EASTERN MOUNT LOFTY RANGES PWRA

Groundwater Level and Salinity Status Report

2011

Government of South Australia
Department of Environment, Water and Natural Resources

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2011 SUMMARY

The Eastern Mount Lofty Ranges Prescribed Water Resources Area (EMLR PWRA) is located 50 km east of Adelaide and covers an area of approximately 2845 km^2. It is a regional-scale prescribed resource for which groundwater, surface water and watercourse water are protected and managed under South Australia's *Natural Resources Management Act 2004*. A water allocation plan (WAP) provides for the sustainable management of the groundwater resources.

The EMLR PWRA is underlain by fractured rock and sedimentary aquifers of varying water quality and yields. About 75% of the area is underlain by aquifers that are inadequate to support irrigation due to high salinities and low yields, with little capacity for increased development.

The fractured rock aquifers (FRAs) in the EMLR PWRA are comprised of the Barossa Complex, Adelaidean sediments, the Normanville Group and the Kanmantoo Group. Generally, Adelaidean sediments are more favourable in terms of recharge, salinity and yields, while the Barossa Complex and Kanmantoo Group provide groundwater of poorer quality at low yields. Groundwater flow within the FRAs generally follows the topography and moves from higher points towards the lowest areas, where it eventually discharges into rivers and streams.

There are three types of sedimentary aquifers in the EMLR PWRA: Permian Sand, Murray Group Limestone (MGL) and Quaternary sediments. The MGL aquifer provides good quality water and high yields, while the Permian Sand aquifer displays a wide variation in characteristics.

The current groundwater observation networks within the EMLR PWRA comprise 148 wells that are monitored for water level and 30 wells for salinity.

Based on the data available, long-term trends show seasonal variations due to agricultural irrigation practices and tend to be slightly declining overall, which was mainly evident within the Kanmantoo Group FRA. This correlates with declining rainfall patterns over the last two decades in the southern part of the PWRA. In 2011, the water levels tended to show little change or a slight rise compared to 2010.

Based on monitoring undertaken since 1995, the Permian Sand aquifer has shown a long-term gradual decline in groundwater levels, mirroring the trend of declining rainfall. However, comparison of water levels from 2010 to 2011 showed stable to slightly rising water levels, with minor declines in a few wells within the Tookayerta Permian management zone.

The aquifer with the most significant declining trend in water level is the Murray Group Limestone aquifer, with levels declining since 2004. However, observation wells in the MGL aquifer displayed little variation between 2010 and 2011.

Overall, the salinity data available for the FRAs indicate slightly increasing trends over the long term. In 2011 the salinity monitoring results compared to those of 2010 show mostly stable or declining salinity.

The long-term salinity trends observed for the MGL aquifer indicate a continuous increase, with a rise of more than 500 mg/L observed in one well from 2005 to 2011 (from 1163 mg/L to 1703 mg/L). While in some observation wells there continues to be a small increase in salinity during 2011, in most wells the salinity recorded shows little change.

ASSESSMENT OF STATUS

FRACTURED ROCK AQUIFERS

The fractured rock aquifers of the Eastern Mount Lofty Ranges PWRA have been assigned a yellow status for 2011:

2011 STATUS

"Gradual adverse trends, indicating low risk to the resource in the medium term"

This means that gradual adverse trends in the resource status have been observed over the reporting period. Continuation of these trends is unlikely to negatively impact the beneficial use of the resource for at least 15 years. The 2011 status for the fractured rock aquifers is supported by:

- overall gradual decline in recovered groundwater levels over the long term
- overall gradual increases in salinity over the long term.

Gradual declines in recovered groundwater levels have been relatively minor and in some areas, levels have been quite stable. Lower-than-average levels were recorded in most areas between 1997–2000 and 2006–09. There has been some recovery and stabilisation of groundwater levels in 2010 and 2011. This is consistent with an incidence of wetter conditions in South Australia in the 2009 to 2011 period, which included the unusually wet summer of 2010–11. Ongoing monitoring is essential to determine if the groundwater level declines will be persistent and present a threat to the sustainability of the fractured rock aquifers.

