LOWER LIMESTONE COAST PWA

GROUNDWATER LEVEL AND SALINITY STATUS REPORT

2011

DEPARTMENT FOR WATER

Government of South Australia
Department for Water

Science, Monitoring and Information Division
Department for Water
25 Grenfell Street, Adelaide
GPO Box 2834, Adelaide SA 5001

Telephone	National	(08) 8463 6946
	International	+61 8 8463 6946
Fax	National	(08) 8463 6999
	International	+61 8 8463 6999
Website	www.waterforgood.sa.gov.au	

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SUMMARY 2011

The Lower Limestone Coast Prescribed Wells Area (PWA) is located in the South East of South Australia, approximately 300 km south-east of Adelaide. It covers an area of 13 300 km^2 and is a regional-scale resource for which groundwater is prescribed under South Australia's *Natural Resources Management Act 2004*. Three Water Allocation Plans – the Comaum-Caroline, Lacepede Kongorong and Naracoorte Ranges – currently provide for sustainable management of the water resources of the Lower Limestone Coast PWA. A combined Lower Limestone Coast Water Allocation Plan that encompasses the three aforementioned Water Allocation Plans is currently under preparation by the South East Natural Resources Management Board.

Metered groundwater extractions for licensed purposes (excluding stock and domestic use) in the Lower Limestone Coast PWA totalled 140 857 ML in 2010–11. This volume includes extractions from both unconfined and confined aquifers and represents a 36% decrease from the previous water-use year.

Previous studies indicate that pasture is the dominant irrigated crop type in the Lower Limestone Coast PWA, accounting for about 61% of the total licensed volume of water extracted for the purpose of irrigation. Lucerne accounts for 13% of the volume used for irrigation, with potatoes using 8% and vines using 7%.

Plantation forest impacts on the regional groundwater resources are significant, particularly where the watertable is shallow and plantations represent a significant land use. It is estimated that the impacts of the existing regional plantation forest on reduced groundwater recharge and direct extraction where the watertable is shallow, is in the order of 200 000 ML per year.

The most widespread influence on groundwater levels in the Lower Limestone Coast PWA is reduced recharge due to drier conditions in recent years. Groundwater levels in the unconfined aquifer throughout the Lower Limestone Coast PWA generally show a consistent decline since 1993 in response to the observed below-average rainfall. Wetter conditions during 2009 to 2011 have led to a partial recovery of water levels in most areas, including those affected by licensed extractions and forestry. Recent above-average rainfall has correlated to a significant decrease in extraction from the unconfined aquifer. Groundwater salinities in the unconfined aquifer are generally stable, with some decreases due to the higher rainfall experienced during 2010 and 2011.

In the north-east of the PWA (Naracoorte Ranges), vegetation clearance is causing salinity increases but it is likely that this trend will eventually reverse as the salt is flushed from the profile and low-salinity recharge then enters the aquifer.

South of Mt Gambier in the Donovans Management Area (MA), declines in water levels have increased the risk of seawater intrusion. Some movement of the salt water interface has been observed in deep observation wells (>100 m deep).

Previous regional declines in confined aquifer water levels are likely to have been caused by hydrostatic unloading (as explained on page 25) but investigations are underway to examine leakage between aquifers. These trends appear to have stabilised during 2009 and 2010. In the artesian area near Kingston where intensive extraction occurs, levels have recovered by several metres in recent years. Salinity trends in the confined aquifer throughout the Lower Limestone Coast PWA are stable.

ASSESSMENT OF STATUS

The Lower Limestone Coast Prescribed Wells Area has been assigned a green status of "No adverse trends, indicating a stable or improving situation" based on current trends. This status for 2011 is supported by:

- stable or slowly rising groundwater levels in response to higher rainfall
- stable groundwater salinity levels over most of the region, with some decreases in salinity observed due to higher rainfall.

There has been a regional decline in groundwater levels of up to 5 m in the unconfined aquifer over the past five to ten year period. There have also been observed localised declines related to the intensity of groundwater resource use.

The generally low salinity of the groundwater means that localised increases in salinity due to irrigation drainage, native vegetation clearance and forestry are not expected to affect water quality related beneficial uses of the resource for a considerable time.

An exception is the Donovans Management Area (MA) where declining groundwater levels due to irrigation extraction and below-average rainfall have increased the risk of seawater intrusion. Salinity increases due to irrigation drainage have been observed in shallow groundwater and there is evidence of some movement of the seawater interface in deep observation wells. Further investigation of the seawater intrusion risk is underway.

For these reasons, the Donovans MA has been assigned a yellow status of "Adverse trends indicating low risk to the resource in the medium term" based on current trends.

STATUS 2011

Seawater Intrusion in Donovans MA

<u>No adverse trends, indicating a stable or improving situation</u>

Trends are either stable (no significant change), or improving (i.e. decreasing salinity or rising water levels).

<u>Adverse trends indicating low risk to the resource in the medium term</u>

Observed adverse trends are gradual and if continued, will not lead to a change in the current beneficial uses of the groundwater resource for at least 15 years. Beneficial uses may be drinking water, irrigation or stock watering.

<u>Adverse trends indicating high risk to the resource eventuating in the short to medium term</u>

Observed adverse trends are significant and if continued, will lead to a change in the current beneficial uses of the groundwater resource in about 10 years.

<u>Degradation of the resource compromising present use within the short term</u>

Trends indicate degradation of the resource is occurring, or will occur within 5 years. Degradation will result in a change in the beneficial use (i.e. no longer suitable for drinking or irrigation purposes) and may take the form of increasing groundwater salinities, or a fall in the groundwater levels such that extractions from the aquifer may not be possible.

BACKGROUND

The Lower Limestone Coast Prescribed Wells Area (PWA) is located in the South East of South Australia, approximately 300 km south-east of Adelaide (Fig. 1). It covers an area of 13 300 km^2 and is a regional-scale resource for which groundwater is prescribed under South Australia's *Natural Resources Management Act 2004*. Three Water Allocation Plans—the Comaum-Caroline, Lacepede Kongorong and Naracoorte Ranges—provide for sustainable management of the water resources of the Lower Limestone Coast PWA. A combined Lower Limestone Coast Water Allocation Plan that covers the entire Lower Limestone Coast PWA is in preparation by the South East Natural Resources Management Board.

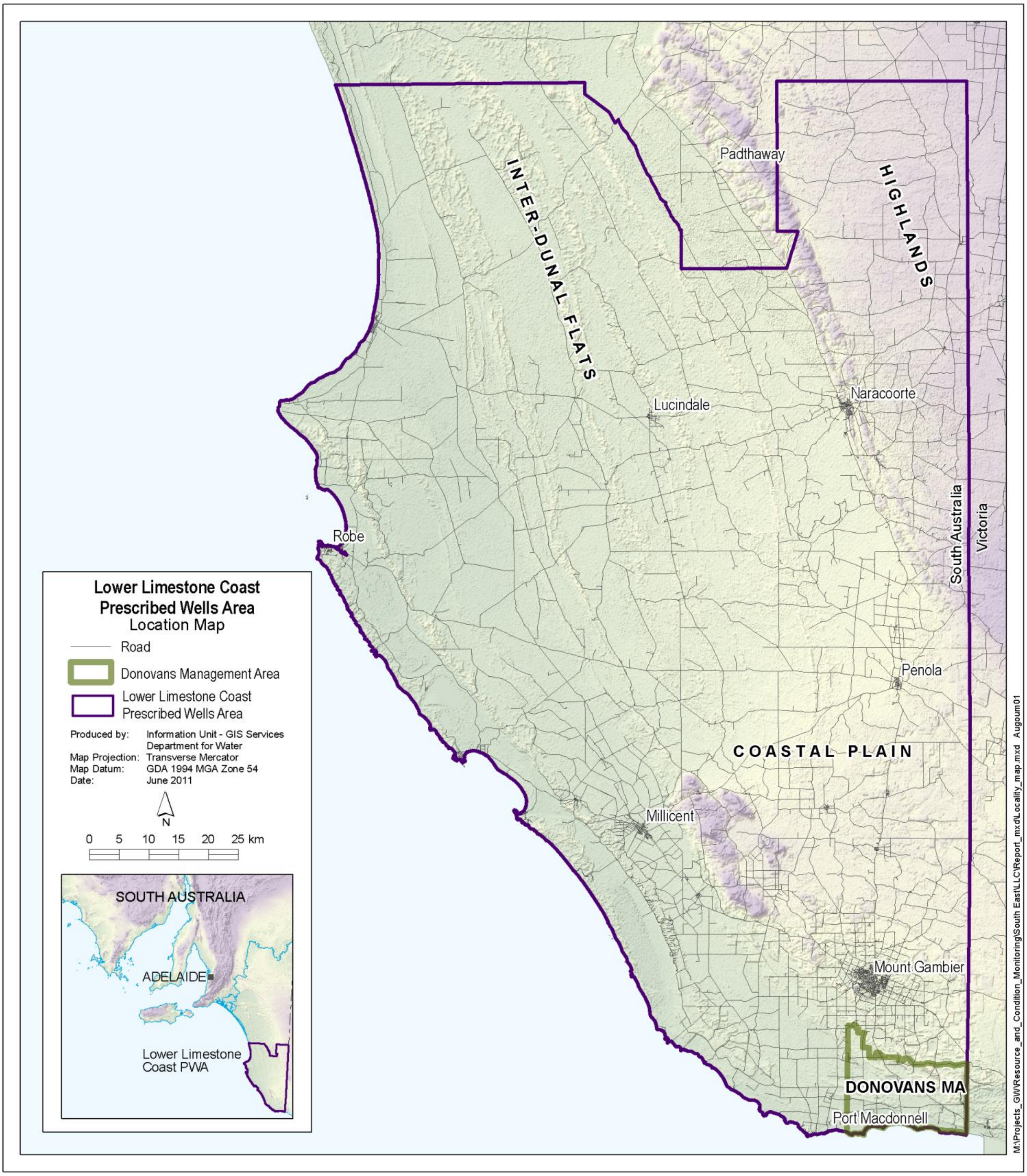

Figure 1. Location of the Lower Limestone Coast PWA

HYDROGEOLOGY

The Lower Limestone Coast PWA is mostly underlain by Tertiary sediments of the Gambier Basin, with a continuous transition to similar sediments of the Murray Basin in the northern portion of the PWA. Most of the region is characterised by a low-lying coastal plain that gently rises from the coast to 70 m above sea level in the eastern and north-eastern part of Lower Limestone Coast PWA, which is associated with the Naracoorte Ranges. The northern and central parts of the Lower Limestone Coast PWA are characterised by north-west trending remnants of the old coastal dunes, separated by inter-dunal flats.

There are two aquifer systems located in the region; an unconfined aquifer comprising Quaternary and Tertiary limestones and an underlying Tertiary Confined Sand aquifer. The confined and unconfined aquifers are generally separated by a low-permeability aquitard.

UNCONFINED AQUIFER

Inter-dunal Flats

A marine transgression about one million years ago eroded away the Tertiary sediments and deposited a range of Quaternary sediments which form the low-lying plain mainly in the northern and central parts of the Lower Limestone Coast PWA, where the depth to the watertable is generally less than 5 m.

Padthaway Formation is the uppermost geological unit in the Quaternary sequence which occurs largely in the inter-dunal flats and reaches a maximum known thickness of 20 m. It consists mainly of off-white, well-cemented, non-fossiliferous, fine-grained limestone with a well-developed secondary porosity.

Coomandook Formation consists of interbedded sandy limestones and shelly sandstones up to 15 m thick with moderate permeability.

Bridgewater Formation has been deposited in a series of topographic ridges that run sub-parallel to the coast with thicknesses up to 90 m. Its lithology varies over the region but generally consists of a shelly and sandy aeolianite. In the inter-dunal flats, it underlies the Padthaway Formation.

The Padthaway and Bridgewater Formations are highly transmissive and the resultant high well yields of up to 300 L/s have enabled irrigators to adopt flood irrigation practices.

Costal Plain

In the south of the Lower Limestone Coast PWA, within the Gambier Basin, the Tertiary Gambier Limestone forms the unconfined aquifer and generally comprises a creamy bryozoal limestone and varies in thickness of up to 400 m offshore to the south. The permeability of the aquifer is highly variable, with very high values associated with karst solution features.

Highlands

Beneath the highlands, in the Murray Basin, the unconfined aquifer is contained within the Tertiary Murray Group Limestone aquifer, which is equivalent to the Gambier Basin Gambier Limestone aquifer and comprises a bryozoal limestone that averages 100 m in thickness. Due to the elevated topography, the depth to the watertable in the Murray Group Limestone can exceed 40 m and typical well yields range between 50 and 200 L/s. Overlying the limestone aquifer is a considerable thickness of Pliocene Sands, which are dry.

CONFINED AQUIFER

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

The confined aquifer in the Murray Basin to the north of the Lower Limestone Coast PWA is referred to as the Renmark Group, which consists of interbedded sands, silt and carbonaceous clay up to 100 m thick.

The confined aquifer is very thin or absent over much of the northern area due to the shallow basement (Padthaway Ridge). It is not widely used due to reported low well yields of 10 to 20 L/s and the availability of much larger supplies in the overlying unconfined aquifer.

Over most of the Lower Limestone Coast PWA, in the Gambier Basin, the main confined aquifer is the Dilwyn Formation, which consists of quartz sands interbedded with dark brown carbonaceous clays. For management purposes, this aquifer is considered regionally as one aquifer, but it is actually a complex multi-aquifer groundwater system. The current understanding of the hydraulic interconnection between the South East sub-aquifers is limited.

A schematic cross-section of the Lower Limestone Coast PWA is displayed in Figure 2.

