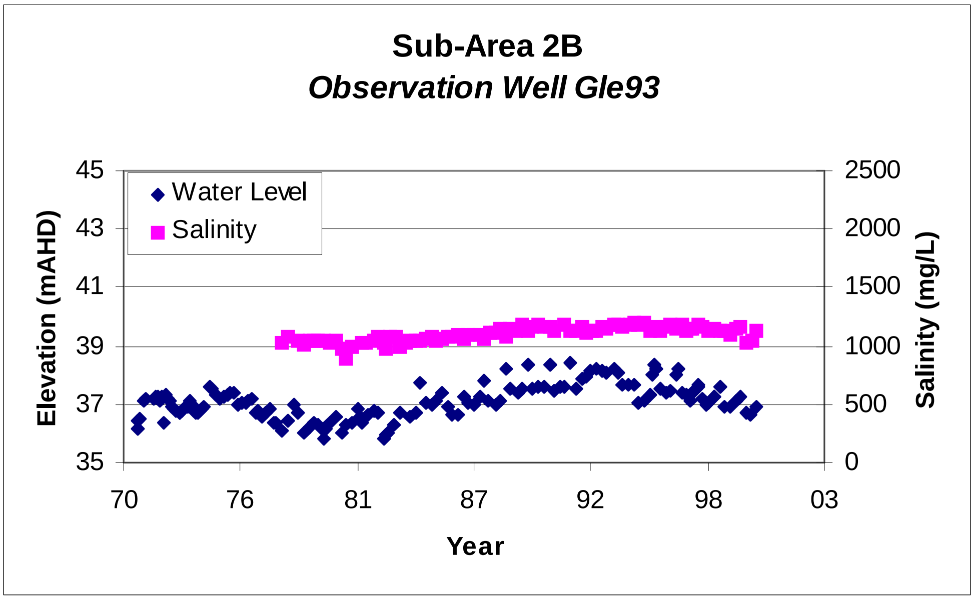
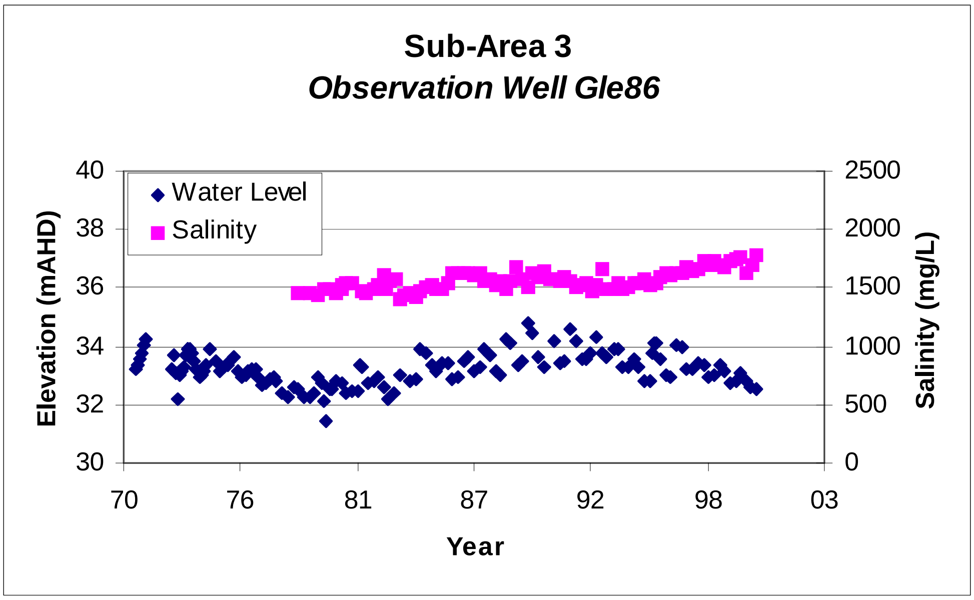
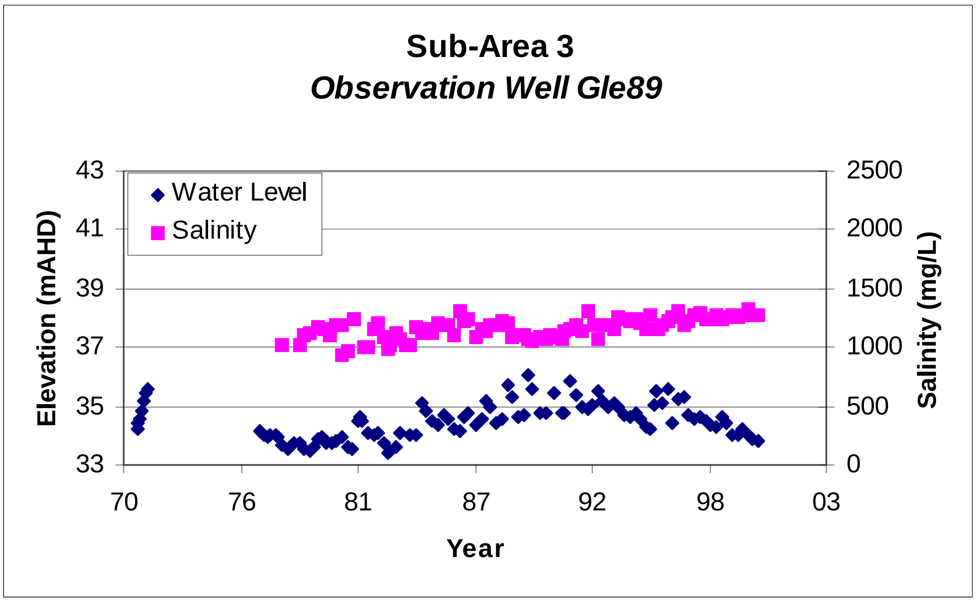