PERMIAN SAND AQUIFER

Tookayerta Permian Management Zone

The Permian Sand aquifer in the Tookayerta Permian Management Zone of the Eastern Mount Lofty Ranges PWRA has been assigned a yellow status for 2011:

2011 STATUS

"Gradual adverse trends, indicating low risk to the resource in the medium term"

This means that gradual adverse trends in the resource status have been observed over the reporting period. Continuation of these trends is unlikely to negatively impact the beneficial use of the resource for at least 15 years. The 2011 status for the Permian Sand aquifer is supported by:

- overall gradual decline in recovered groundwater levels over the long term.

Although the observed groundwater level trends of 2011 are showing a slight recovery from previous years, this may be attributed to the unusually wet summer of 2010–11. Ongoing monitoring is essential to determine if the groundwater level declines will be persistent and present a threat to the sustainability of the Permian Sand aquifer in the Tookayerta Permian Management Zone.

Finniss Permian 1 Management Zone

The Permian Sand aquifer in the Finniss Permian 1 Management Zone of the Eastern Mount Lofty Ranges PWRA has been assigned a yellow status for 2011:

2011 STATUS

"Gradual adverse trends, indicating low risk to the resource in the medium term"

This means that gradual adverse trends in the resource status have been observed over the reporting period. Continuation of these trends is unlikely to negatively impact the beneficial use of the resource for at least 15 years. The 2011 status for the Permian Sand aquifer is supported by:

- overall gradual decline in recovered groundwater levels over the long term.

Although the observed groundwater level trends of 2011 are showing a slight recovery from previous years, this may be attributed to the unusually wet summer of 2010–11 and above-average rainfall recorded at the the Finnis rainfall station. Ongoing monitoring is essential to determine if the groundwater level declines will be persistent and present a threat to the sustainability of the Permian Sand aquifer in the Finniss Permian 1 Management Zone.

MURRAY GROUP LIMESTONE AQUIFER

Currency Limestone Management Zone

The Murray Group Limestone aquifer in the Currency Limestone Management Zone of the Eastern Mount Lofty Ranges PWRA has been assigned a yellow status for 2011:

2011 STATUS

"Gradual adverse trends, indicating low risk to the resource in the medium term"

This means that gradual adverse trends in the resource status have been observed over the reporting period. Continuation of these trends is unlikely to negatively impact the beneficial use of the resource for at least 15 years. The 2011 status for the Murray Group Limestone aquifer is supported by:

- the gradual decline in recovered groundwater levels since 2004
- the gradual increase in salinity since 1999.

There has been some recovery in groundwater levels in 2011, however, this may be due to above-average rainfall. Ongoing monitoring is essential to determine if the groundwater level declines will be persistent and present a threat to the sustainability of the Murray Group Limestone aquifer in the Currency Limestone Management Zone.

No adverse trends, indicating negligible risk to the resource

Groundwater status was observed to be stable, i.e. no significant change or improving, over the reporting period. Continuation of these trends favours a very low likelihood of negative impacts on beneficial uses such as drinking water, irrigation or stock watering.

Gradual adverse trends indicating low risk to the resource in the medium term

Gradual adverse trends in the resource status have been observed over the reporting period. Continuation of these trends is unlikely to negatively impact the beneficial use of the resource for at least 15 years.

Significant adverse trends indicating high risk to the resource in the short to medium term

Significant adverse trends in the resource status have been observed over the reporting period. Continuation of these trends will likely lead to negative impacts on the beneficial use of the resource within 5 to 10 years.

Substantial adverse trends indicating extreme risk to the resource in the short term

Very significant adverse trends in the resource status have been observed over the reporting period. Continuation of these trends will most certainly lead to negative impacts on the beneficial use of the resource within 5 years.