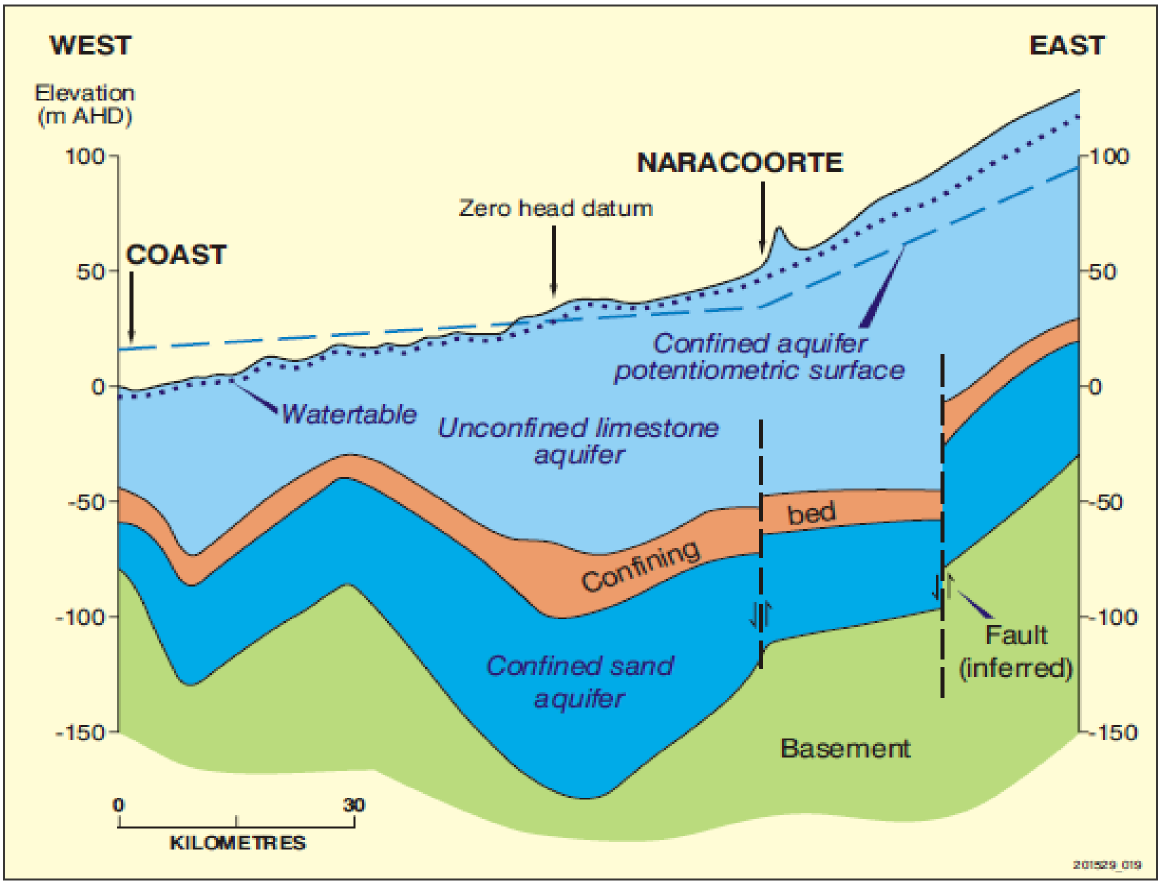

Figure 2. Geological cross-section of the Lower Limestone Coast PWA

A summary of the hydrogeology is presented in Table 1.

Table 1. Hydrogeology of the Lower Limestone Coast PWA

AGE	STRATIGRAPHY		HYDROGEOLOGY	
	Unit	Lithology	Unit	Description
INTER-DUNAL FLATS				
Quaternary	Padthaway Formation	Off-white, well-cemented, fine-grained limestone deposited in inter-dunal flats	**Unconfined aquifer**	Mainly used for irrigation and stock supplies. High yields of up to 300 L/s enable flood irrigation. Depth to the watertable about 5 m.
	Bridgewater Formation	Shelly and sandy aeolianite deposited in inter-dunal flats and a series of topographic ridges		
	Coomandook Formation	Interbedded sandy limestones and shelly sandstones		
Tertiary	Nurrawaturk Marl	Grey-green glauconitic marl	**Aquitard**	Confining layer, equivalent to the Ettrick Formation in the Murray Basin.
	Renmark Group	Interbedded sands, silt and carbonaceous clay	**Confined aquifer**	Generally thin or absent, present in the Murray Basin region of the PWA.
	Dilwyn Formation	Carbonaceous sands and clays	**Confined aquifer**	Main confined aquifer, present in the Otway Basin region of the PWA.
COASTAL PLAIN				
Tertiary	Gambier Limestone	Creamy bryozoal limestone	**Unconfined aquifer**	Depth to water can be >40 m, well yields range between 50 and 200 L/s, present in the Otway Basin region of the PWA.
	Renmark Group	Interbedded sands, silt and carbonaceous clay	**Confined aquifer**	Generally thin or absent, present in the Murray Basin region of the PWA.
	Dilwyn Formation	Carbonaceous sands and clays	**Confined aquifer**	Main confined aquifer, present in the Otway Basin region of the PWA.
HIGHLANDS				
Tertiary	Pliocene Sands	Non marine, fine to medium clayey quartz sand		Unsaturated
	Murray Group Limestone	White bryozoal and shelly limestone	**Unconfined aquifer**	Not generally utilised as an aquifer, present in the Murray Basin region of the PWA.
	Nurrawaturk Marl	Grey-green glauconitic marl	**Aquitard**	Confining layer, equivalent to the Ettrick Formation in the Murray Basin.
	Renmark Group	Interbedded sands, silt and carbonaceous clay	**Confined aquifer**	Generally thin or absent, present in the Murray Basin region of the PWA.
	Dilwyn Formation	Carbonaceous sands and clays	**Confined aquifer**	Main confined aquifer, present in the Otway Basin region of the PWA.

GROUNDWATER FLOW AND SALINITY

UNCONFINED AQUIFER

The contours of the unconfined aquifer watertable elevation (Fig. 3) indicate that groundwater flow occurs from the topographic high of the Dundas Plateau located in western Victoria. From there, groundwater flows in a radial direction westward and southward to the coast. The contours also show two areas where the hydraulic gradient becomes steeper. These areas are associated with the Kanawinka Fault in the north-east and the Tartwaup Fault just to the north of Mount Gambier, suggesting an impact of the faulting on the hydraulic properties of the unconfined aquifer due to changes in the aquifer lithology type or thickness across these faults.

The groundwater salinity of the unconfined aquifer is also shown in Figure 3. Groundwater is generally of good quality, ranging from less than 1000 mg/L in the higher rainfall areas in the south, to more than 3000 mg/L in the north-west.

CONFINED AQUIFER

The potentiometric surface for the confined aquifer is presented in Figure 4. The potentiometric gradient is similar to the unconfined aquifer with groundwater flow generally moving from west to east across the upper part of Lower Limestone Coast PWA and to the south-west in the lower part of PWA.

The groundwater salinity of the confined aquifer is generally less than 1000 mg/L in the Lower Limestone Coast PWA (Fig. 4). In the northern part of the Lower Limestone Coast PWA, the confined aquifer salinity increases rapidly (to more than 3000 mg/L) as the aquifer thins and the groundwater circulation becomes restricted near the shallow basement.

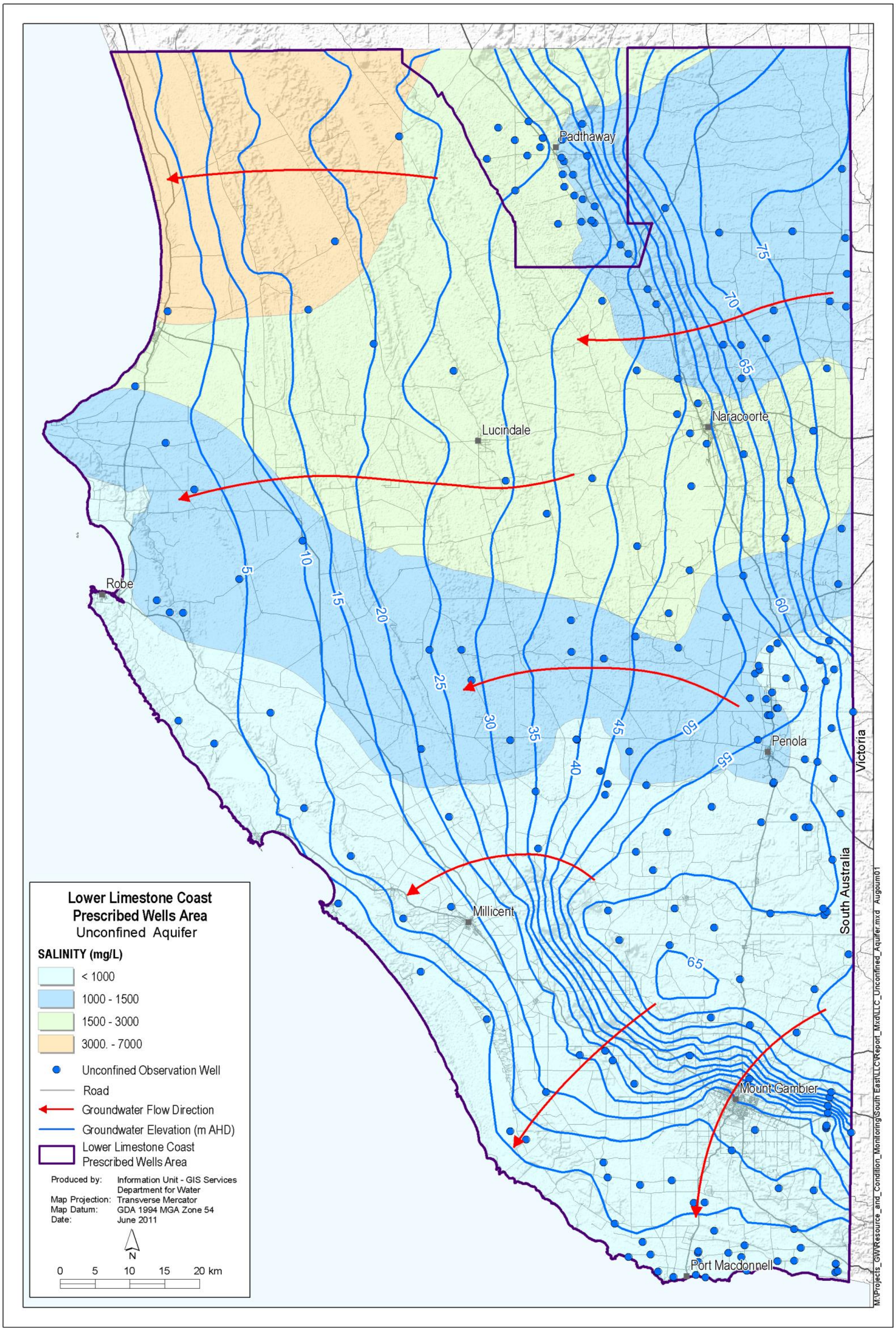

Figure 3. Groundwater flow and salinity distribution (winter 2010) for the unconfined aquifer in the Lower Limestone Coast PWA*

*As there were no discernible changes in water levels or salinity, the potentiometric surface and salinity ranges from the previous year have been used

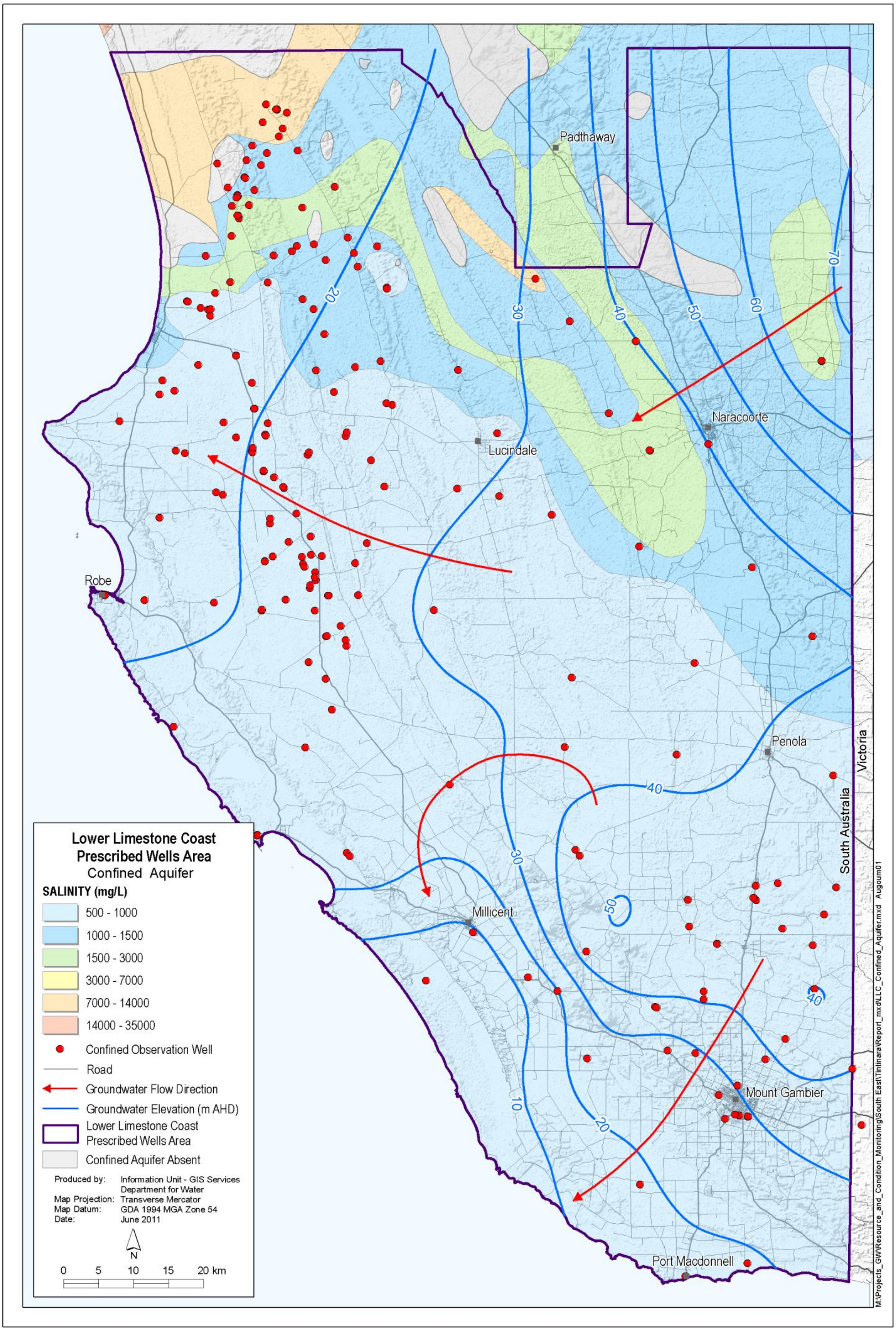

Figure 4. Groundwater flow and salinity distribution (winter 2010) for the confined aquifer in the Lower Limestone Coast PWA*

*As there were no discernible changes in water levels or salinity, the potentiometric surface and salinity ranges from the previous year have been used

GROUNDWATER DEPENDENT ECOSYSTEMS

Whilst groundwater dependent ecosystems (GDEs) have not been considered in the assessment of the annual status of the groundwater resource, it is important to note the presence and ecological characteristics of the GDEs found in the Lower Limestone Coast PWA. Groundwater dependent ecosystems can be defined as ecosystems where groundwater provides all or part of the water quantity, chemistry or temperature requirements, either permanently, seasonally or intermittently. It is generally considered that shallow watertables less than 10 m below the surface are more likely to support GDEs than deeper watertables. Shallow watertables are more susceptible to changes in groundwater levels which affect connectivity to GDEs and the ecological value of sites. The exception to this is stygofauna (animals that inhabit water filled cracks and pools below the ground), which can be found at greater depths.