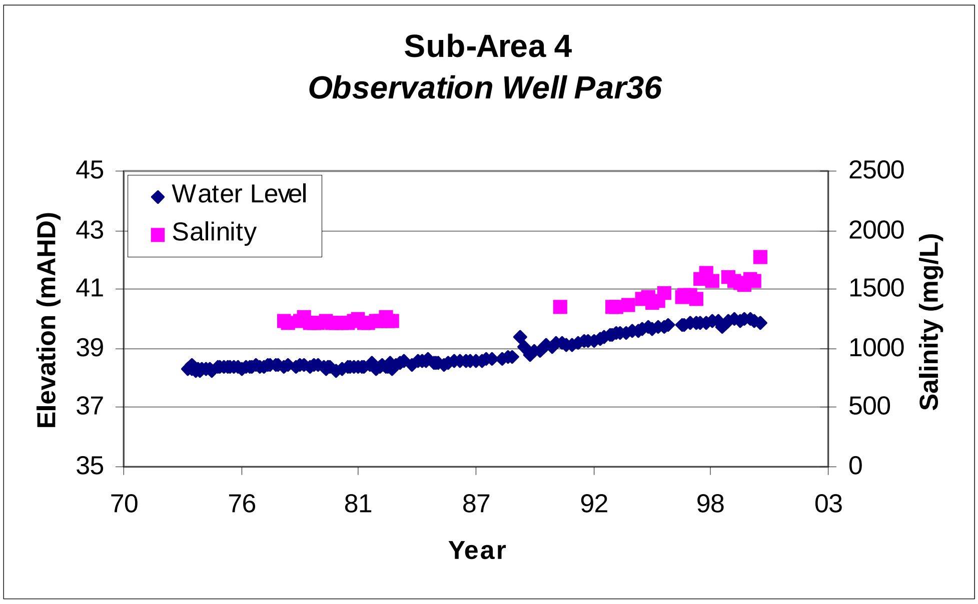
25
23
2500
2000
1500
1000
500
0
70
76
81
87
92
98
03
Year