BACKGROUND

The EMLR PWRA is located 50 km east of Adelaide and lies within the Murray-Darling Basin. It covers an area of approximately 2845 km^2 incorporating the eastern slopes of the Mount Lofty Ranges and the Murray Plains (Fig. 1). It is a regional-scale prescribed resource for which groundwater is protected and managed under South Australia's *Natural Resources Management Act 2004*. A water allocation plan (WAP) provides for the sustainable management of the groundwater resources.

The Angas Bremer Prescribed Wells Area (PWA) is located wholly within the boundaries of the EMLR PWRA and a separate groundwater level and salinity status report has been prepared for this PWA and can be found on the WaterConnect website.

HYDROGEOLOGY

The EMLR PWRA is part of the larger Adelaide Geosyncline and is topographically separated into highland (hills) and lowland (plains) regions. The hills region is underlain by consolidated basement rock and the plains region is underlain by unconsolidated sediments of the Murray Basin.

There are a number of different aquifers in the EMLR PWRA. The consolidated basement rock formations of the hills area form the FRAs, where groundwater is stored and moves through joints and fractures in rock. The unconsolidated sediments of the Murray Basin (e.g. MGL), the Permian Sand formation and Quaternary alluvium, form the sedimentary aquifers of the EMLR PWRA (Fig. 2). In the sedimentary aquifers, groundwater is stored in and flows through the pore spaces within the sediments. Recharge to all aquifers of the EMLR PWRA generally occurs directly from rainfall percolating down to the watertable through the soil profile or indirectly from throughflow from adjacent aquifers.

Fractured Rock Aquifers

There are four FRAs in the EMLR PWRA, namely the Barossa Complex, Adelaidean sediments and the Kanmantoo and Normanville Groups (Fig. 2 and Table 1).

Barossa Complex

The Barossa Complex FRA comprises basement rocks of gneisses, schists and pegmatites formed about 1600 million years ago and represent the oldest rocks in the Mount Lofty Ranges. In general, this formation is tight and impermeable with few open systems of fractures and joints in which groundwater is stored and transmitted. Clayey weathered materials have in-filled joints and fractures and soluble components of these materials can dissolve and raise the salinity of the groundwater. The clays can also restrict the infiltration of rainwater.

Adelaidean sediments

Adelaidean sediments FRAs consist mainly of sandstone, siltstone, shale and slate, with minor beds of quartzite. Adelaidean sedimentary rocks have not been subjected to the heat and pressure of metamorphism and this has resulted in the joints and fractures of this formation being open and permeable, resulting in relatively high yields. In addition, these sediments occur in the west of the region where the rainfall is higher, resulting in higher recharge and low salinities.

Kanmantoo Group and Normanville Group

The Kanmantoo Group is the largest FRA and consists of greywacke, schist and gneiss (Fig. 2). The sediments of the Murray Basin overlie the Kanmantoo Group in the plains region of the EMLR PWRA. The Kanmantoo Group is generally considered to be a poor aquifer due to the impermeable nature of the rocks and generally poor yields. While isolated instances of low salinity can occur, lower rainfall to the east reduces recharge and flushing in this formation resulting in higher salinities.

The Normanville Group FRA is represented by the occurrence of the Macclesfield Marble. This unit has developed secondary porosity (fissures) and can provide greater yields and allows greater recharge and hence lower salinities than surrounding rock units.

Sedimentary aquifers

There are three types of sedimentary aquifers in the EMLR PWRA, namely the Permian Sand, MGL and Quaternary aquifers (Fig. 2 and Table 1).

Permian Sand

The Permian Sand aquifer, also known as the Cape Jervis Formation, can be found in several large U-shaped valleys that were carved by large continental ice sheets in the Kanmantoo Group FRA about 280 million years ago (Permian era). It comprises glacial deposits of unconsolidated sands, silts and clays with occasional gravel beds. The Permian Sand aquifer forms part of the eastern slopes of the hills region and underlies the Murray Basin sediments of the plains region. The Permian Sand aquifer can be highly permeable which results in high yields and low salinities. However, productivity of this aquifer varies due to a high clay content in some areas and at these locations, the aquifer is instead low yielding and high in salinity. Despite this variability, the Permian Sand aquifer is widely developed for localised irrigation and town water supply.