The Lower Limestone Coast PWA is known to support seven different categories of GDE's namely; wetlands, karst rising springs, lakes, phreatopytic vegetation communities such as River Red Gum (*Eucalyptus camaldulensis*) accessing shallow groundwater, subterranean stygofauna communities, marine ecosystems (via discharge of groundwater to nearshore coastal environments) and permanent refuge pools within watercourses which subsist during dry periods via base flow from the unconfined Tertiary Limestone aquifer.

Many of the GDE's in the Lower Limestone Coast PWA provide habitat for rare and unique aquatic dependent biota, many of which are listed under state and national legislation. For example, the Yarra Pygmy Perch (*Nannoperca obscura*, Vulnerable, *Environment Protection and Biodiversity Conservation Act 1999*) is dependent on groundwater discharge into refuge pools and wetlands across the region, whilst the karst rising springs near Port Macdonnell support the only populations of Variegated Pygmy Perch (*Nannoperca variegata*, Vulnerable, *Environment Protection and Biodiversity Conservation Act 1999*) and Glenelg Spiny Crayfish (*Euastacus bispinosus*, Endangered, *Environment Protection and Biodiversity Conservation Act 1999*) in South Australia.

RAINFALL

The climate of the Lower Limestone Coast PWA is typified by hot, dry summers and cool, wet winters. Annual rainfall ranges from 758 mm in the south to approximately 587 mm in the north. Potential annual evapotranspiration increases from approximately 1400 mm in the south to approximately 1800 mm in the north.

Figures 6 to 9 show the rainfall records for Mount Gambier, Penola, Beachport and Kingston respectively, with locations shown in Figure 5. Data is sourced from the SILO Climate Database, which is hosted by the Queensland Climate Change Centre of Excellence. Any missing rainfall records are interpolated from nearby rainfall stations. This practise is commonly applied throughout the world where data is limited. More information is available at:

http://www.longpaddock.qld.gov.au/silo/about.html

The annual rainfall is displayed as blue columns, with the cumulative deviation from average annual rainfall also plotted in orange, which measures the difference between the actual measured annual rainfall and the long-term average annual rainfall. An upward trend in this line indicates above-average rainfall, and conversely, a downward trend indicates below-average rainfall.

The rainfall records are showing some similarity in the general trends for all stations; however, the following trends are notable:

- Both Mount Gambier and Kingston display a long-term below-average trend since 1960, apart from a wetter period in the early 2000s
- Both Penola and Beachport display a below-average trend since 1993, apart from a wetter period in the early 2000s
- All stations recorded below-average rainfall since the 2006 drought until 2009, when rainfall reached the average or above average. This continues through to 2011, with the exception of Beachport and Kingston. These stations recorded below-average rainfall in 2011.

Groundwater level trends in shallow aquifers on the low lying plains will be strongly influenced by the seasonality and magnitude of rainfall events.

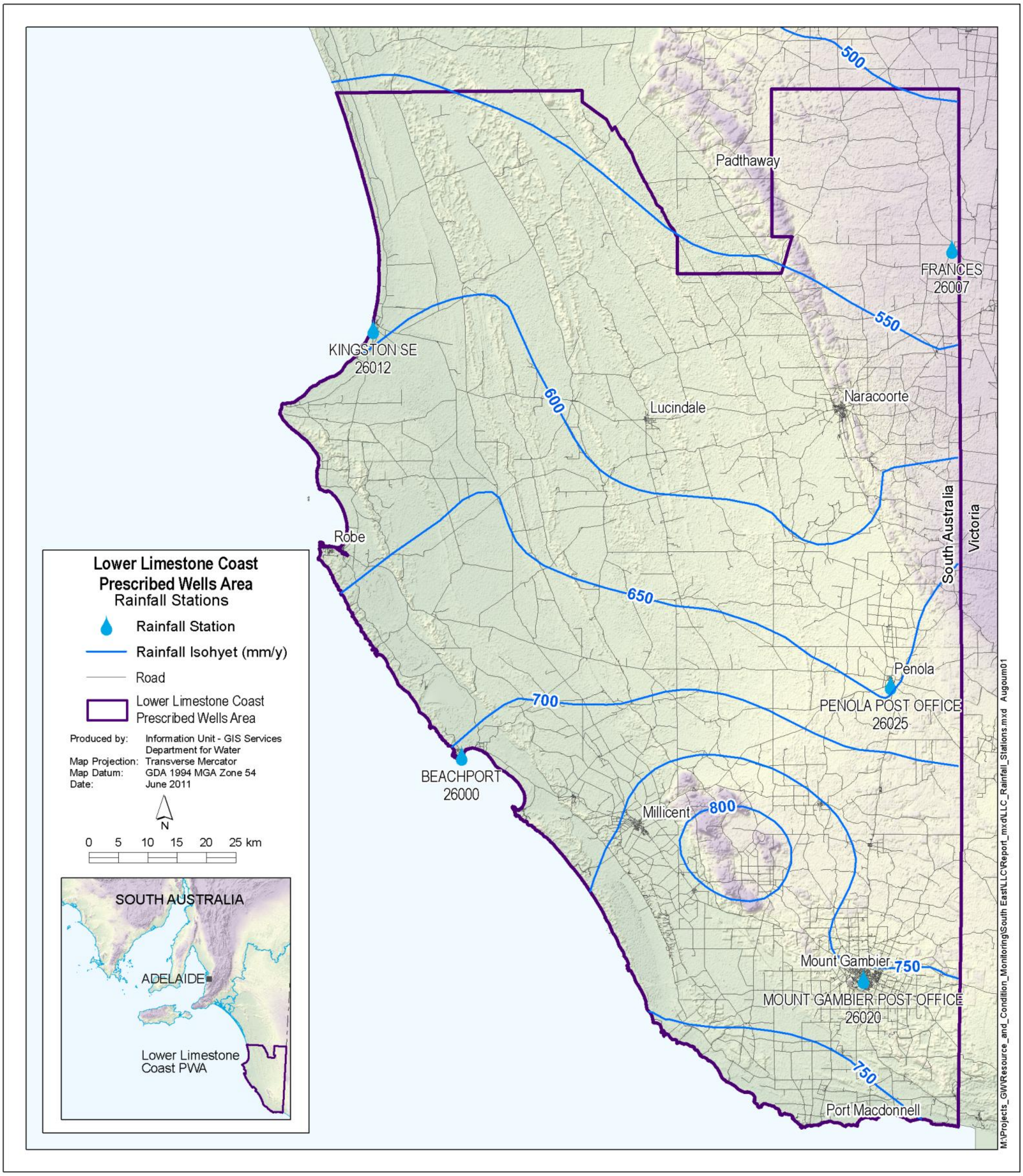

Figure 5. Location of rainfall stations and rainfall isohyets in the Lower Limestone Coast PWA

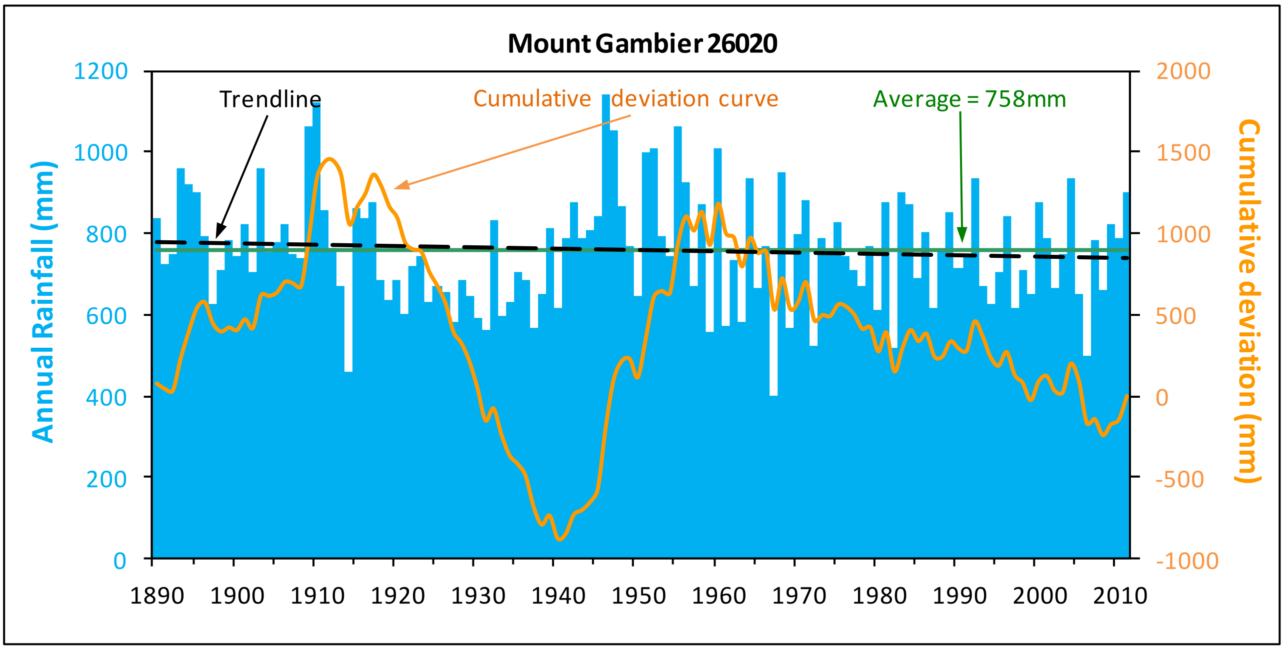

Figure 6. Annual rainfall and annual cumulative deviation for Mount Gambier in the Lower Limestone Coast PWA

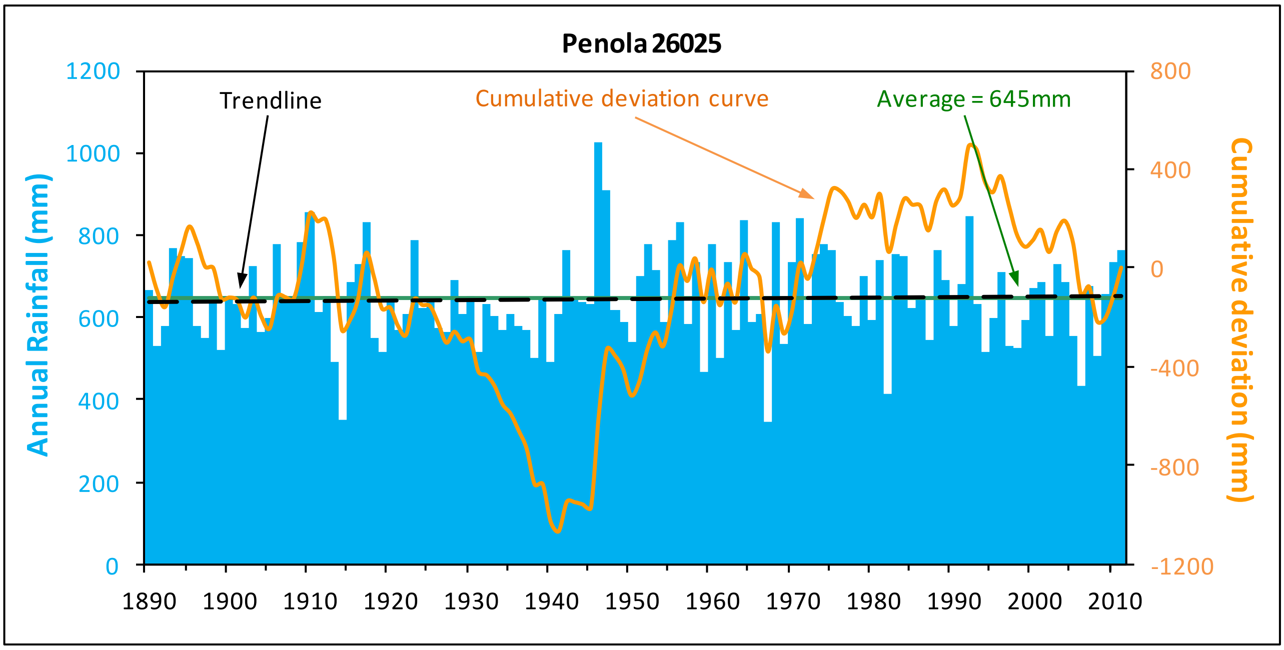

Figure 7. Annual rainfall and annual cumulative deviation for Penola in the Lower Limestone Coast PWA