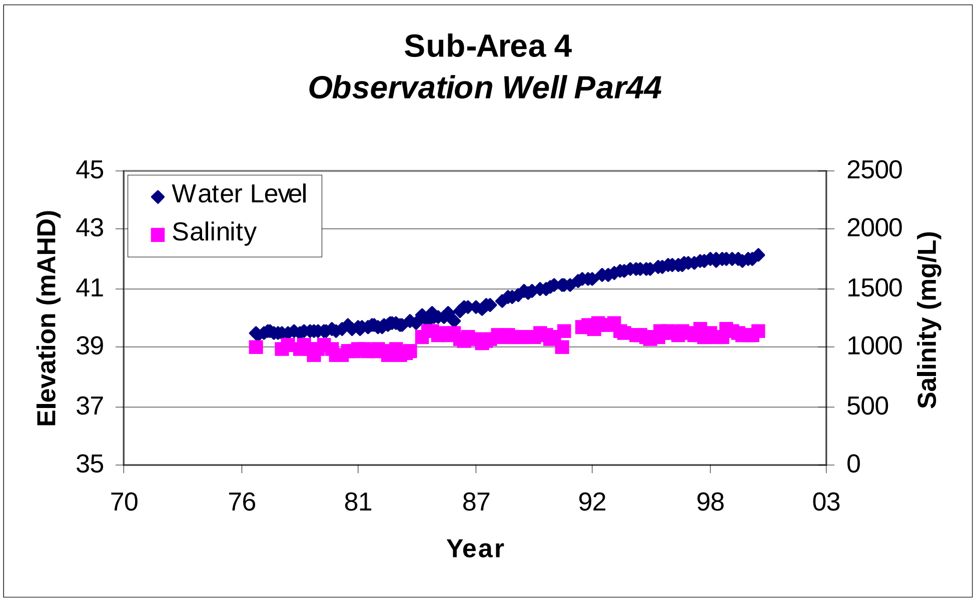

Sub-Area 2B
Observation Well Gle101
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
40
38
36
34
32
30
2500
2000
1500
1000
500
0
70
76
81
87
92
98
03
Year


Sub-Area 2B
Observation Well Gle93
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
45
43
41
39
37
35
2500
2000
1500
1000
500
0
70
76
81
87
92
98
03
Year


Sub-Area 3
Observation Well Gle86
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
40
38
36
34
32
30
2500
2000
1500
1000
500
0
70
76
81
87
92
98
03
Year


Sub-Area 3
Observation Well Gle89
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
43
41
39
37
35
33
2500
2000
1500
1000
500
0
70
76
81
87
92
98
03
Year


Sub-Area 4
Observation Well Par36
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
Year
45
43
41
39
37
35
2500
2000
1500
1000
500
0
70
76
81
87
92
98
03


Sub-Area 4
Observation Well Par44
Water Level
Salinity
Elevation (mAHD)
Salinity (mg/L)
Year
45
43
41
39
37
35
2500
2000
1500
1000
500
0
70
76
81
87
92
98
03

Appendix C

Groundwater Management Options for the Padthaway Irrigation Area

MANAGEMENT OPTION	POSSIBLE ADVANTAGES	POSSIBLE DISADVANTAGES	UNCERTAINTIES
1. Sourcing water from the Naracoorte Ranges	• better quality water for irrigation • reduced salt load returning to the aquifer • reduced groundwater pumping in the intensive irrigation area	• local waterlogging/ rising groundwater levels • continued increase of salinity at a reduced rate • reduced well yields • cost of construction • groundwater competition in the ranges	• water logging/rising groundwater levels in western part of the area
2. Pumping from deeper parts of the aquifer	• better quality groundwater for irrigation • reduced salt load returning to the aquifer	• local waterlogging/rising groundwater levels • continued increase of salinity at a reduced rate • reduced well yields • cost of construction	• water logging/rising groundwater levels in western part of the area • degree of inter-connection between the aquifer sub-units
3. Artificial Recharge	• better quality groundwater for irrigation • some control of groundwater salinity increase	• local waterlogging/rising groundwater levels • continued increase of salinity at a reduced rate • cost of construction	• water logging/rising groundwater levels in western part of the area • volume of surface water available
4. Interception channel	• better quality groundwater for irrigation • replacement of more saline groundwater with better quality groundwater from the ranges	• continued increase of salinity at a reduced rate • lowering groundwater levels • cost of construction	• disposal of drainage water • local community acceptance
5. Improved irrigation efficiency	• reduced salt load returning to the aquifer • some control of groundwater salinity increase • reduced groundwater pumping in the intensive irrigation area	• continued increase of salinity at a reduced rate	• local community acceptance
6. Reduction in allocation	• reduced salt load returning to the aquifer • some control of groundwater salinity increase • reduced groundwater pumping in the intensive irrigation area	• continued increase of salinity at a reduced rate • reduced economic return	• local community acceptance