Murray Group Limestone

The MGL formation occurs in the Murray Basin and predominantly consists of shallow marine fossiliferous limestone that was deposited about 50 million years ago. The aquifer is up to 100 m thick and overlies the Kanmantoo Group FRA and the Permian Sand aquifer in some areas. It is confined by the overlying Quaternary clay sediments to the south-west of Murray Bridge; however, it is unconfined to the north. It is considered to be a good aquifer with low salinity groundwater in the southern area of the plains region, where it is the main source of groundwater for irrigation. This is the result of freshwater recharge to the aquifer thought to have occurred several thousand years ago during a period that experienced much higher rainfall. However, today there is little evidence of freshwater recharge to this aquifer. The current extraction from this aquifer is gradually depleting the low salinity groundwater resource and as a result the water salinity of the aquifer is increasing.

Quaternary

The Quaternary sediments consist of unconsolidated alluvium. The 10 to 20 m thick sequence is found at the lowest points in the catchments adjacent to drainage lines and consists mainly of clays, silts, sands and occasional gravels. This aquifer is generally low yielding throughout the EMLR PWRA, with salinity concentrations that make it unviable for most irrigation practices.

For more detailed information about the hydrogeology of the EMLR PWRA please see:

Zulfic, D. And Barnett, S. (2004) *Eastern Mount Lofty Ranges Groundwater Assessment* (DWLBC Report 2003/25), Knowledge and Information Division, Department of Water, Land and Biodiversity Conservation, Government of South Australia

http://www.waterconnect.sa.gov.au/Content/Publications/DEWNR/dwlbc_report_2003_25.pdf

Green, G. and Stewart, S. (July 2008) *Interactions between groundwater and surface water systems in the Eastern Mount Lofty Ranges* (DWLBC Report 2008/27), Knowledge and Information Division, Department of Water, Land and Biodiversity Conservation, Government of South Australia

http://www.waterconnect.sa.gov.au/Content/Publications/DEWNR/dwlbc_techrpt_2008_27.pdf