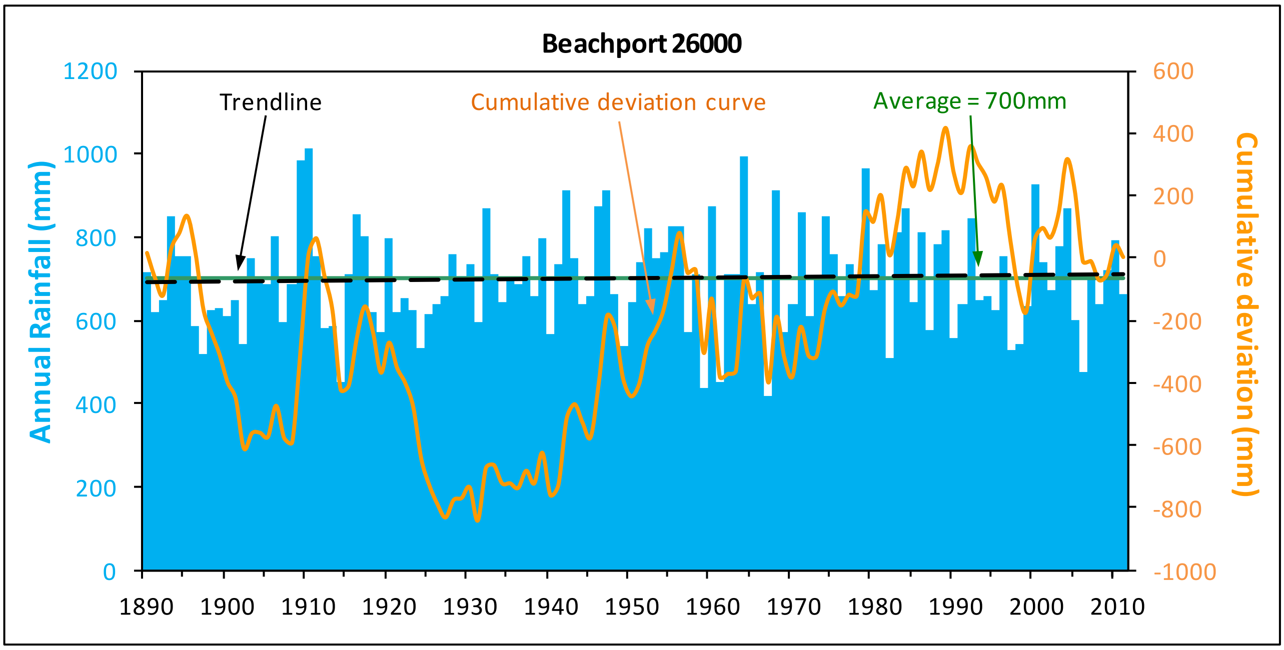

Figure 8. Annual rainfall and annual cumulative deviation for Beachport in the Lower Limestone Coast PWA

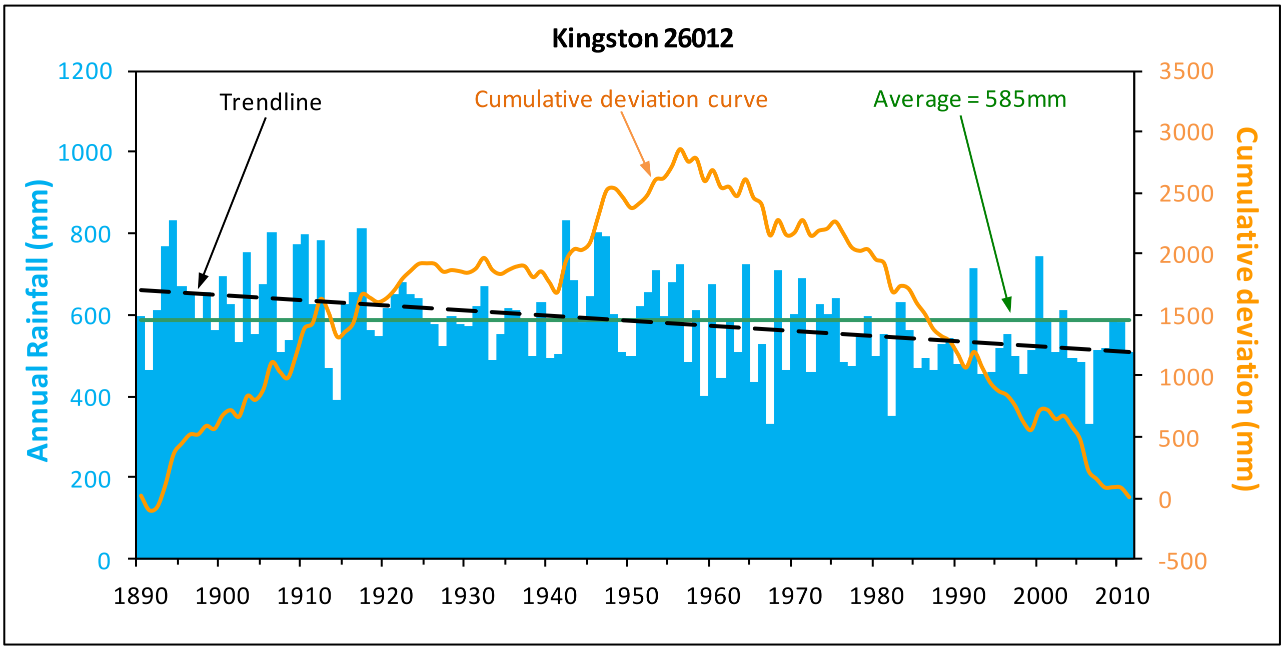

Figure 9. Annual rainfall and annual cumulative deviation for Kingston in the Lower Limestone Coast PWA

GROUNDWATER USE

The Department for Water's 'Water Allocation and Use in the South East 2010–2011' report indicated that groundwater extractions for licensed purposes (excluding stock and domestic use) in the Lower Limestone Coast PWA totalled 140 857 ML in the 2010–11 water-use year (Fig. 10). This volume includes extractions from both unconfined and confined aquifers and represents a 36% decrease from the previous water-use year. The 2007–08 water-use year was the first to use metered data to determine extraction volumes. Prior to this, estimates were made based on the area irrigated and the theoretical crop irrigation requirement. Consequently, the observed significant increase in 2007–08 may not only be due to below-average rainfall occurring and therefore a longer irrigation season, but could also be due to a more accurate measurement of the extraction.

Figure 10. Historical licensed groundwater use for the Lower Limestone Coast PWA

The total groundwater use apportioned to the source aquifer as outlined in the Department for Water's 'Water Allocation and Use in the South East 2010-2011' report can be seen in Figure 11. Data indicates that the extraction from the unconfined aquifer of 127 322 ML is much higher than that from the confined aquifer (13 535 ML). Extraction levels from both aquifers for 2010–11 are well below the limits permitted for extraction.

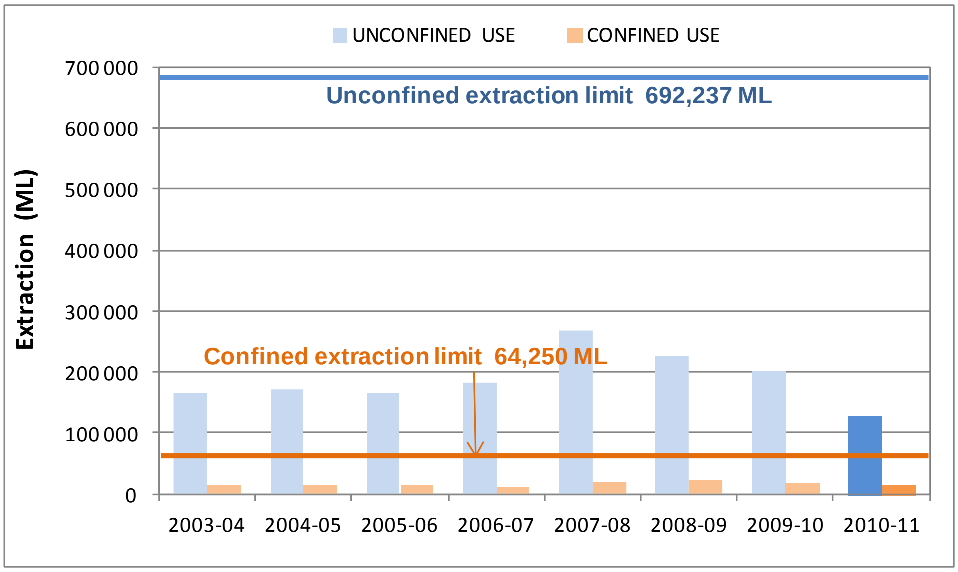

Figure 11. Historical licensed groundwater use for confined and unconfined aquifers in the Lower Limestone Coast PWA

Table 2 below shows the various categories of licensed groundwater use in the Lower Limestone Coast PWA for 2010–11 shaded in yellow, which can be compared to the previous years. Irrigation is dominant with 91% of groundwater use. Data is sourced from the 'Department for Water's Water Allocation and Use in the South East 2010–2011' report.

Table 2. Description of licensed groundwater use for the Lower Limestone Coast PWA (includes metered and estimated data[1]).

WATER USE	2010–11 (ML)	% of use	2009–10 (ML)	% of use	2008–09 (ML)	% of use	2007–08 (ML)	% of use
Irrigation	128 391	91	204 286	93	231 796	94	268 617	93
Industrial	4102	2.9	4202	2	3247	1.3	7599	2.6
Recreation	959	0.7	1651	0.7	2044	0.8	1430	0.5
Aquaculture	3332	2.4	4524	2	4015	1.6	5360	1.8
Town Water Supply	4074	3	5085	2.3	5808	2.3	6072	2.1
Total use (ML)	140 857	100	219 748	100	246 908	100	289 077	100

Figure 12 shows the proportion of water applied to the various irrigated crops in 2008–09, expressed as a percentage of the total volume. This data set was used because the information is not currently available for 2010–11. Pasture was the dominant irrigated crop type in the Lower Limestone Coast PWA in 2008–09 accounting for 61% of the total licensed volume of water extracted for the purpose of irrigation. Lucerne used 13%, with potatoes using 8% and vines using 7%.

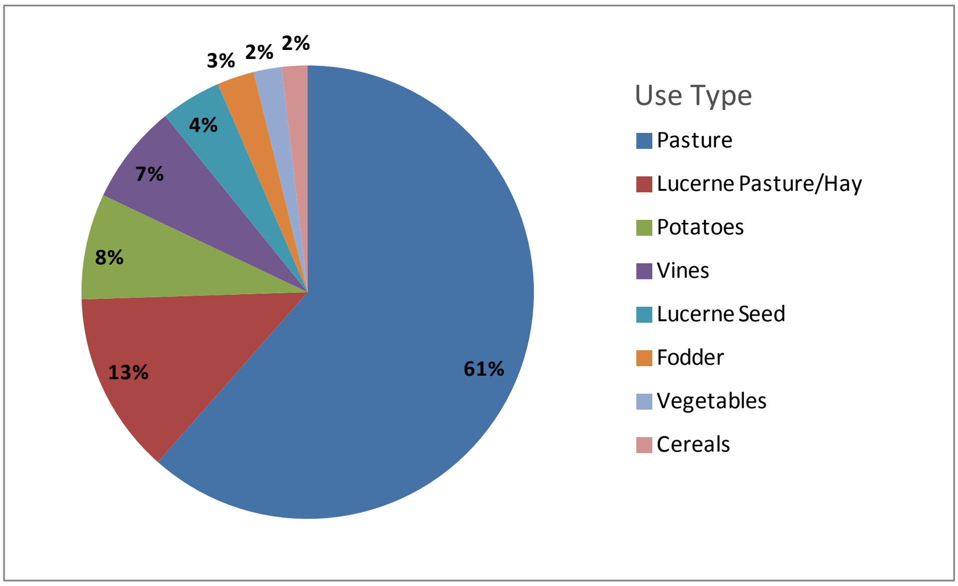

Figure 12. Groundwater proportions used per type of crop for the Lower Limestone Coast PWA in 2008–09

In addition to the water extracted by licensed groundwater users, it is also estimated that the impacts of the existing regional plantation forests on reduced groundwater recharge and direct extraction where the watertable is shallow is in the order of 200 000 ML per year.

1 Figures displayed in Table 2 of the volumes of water used are based on data provided during August 2011 for the 2010–11 water use year and further refinement of data may have occurred since that time. As such, figures should be considered as indicative.

GROUNDWATER OBSERVATION NETWORKS

WATER LEVEL NETWORK

Groundwater level monitoring in the Lower Limestone Coast PWA began in 1971. There are currently 489 wells monitoring water levels in the unconfined aquifer located in areas of highest risk to the groundwater resource, such as around the Blue Lake and areas of intense groundwater use (e.g. industrial extraction near Millicent). Monitoring locations for the northern portion of the Lower Limestone Coast PWA are shown in Figure 13, with the southern portion displayed in Figure 14.

A total of 102 wells monitor water levels in the confined aquifer, with a concentration of observation wells to the south-east of Kingston where large extractions occur (Fig. 15).

SALINITY NETWORK

The groundwater salinity observation network in the Lower Limestone Coast PWA is shown in Figure 16. There are 195 wells currently monitoring the unconfined aquifer and 42 monitoring the confined aquifer.