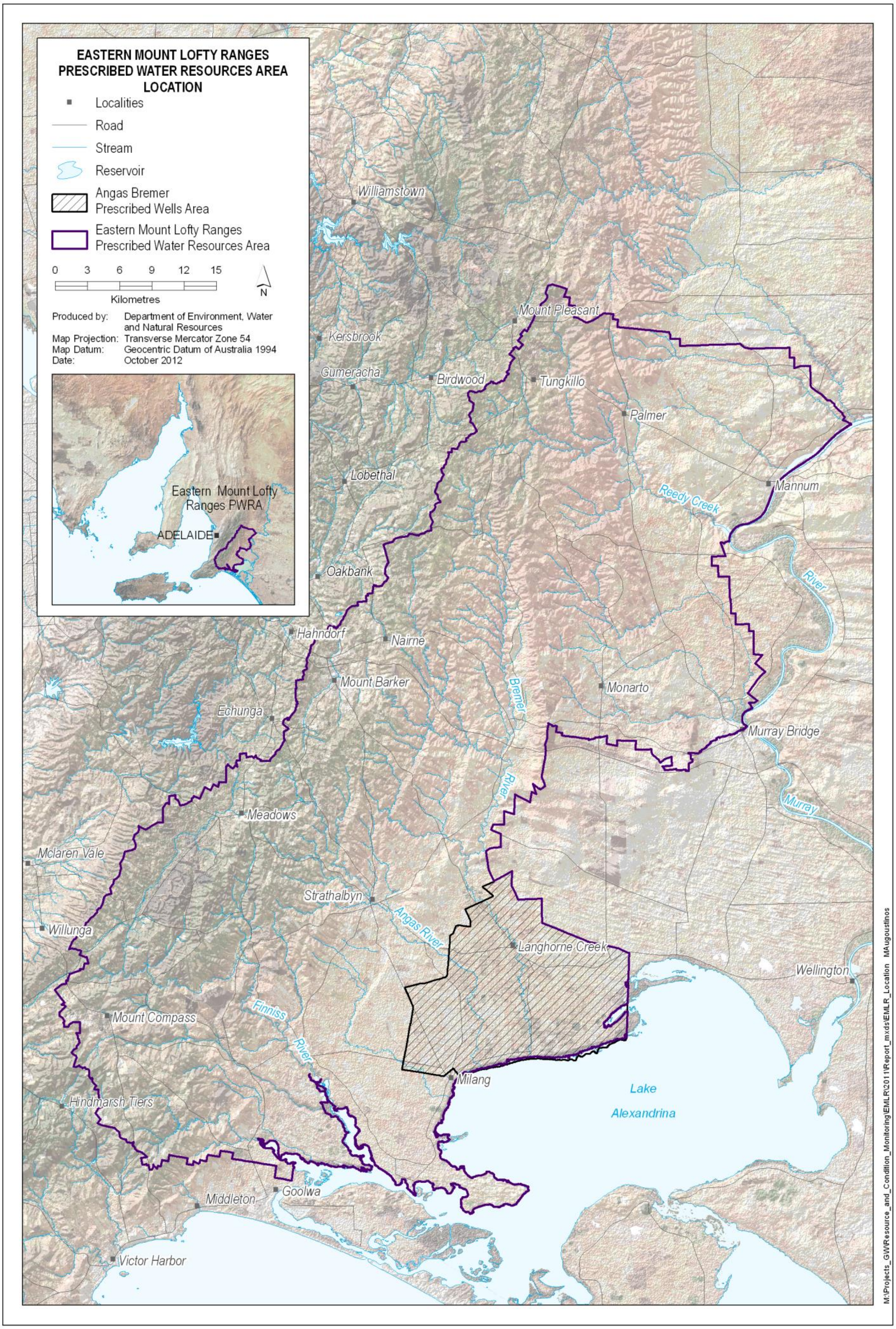

Figure 1. Location of the Eastern Mount Lofty Ranges Prescribed Water Resources Area