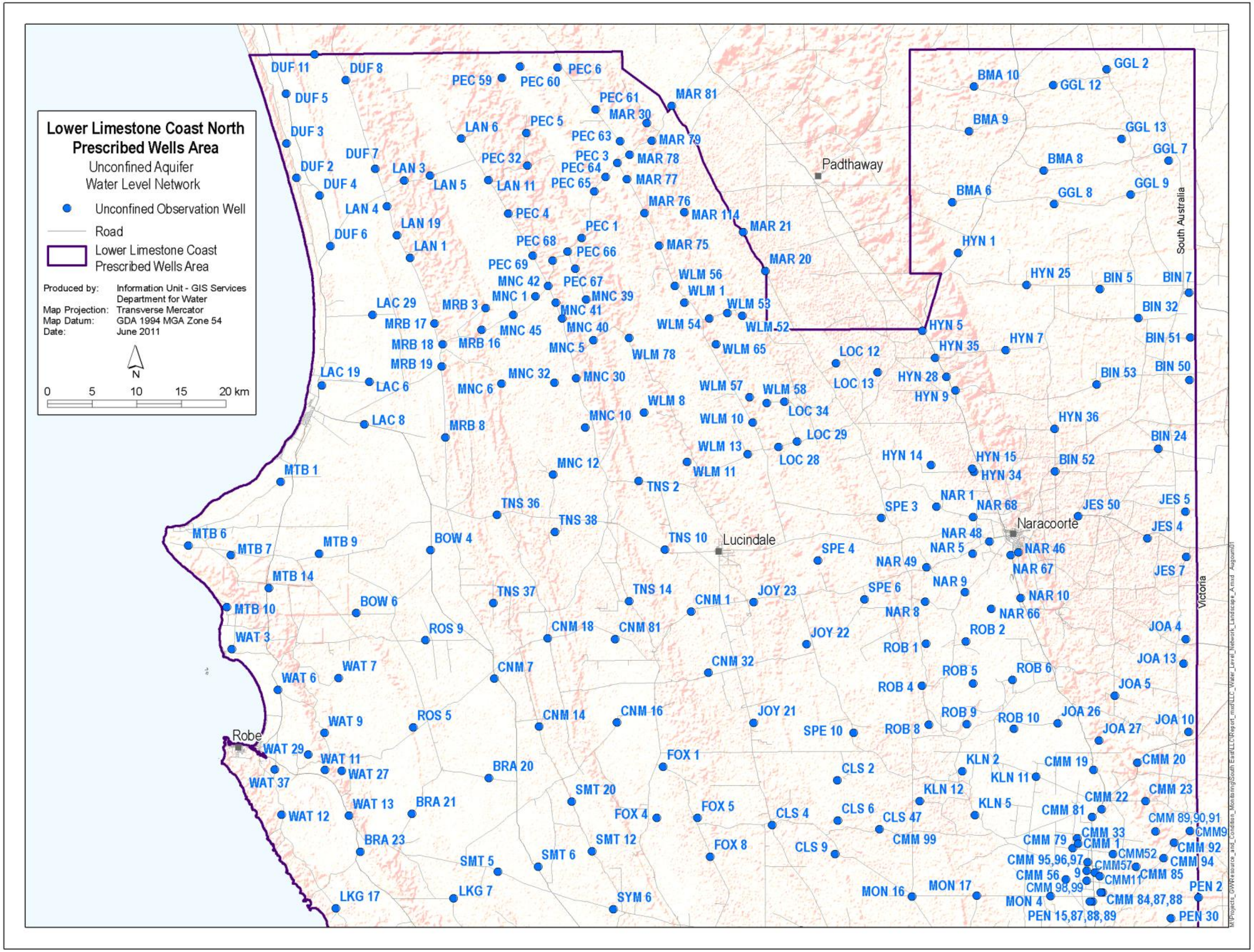

Figure 13. Location of water level observation wells for the unconfined aquifer in the northern part of the Lower Limestone Coast PWA

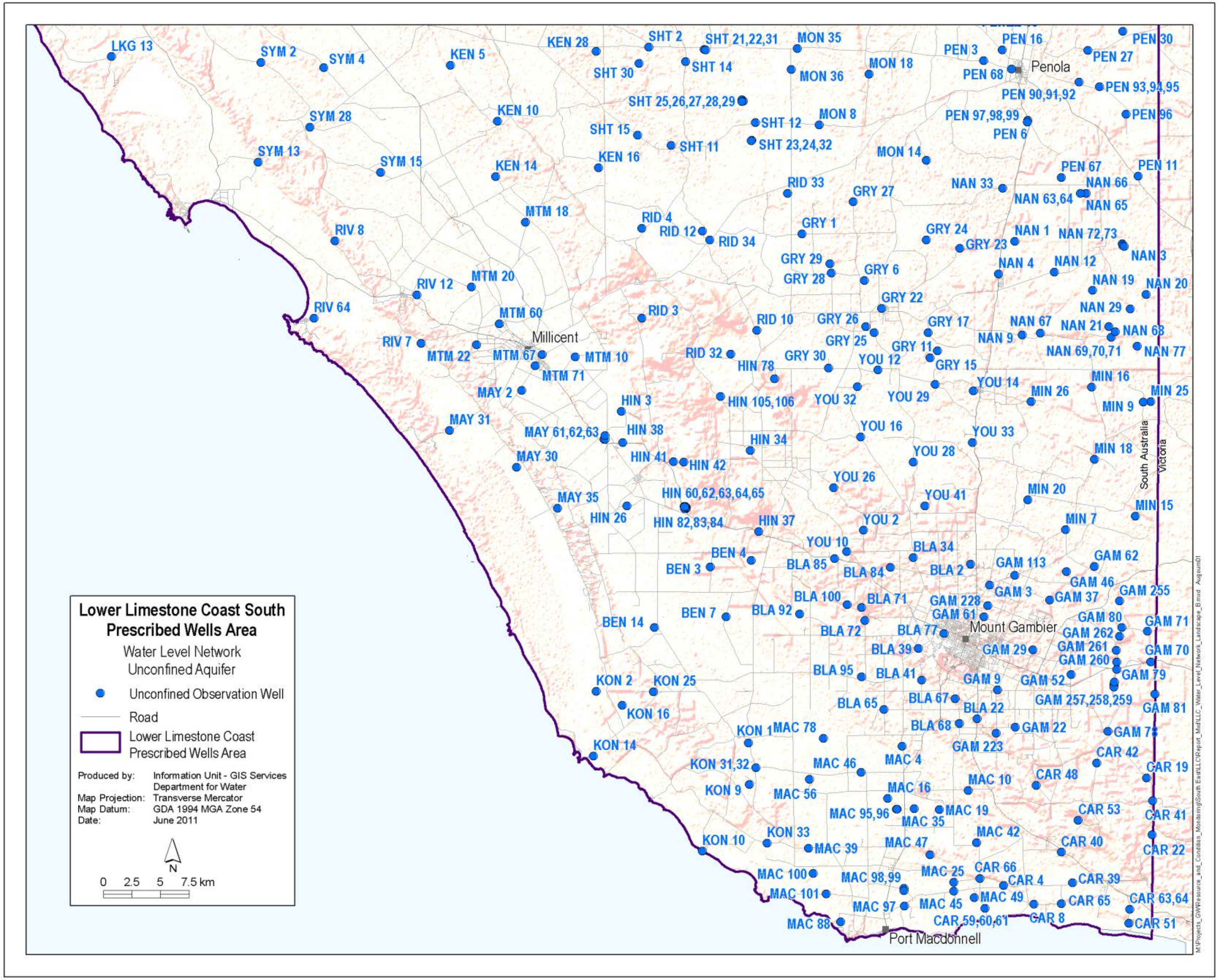

Figure 14. Location of water level observation wells for the unconfined aquifer in the southern part of the in the Lower Limestone Coast PWA

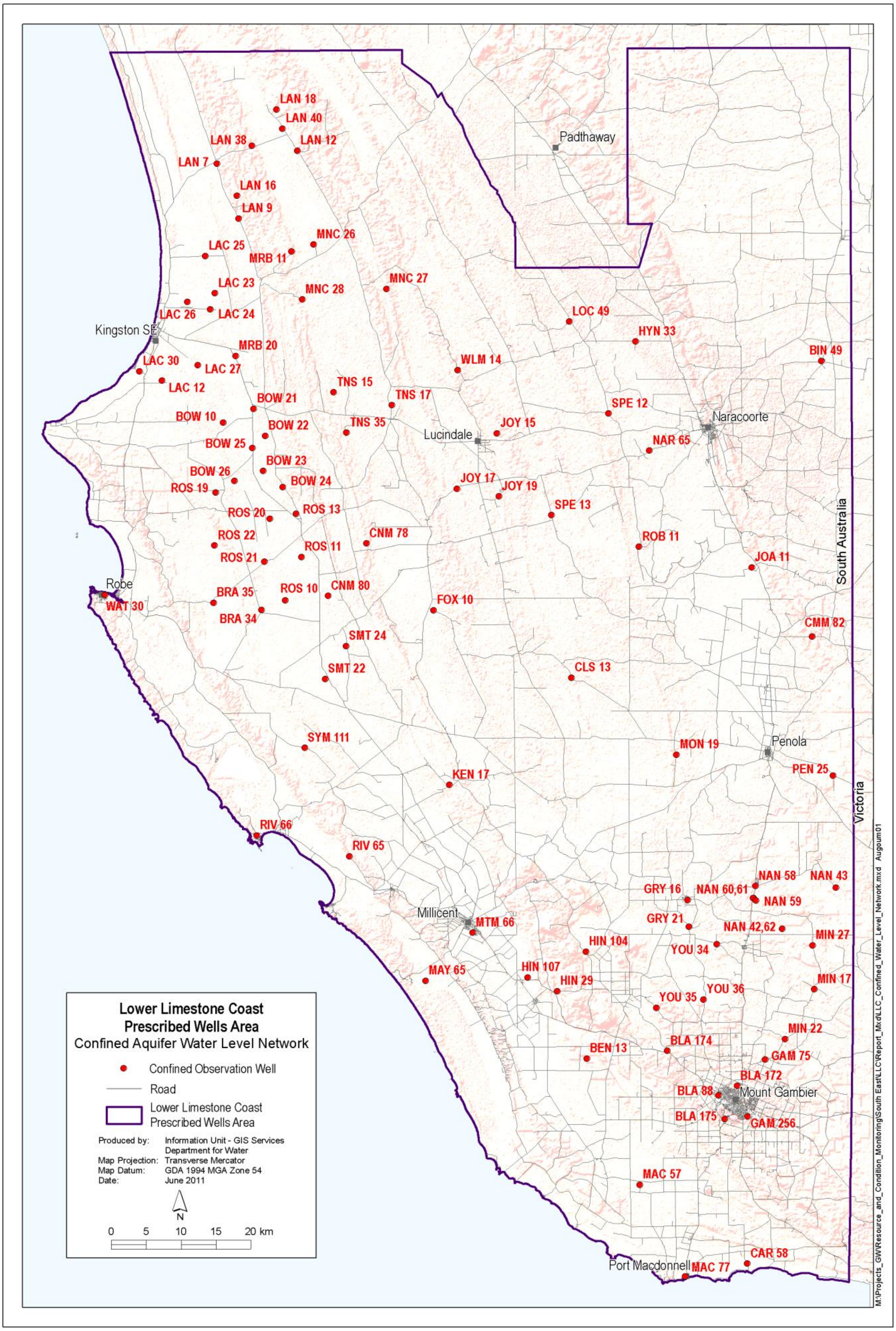

Figure 15. Location of water level observation wells for the confined aquifer in the in the Lower Limestone Coast PWA

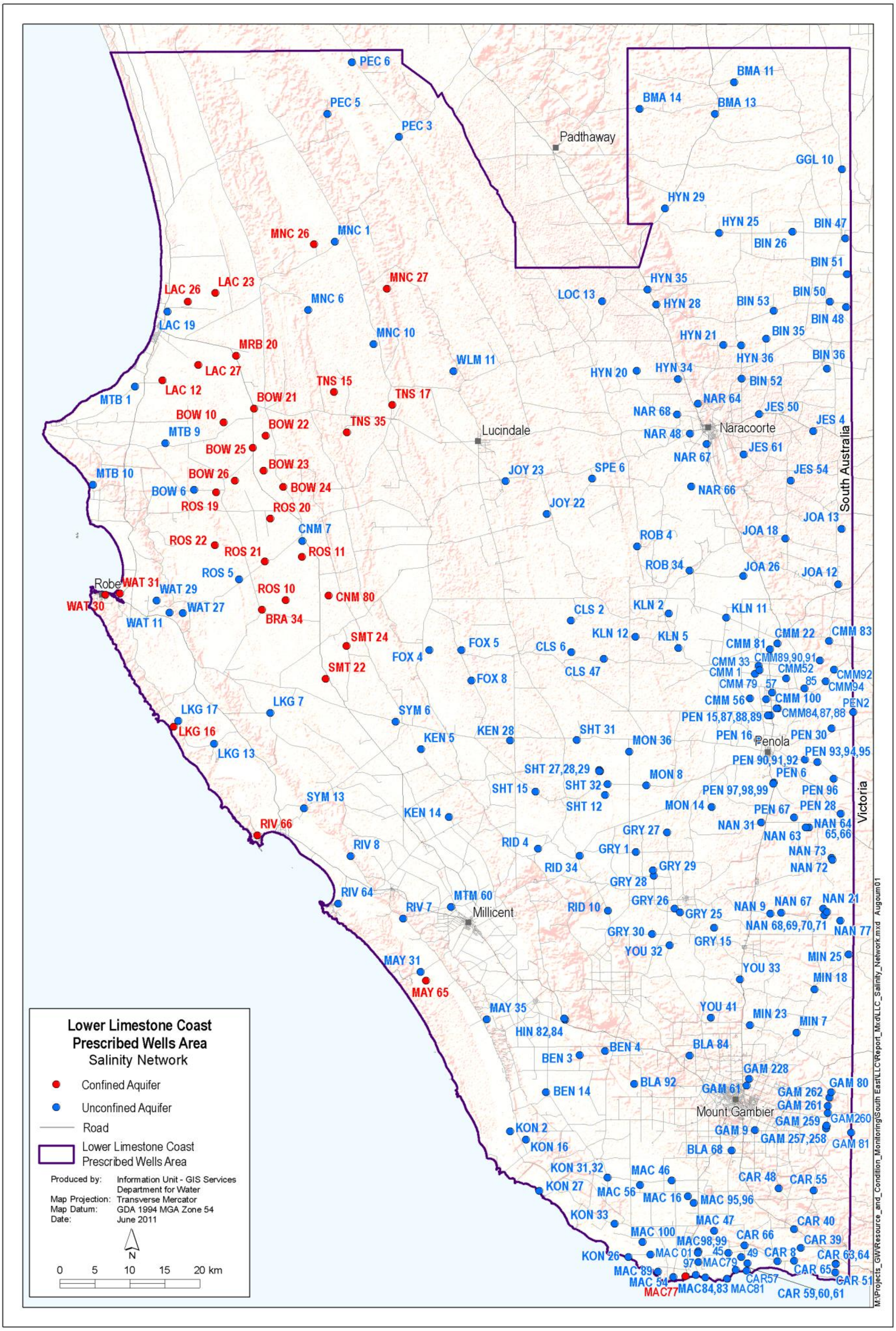

Figure 16. Location of salinity observation wells in the Lower Limestone Coast PWA

GROUNDWATER LEVEL TRENDS

UNCONFINED AQUIFER

INTER-DUNAL FLATS

Figure 17 presents the representative hydrographs for observation wells in the shallow watertable inter-dunal flats. The watertable is less than three metres below the ground surface and shows a rapid response to rainfall events and high seasonal fluctuations due to losses from the aquifer by evapotranspiration during summer coupled with extraction. The trends are relatively stable with the winter maximum water levels showing a broad relationship with rainfall trends.

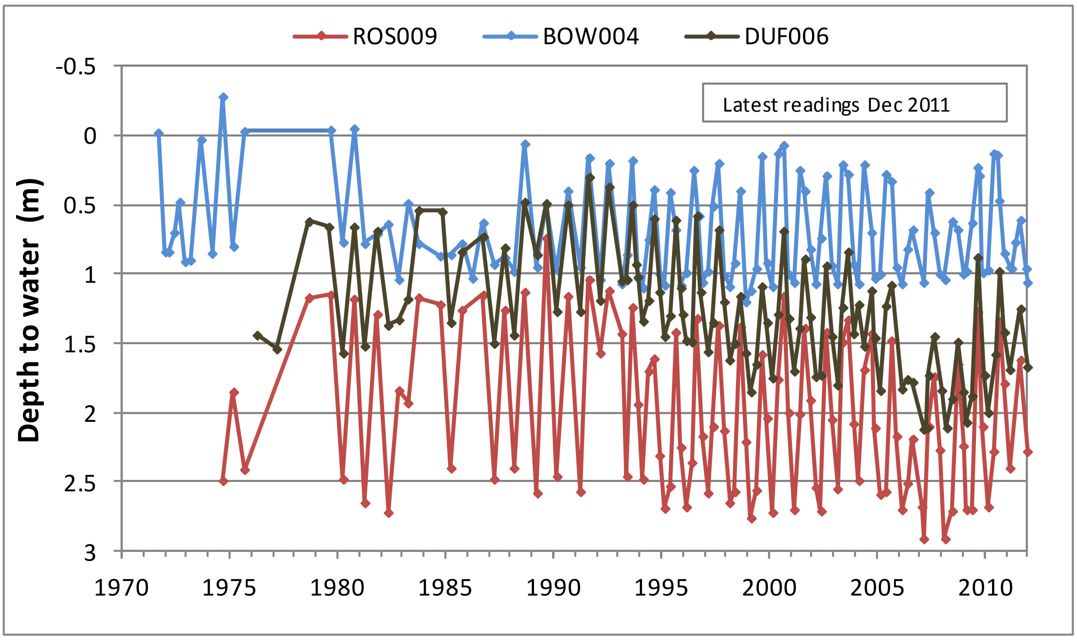

Figure 17. Groundwater level trends for the inter-dunal flat unconfined aquifer in the Lower Limestone Coast PWA

COASTAL PLAIN

Within the broad Coastal Plain there are a number of processes that are affecting groundwater levels. The most widespread influence on groundwater levels in the Lower Limestone Coast PWA is reduced recharge due to drier conditions in recent years. As discussed earlier, the region has generally experienced below-average rainfall since 1993. Figure 18 presents groundwater levels from throughout the Lower Limestone Coast PWA that show a consistent decline in groundwater levels since 1993. The main factor driving this declining trend is likely to be reduced recharge. It should be noted that extraction and land use change may also contribute to localised declines. Wetter conditions during 2009 to 2011 have led to some recovery of water levels in most areas.

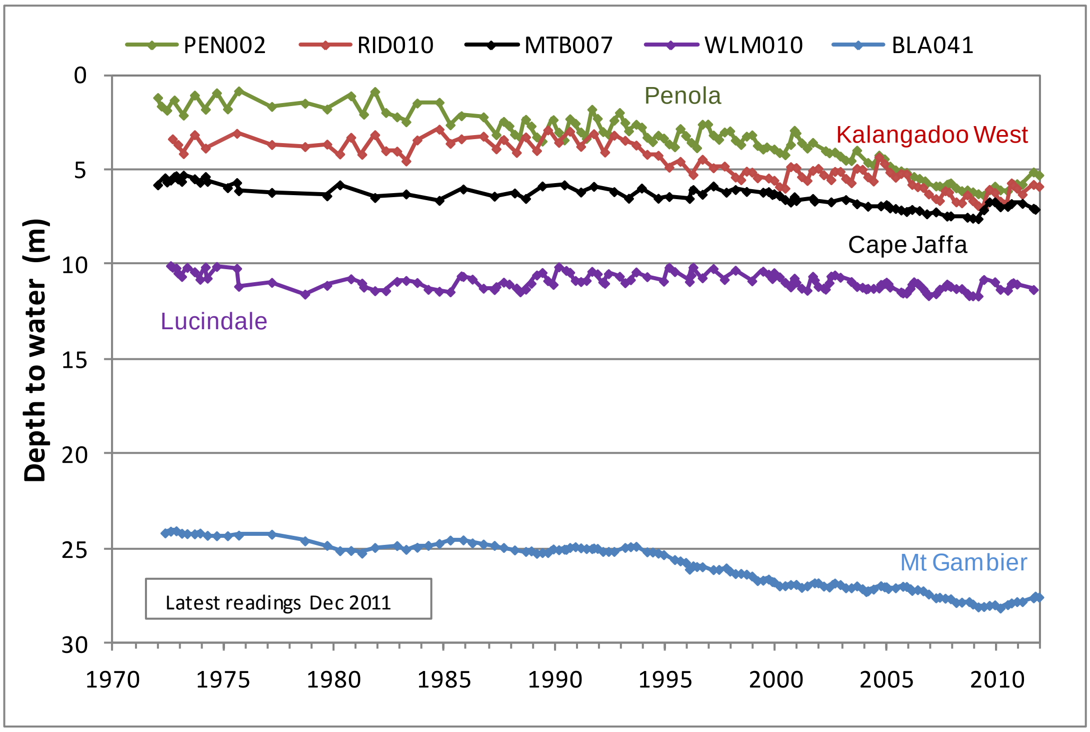

Figure 18. Groundwater level trends showing regional decline in the unconfined aquifer in the Lower Limestone Coast PWA

Extractions from groundwater resources in the Lower Limestone Coast PWA are used for a number of purposes, including town water supplies, irrigation, industrial purposes and stock and domestic supplies. These activities will impact on groundwater levels where extractions are concentrated. Figure 19 displays the response in two observation wells located in an area of intensive licensed extraction in the Donovans MA south of Mount Gambier (locations of MAC035 and KON001 are displayed in Figure 14). The hydrographs are showing a decline in water level due to the combined effects of reduced recharge since 1993 and increased extraction, with the large seasonal fluctuations a response to extraction during summer. Figure 19 displays an example of the impacts of licensed extractions (HIN038). All three wells are showing rising trends due to recent above-average rainfall.

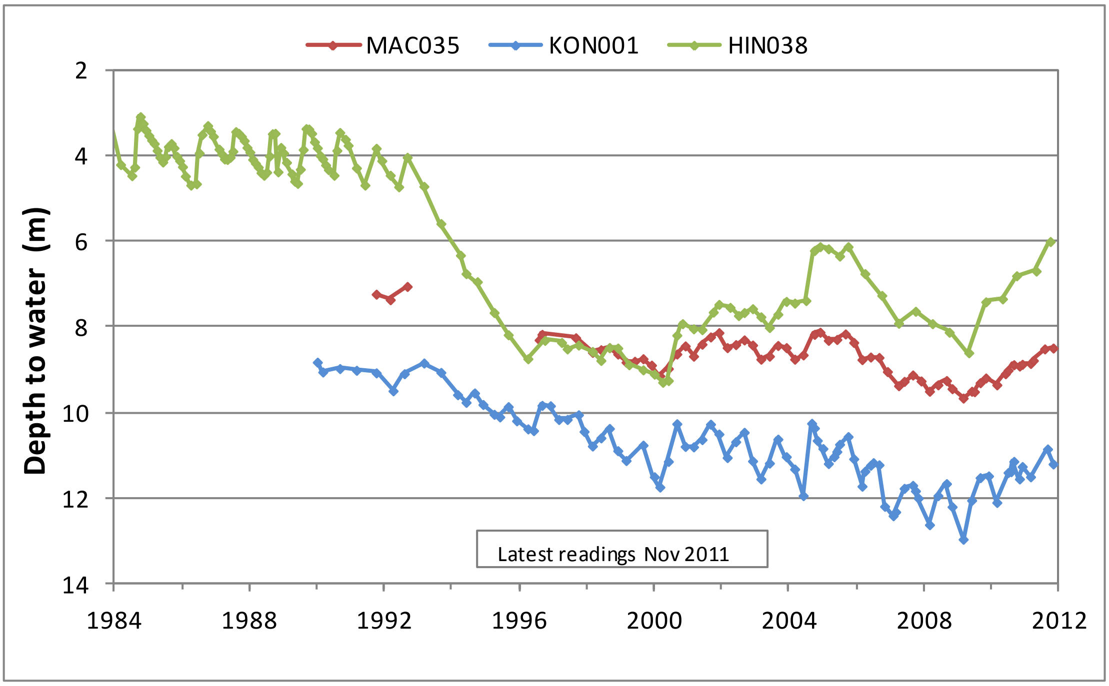

Figure 19. Groundwater level trends influenced by licensed extractions from the unconfined aquifer in the Lower Limestone Coast PWA

The impact from land-use change such as plantation forests can have a significant effect on groundwater levels. Plantations of radiata pine and blue gums intercept rainfall and hence reduce recharge into the aquifer. They can also extract groundwater where the watertable is relatively shallow. In Figure 20, observation wells SHT012 and MON035 show the typical fall of several metres in watertable levels in response to the establishment of large areas of blue gums in the late 1990s. The recent rise in both of these wells is likely due to increased rainfall and the harvesting of plantations to the north and east of SHT012. Well MON008 is located in nearby open pasture and displays a similar but smaller declining trend that is due to below-average rainfall and also a more significant response to recharge from increased rainfall during 2009 to 2011. Well NAN009 is located within a pine plantation near Nangwarry. Following a slow decline in groundwater level due to recharge reduction and possibly direct extraction, water levels show a rapid rise in 1983 following a large bushfire that destroyed the trees and allowed recharge to the aquifer to occur. After the area was replanted several years later, the decline in groundwater levels resumed.

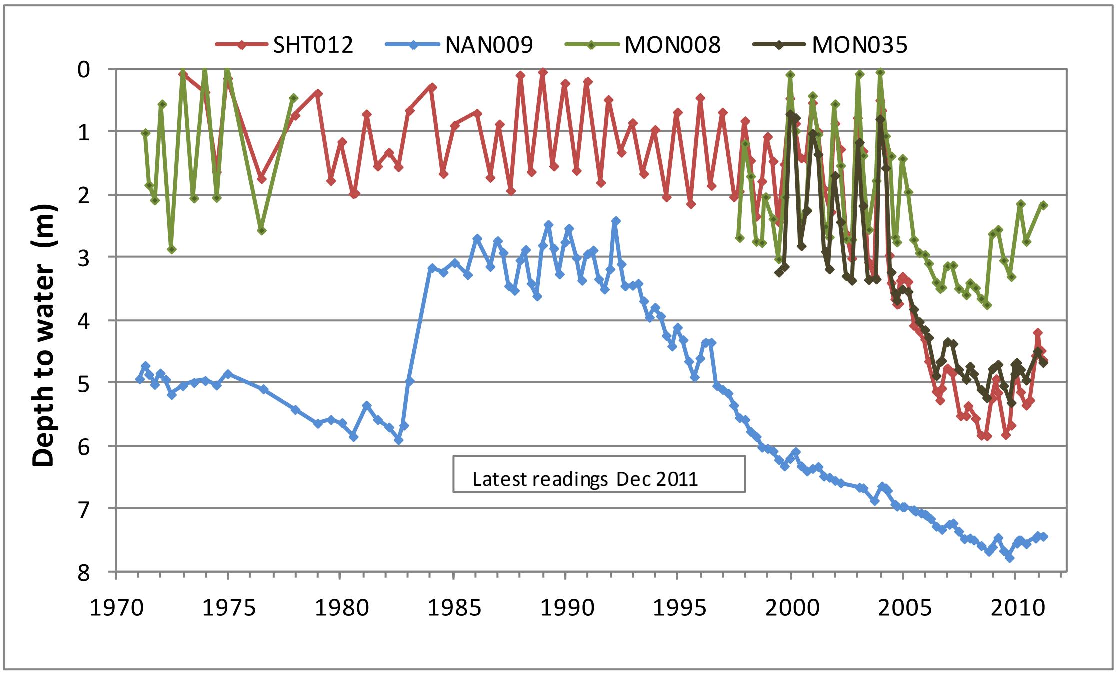

Figure 20. Groundwater level trends beneath forested areas in the unconfined aquifer in the Lower Limestone Coast PWA

HIGHLANDS

In the unconfined aquifer beneath the highlands where the depth to the watertable is more than 10 m, groundwater level trends are responding to widespread clearance of native vegetation, which has resulted in increased recharge rates and hence rising groundwater levels. These trends are also recorded in the Tatiara and Padthaway PWAs to the north. Figure 21 presents the gradual rising trends of up to 0.2 m/y for several representative observation wells. This rising trend persisted for several years after the prolonged period of below-average rainfall commenced in the mid 1990s, as shown by the cumulative deviation from mean annual rainfall graphed in orange for the nearby Frances (26007) rainfall station.

Most observation wells now show stable or declining trends in a delayed response to the below-average rainfall, with the lag time varying depending on the depth to the watertable and the permeability of the sediments.

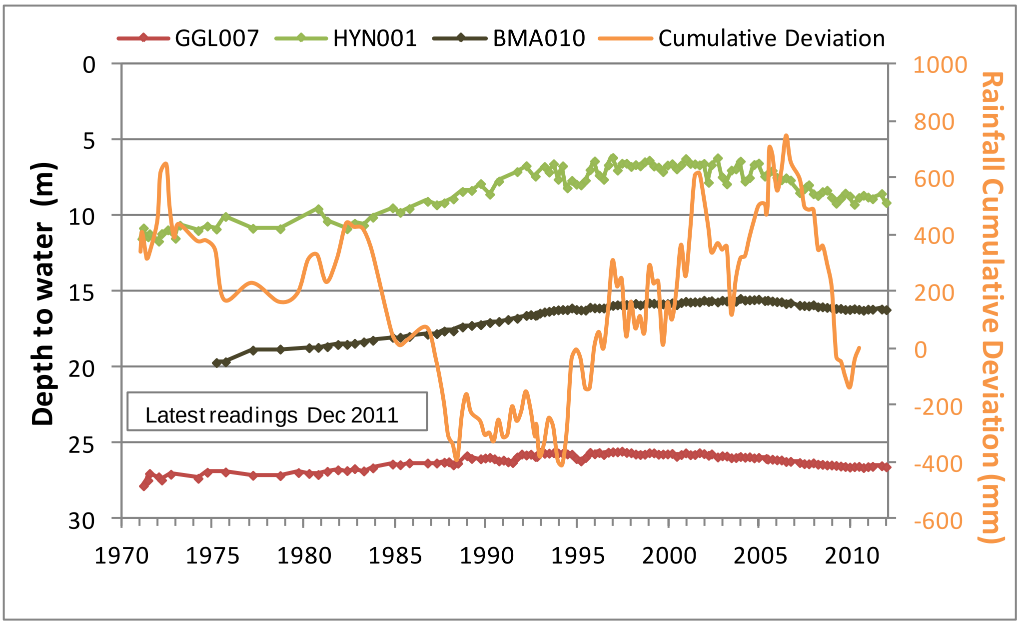

Figure 21. Groundwater level trends for the Naracoorte Ranges unconfined aquifer in the Lower Limestone Coast PWA

CONFINED AQUIFER

Over most of the Lower Limestone Coast PWA, outside the central artesian area (inland of Kingston to Beachport), the water level trends in the confined aquifer were relatively stable until 1993, after which declining trends are evident as shown in Figure 22. There is limited extraction from the confined aquifer in this area and no direct recharge from rainfall and therefore the trends (which are identical to those recorded for the overlying unconfined aquifer in Fig. 18) are thought to be caused by the process of hydrostatic loading. A falling watertable results in less water being stored in the unconfined aquifer and consequently, less weight pressing down on the confining layer. This reduction in weight reduces the hydrostatic pressure on the underlying confined aquifer and causes confined water levels to also fall. It should be noted that investigations are underway to examine the contribution of leakage between aquifers in causing these falling trends.