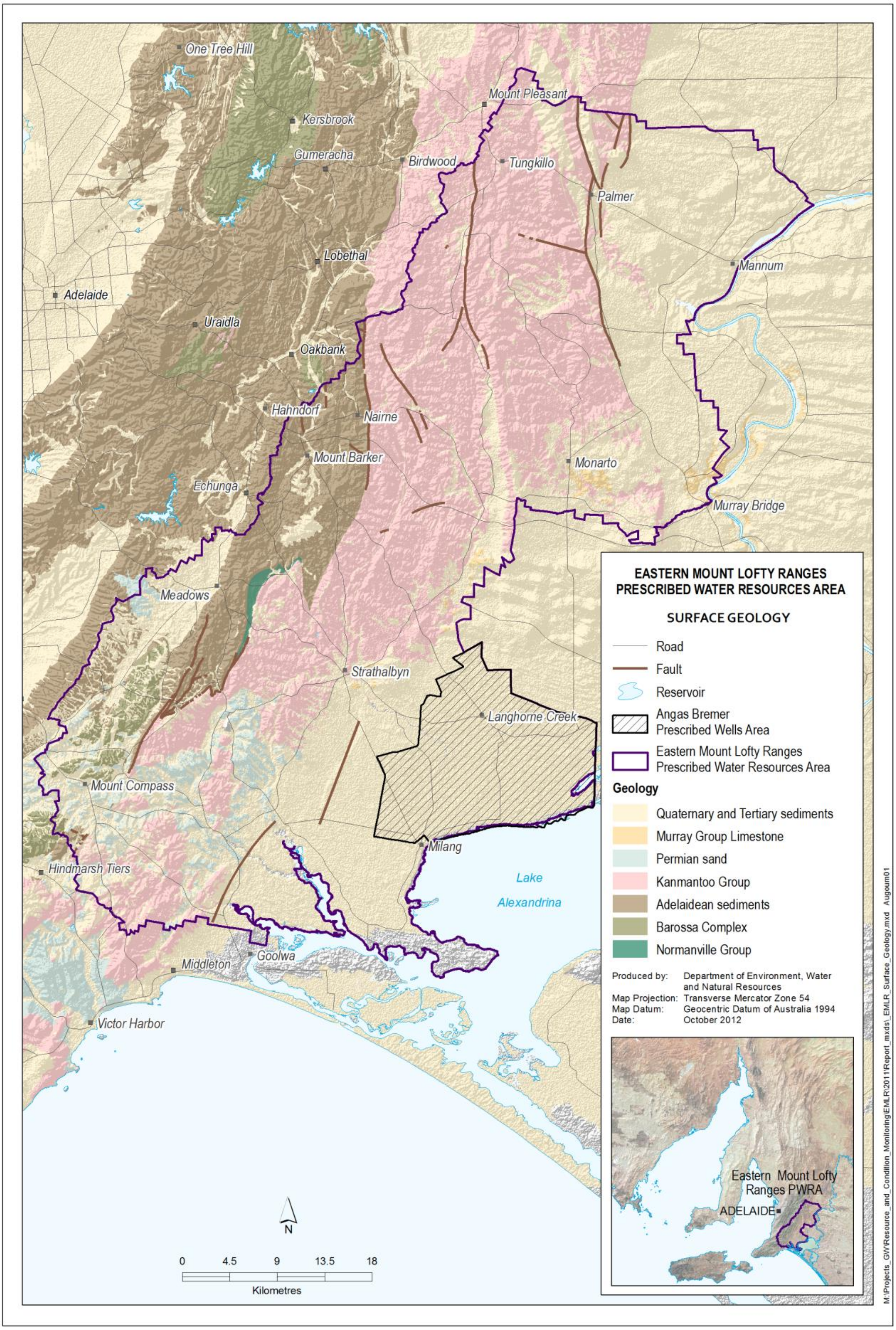

Figure 2. Surface geology of the Eastern Mount Lofty Ranges Prescribed Water Resources Area

Table 1. Hydrostratigraphy of the Eastern Mount Lofty Ranges Prescribed Water Resources Area

AGE	STRATIGRAPHY		HYDROGEOLOGY	
	UNIT	LITHOLOGY	AQUIFER	DESCRIPTION
QUATERNARY	Undifferentiated Quaternary	Unconsolidated alluvial sediments including clays, silts, sands and gravels	Quaternary	Unconfined aquifer, salinities from 2000 mg/L to 10 000 mg/L
TERTIARY	Murray Group Formation	Limestone (comprising marine fossils), sandstone, minor carbonaceous clay and silts	Murray Group Limestone	Confined aquifer (except to the north), salinities from 1000 mg/L to 4000 mg/L
PERMIAN	Cape Jervis Formation	Glacial deposits of unconsolidated sands, silts, clays and gravels	Permian Sand	Hills Region: Unconfined aquifer, salinities less than 500 mg/L Plains Region: Confined aquifer of slightly higher salinities Varies in productivity (10 to 30 L/s) due to changes in sedimentary deposition, higher clay contents in some areas result in low yields and high salinity
CAMBRIAN	Normanville Group	Macclesfield Marble	Normanville Group	Greater yields and lower salinity ranging from 500 to 2000 mg/L
	Kanmantoo Group	Metamorphosed greywacke, schist and gneiss	Kanmantoo Group	Generally low yields, salinity ranges from 2000 to 3000 mg/L, although there are isolated instances of low salinity and high yields.
NEOPROTEROZOIC	Adelaidean sediments	Sandstone, siltstone, shale and slate, with minor beds of quartzite	Adelaidean sediments	Relatively high yields of up to 15 L/s and low salinity around 1500 mg/L
PALAEOPROTEROZOIC	Barossa Complex	Metamorphosed gneiss, schist and pegmatites	Barossa Complex	Generally low yields and low salinity (200–560 mg/L)

GROUNDWATER FLOW AND SALINITY

Fractured rock aquifers

Localised groundwater flow within the FRAs tends to follow the topography, with groundwater flowing from high points in the catchments to low points where groundwater discharges to streams. The regional flow direction of the FRAs is from north-west to south-east (Fig. 3).

The Barossa Complex FRA typically has low yields and low salinity, typically ranging between 200–560 mg/L. The low salinity is probably due to high recharge associated with higher elevations around the catchment margins.

The Adelaidean sediments FRA generally experiences high recharge, lower salinity and higher yields due to the secondary porosity features (e.g. joints and fractures) of this formation. This formation outcrops in the western part of the region where the rainfall is higher, resulting in the high recharge rates and low salinities that are typical of this formation. This results in relatively high yields of up to 15 L/s and low salinities of 1500 mg/L.

The Kanmantoo Group FRA typically has higher salinities due to the lower rainfall to the east resulting in reduced flushing and recharge to this aquifer. Salinity concentrations typically range between 2000 and 3000 mg/L. However, isolated instances of low salinity and high yields still occur.

The Normanville Group FRA has secondary porosity (fissures) which can provide greater yields and allow greater recharge. The salinity of groundwater wells accessing the Normanville Group generally ranges from 500 to 2000 mg/L.

Sedimentary aquifers

The Permian Sand aquifer is generally quite permeable and allows high recharge rates from rainfall, resulting in high yields of 10 to 30 L/s. Based on groundwater salinity data recorded for this aquifer since 1975, the groundwater salinity of the Permian Sand aquifer ranges from less than 1000 mg/L to up to 8000 mg/L (Fig. 4). Figure 4 only displays the Permian Sand aquifer where it is exposed as the surface geology in the eastern hills of the EMLR PWRA, not where the aquifer is overlain by the MGL aquifer. The portion of the Permian Sand aquifer displayed in Figure 4 is mostly characterised by salinity levels less than 1000 mg/L. Some areas that experience higher recharge rates are known to have very low salinities of below 500 mg/L. Similar to the FRAs, the regional flow direction is from the north-west to south-east (Fig. 4), with isolated areas of the FRAs influencing the flow direction within certain parts of the Permian Sand aquifer. For example, in the north-east corner the flow direction is predominantly from north to south and there are indications of localised flow from south to north.

The MGL aquifer is recharged by throughflow from the Permian Sand aquifer and downward leakage from the overlying Quaternary aquifer. This formation also underlies the Angas Bremer PWA and as such, the data available for this area was also considered in assessing the groundwater flow and salinity characteristics although the representation of this information is not included in Figure 4 as it can be seen in the *Angas Bremer PWA Groundwater Level and Salinity Status Report 2011*. The regional flow direction is from the north-west to south-east (Fig. 4). The groundwater salinity of the MGL aquifer ranges from less than 1000 mg/L to more than 8000 mg/L. There is an area of suitable groundwater quality (i.e. salinity less than 1500 mg/L) that coincides with a decline in groundwater elevation, most likely in response to groundwater extraction being concentrated in this area.

The Quaternary aquifer generally has higher salinities of 7000 mg/L to 10 000 mg/L, except near some of the freshwater swamps (about 2000 mg/L). The regional flow direction of this aquifer where it overlies the MGL aquifer is influenced by the recharge received from the freshwater rivers and swamps, with groundwater flowing from these features out towards the lower lakes.