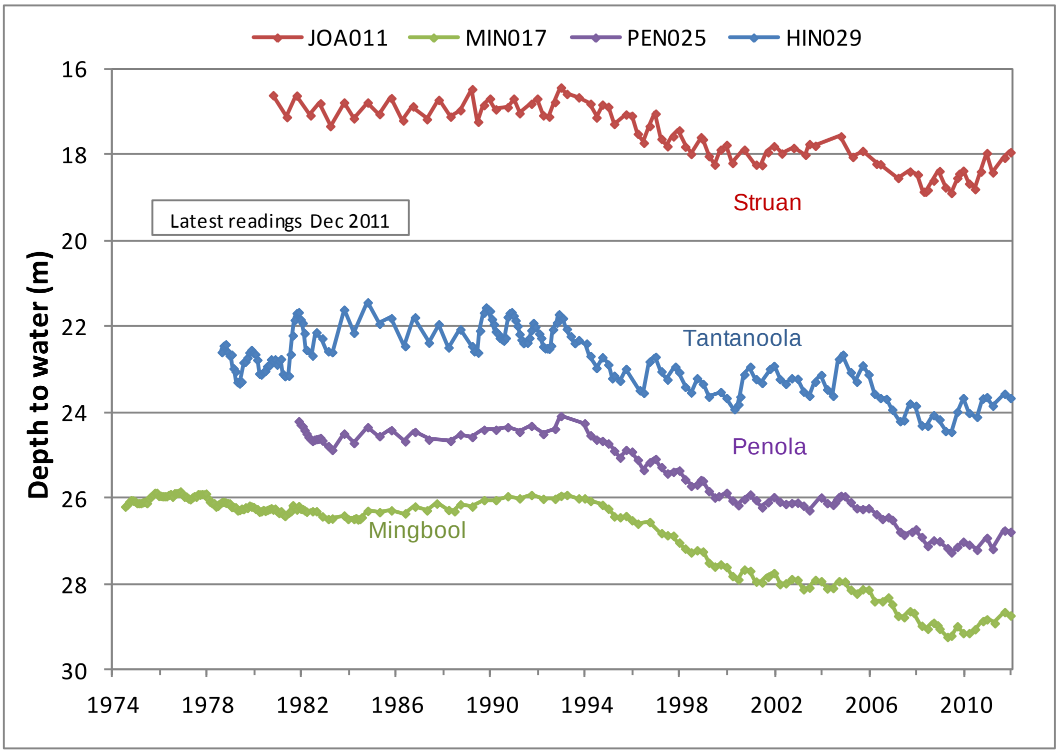

Figure 22. Groundwater level trends for the confined aquifer in the Lower Limestone Coast PWA

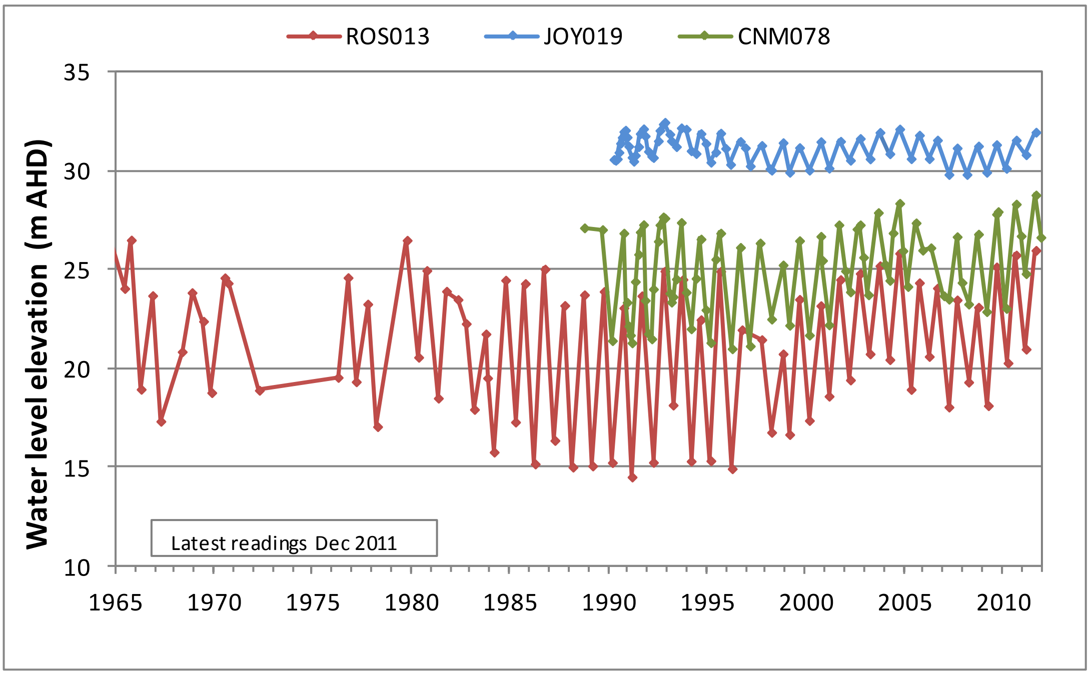

Figure 23. **Groundwater level trends for the artesian part of the confined aquifer in the Lower Limestone Coast PWA**

The hydrographs for the confined aquifer observation wells in the central artesian area (inland of Kingston to Beachport) show significant seasonal fluctuations due to high levels of irrigation use in the area (Fig. 23). The water level trends are consistent and show both rising and falling trends since 1990. The rise in pressure levels over the last four years is probably due to the South East Confined Aquifer Well Rehabilitation Scheme which has greatly reduced the number of uncontrolled flowing wells and allowed increased irrigation efficiency. The increased hydrostatic pressure from the rising watertable in the overlying unconfined aquifer may have contributed during 2009 to 2011.

UNCONFINED AQUIFER

INTER-DUNAL FLATS

Groundwater salinity trends in the unconfined aquifer from the inter-dunal flats are generally stable, as indicated in Figure 24. Areas of flood irrigation may locally increase groundwater salinity through the recycling of salt by irrigation drainage water (well ROS005 presents a typical case of this process). Well PEC005 in Figure 24 (which refers to the right axis in blue) is located on a dunal ridge. The increasing salinity is probably caused by the clearance of native vegetation in a similar process to that occurring in the Naracoorte Ranges.

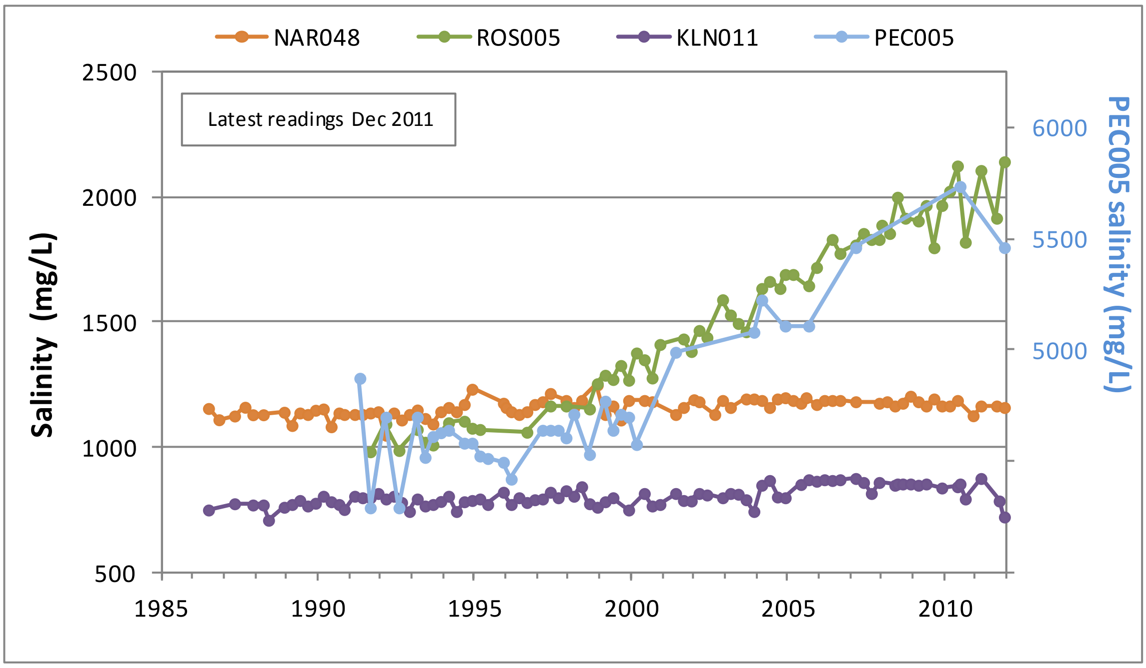

Figure 24. Groundwater salinity trends in the Coastal Plain unconfined aquifer in the Lower Limestone Coast PWA

COASTAL PLAIN

Over large areas of the southern part of the Lower Limestone Coast PWA where stresses on the groundwater system (such as intensive extraction or land use change) are absent, salinity trends are reasonably stable as presented in Figure 25. Small seasonal variations are evident, especially a decreasing trend in recent years in response to higher rainfall.

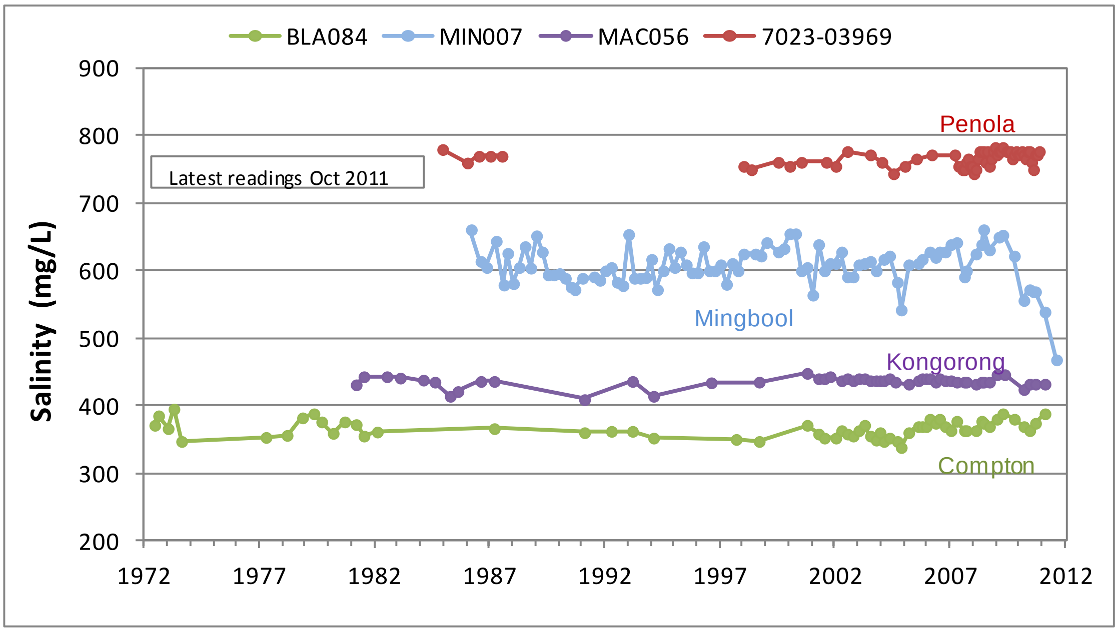

Figure 25. Groundwater salinity trends for the Coastal Plain unconfined aquifer in the Lower Limestone Coast PWA

Elsewhere, salinities have responded in different ways as a result of changes in land use and irrigation. Figure 26 presents salinity trends from the Coonawarra district (near Penola) where vineyards are irrigated. Well CMM081 is located just to the north of the irrigated area and shows a stable unaffected trend. The other wells display a gradual rising trend since the mid 1990s which peaks dramatically during 2004 to 2006 before decreasing back toward normal levels.

A possible explanation for this increase can be seen in the graph of the cumulative deviation of the winter annual rainfall for Penola (Station 26025) shown in orange also presented in Figure 26 (refers to the right axis). This graph shows a series of drier winters from 1996 to 2003. During this period, it is possible that salt has accumulated in the unsaturated zone above the watertable, likely due to reduced flushing by winter rain. The comparatively wetter winters in 2004 and 2005 would have flushed the accumulated salt down, back into the aquifer. The timing of the peak salinity would vary depending on the depth to the watertable (a deeper watertable means a longer time to flush the salt). The reduction in salinity since the 2006 drought is likely due to reduced flushing and suggests that salt is again being accumulated in the unsaturated zone.

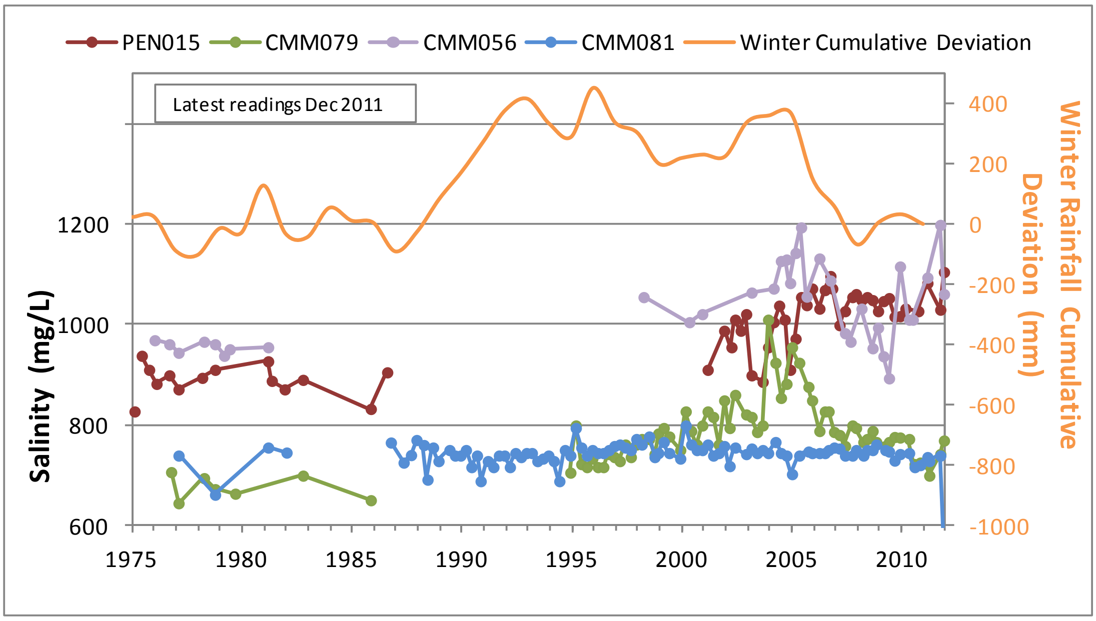

Figure 26. Groundwater salinity trends for the Coonawarra area in the Lower Limestone Coast PWA

Near the coast to the south of Mount Gambier in the Donovans MA (Fig. 1), where extractions have increased markedly, the decline in groundwater levels has resulted in salinity increases at depth which is most likely due to seawater intrusion. In Figure 27, well CAR061 (refer to the right axis in blue) is 180 m deep and is located 1.2 km inland from the coast. It has intersected the seawater interface and has an observed rate of rise of 357 mg/L/y. Further investigation of the seawater intrusion risk (including regional extent) is underway.

Well CAR039 (Fig. 27) is located further inland adjacent to intensive irrigation and its rise of 8 mg/L/y is due to irrigation drainage flushing salt to the watertable.

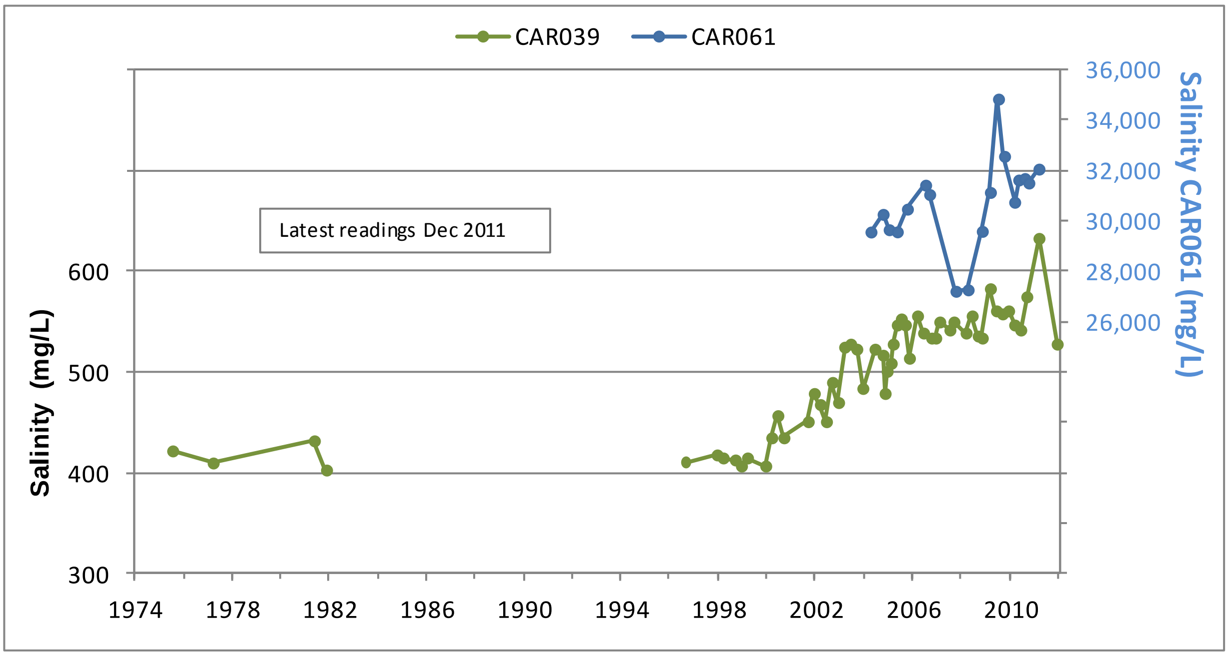

Figure 27. Groundwater salinity trends near the southern coast in the Lower Limestone Coast PWA

HIGHLANDS

Groundwater salinity monitoring on a regular basis began during 1987 in the former Naracoorte Ranges PWA. The widespread clearance of native vegetation has resulted in increased recharge rates and the flushing of salt, which was previously stored in the root zones of native vegetation, down to the watertable. This process is occurring independent of any irrigation activity, although drainage beneath irrigated areas is likely to accelerate the process locally.

Figure 28 shows a variety of trends. Observation wells BMA013 and JOA012 have been showing rises of 10 mg/L/y up until 2000 due to flushing of salt into the aquifer. Salinity levels appear now to have stabilised. Wells BIN026 and HYN021 also showed an earlier rising trend but are now displaying a decreasing trend over the last 10–20 years which may indicate that the unsaturated zone salt has almost been completely flushed and lower salinity water is now recharging the aquifer. This freshening of the groundwater following a salinity increase is well documented in the Padthaway PWA to the north.

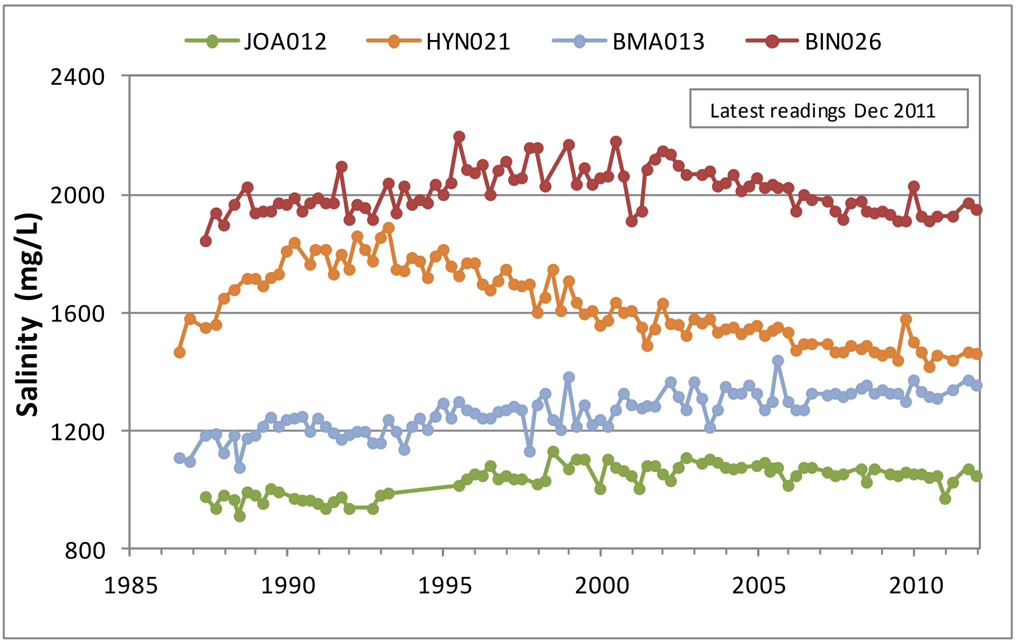

Figure 28. Groundwater salinity trends in the Naracoorte Ranges unconfined aquifer in the Lower Limestone Coast PWA

CONFINED AQUIFER

Groundwater salinity trends in the confined aquifer throughout the Lower Limestone Coast PWA are mostly stable. Figure 29 presents data from observation wells in the artesian area (inland of Kingston to Beachport) where most extractions occur. Trends are generally stable with some slight decreasing trends apparent since 2005.

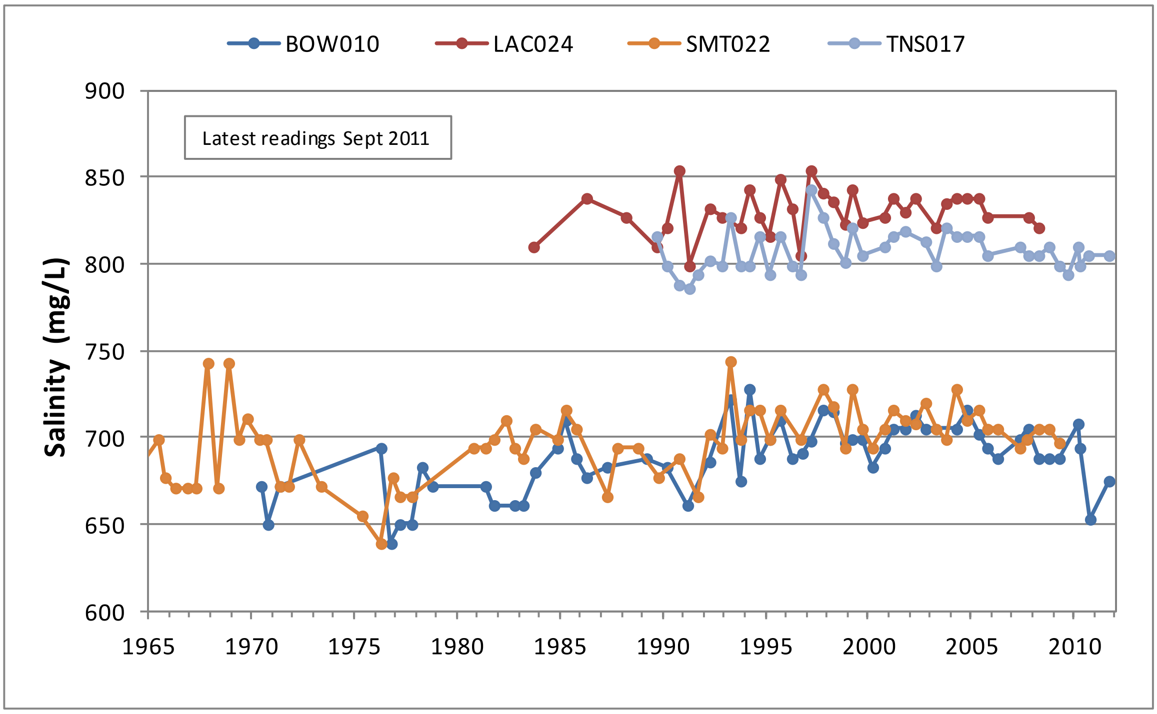

Figure 29. Groundwater salinity trends for the confined aquifer in the Lower Limestone Coast PWA

Most of the town water supplies in the Lower Limestone Coast PWA are obtained from the confined aquifer. Figure 30 presents a selection of wells from throughout the area which show long-term stable trends.

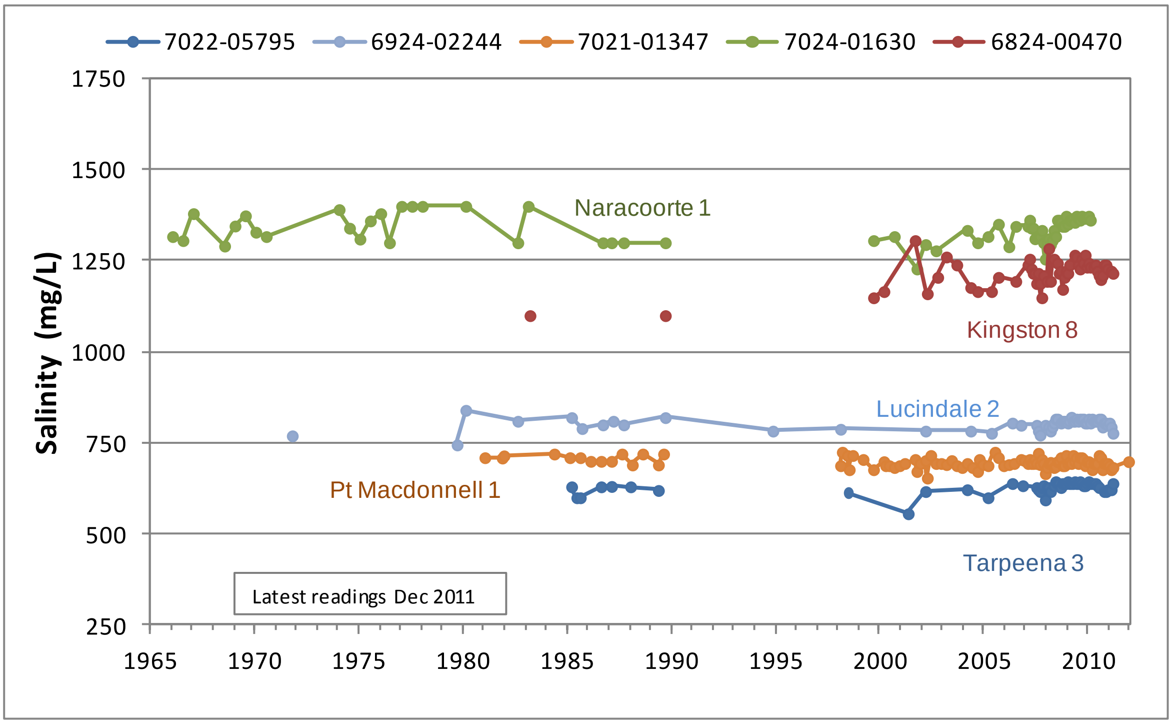

Figure 30. Groundwater salinity trends for confined aquifer town water supply wells in the Lower Limestone Coast PWA