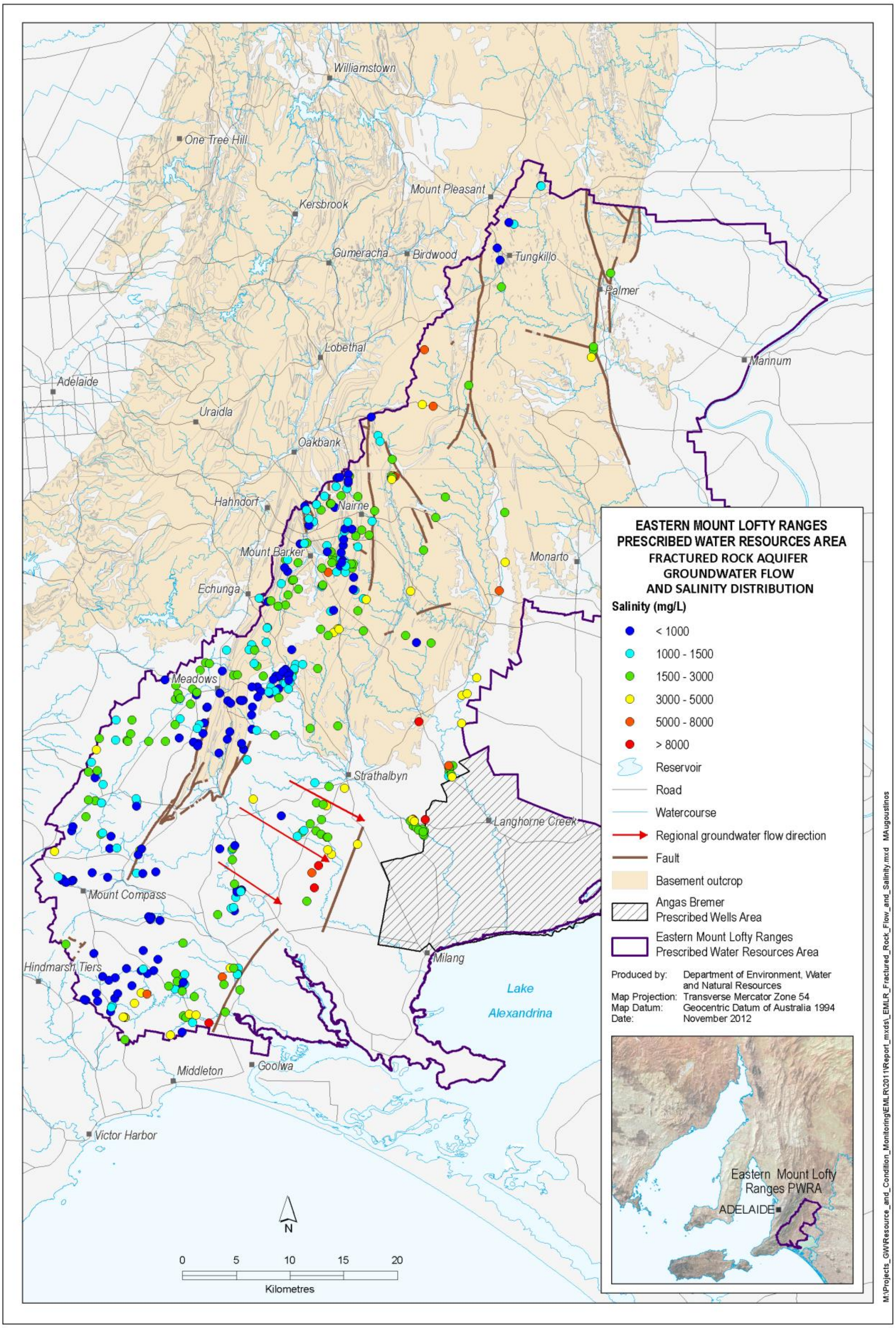

Figure 3. Groundwater flow and salinity distribution of the fractured rock aquifer in the Eastern Mount Lofty Ranges Prescribed Water Resources Area

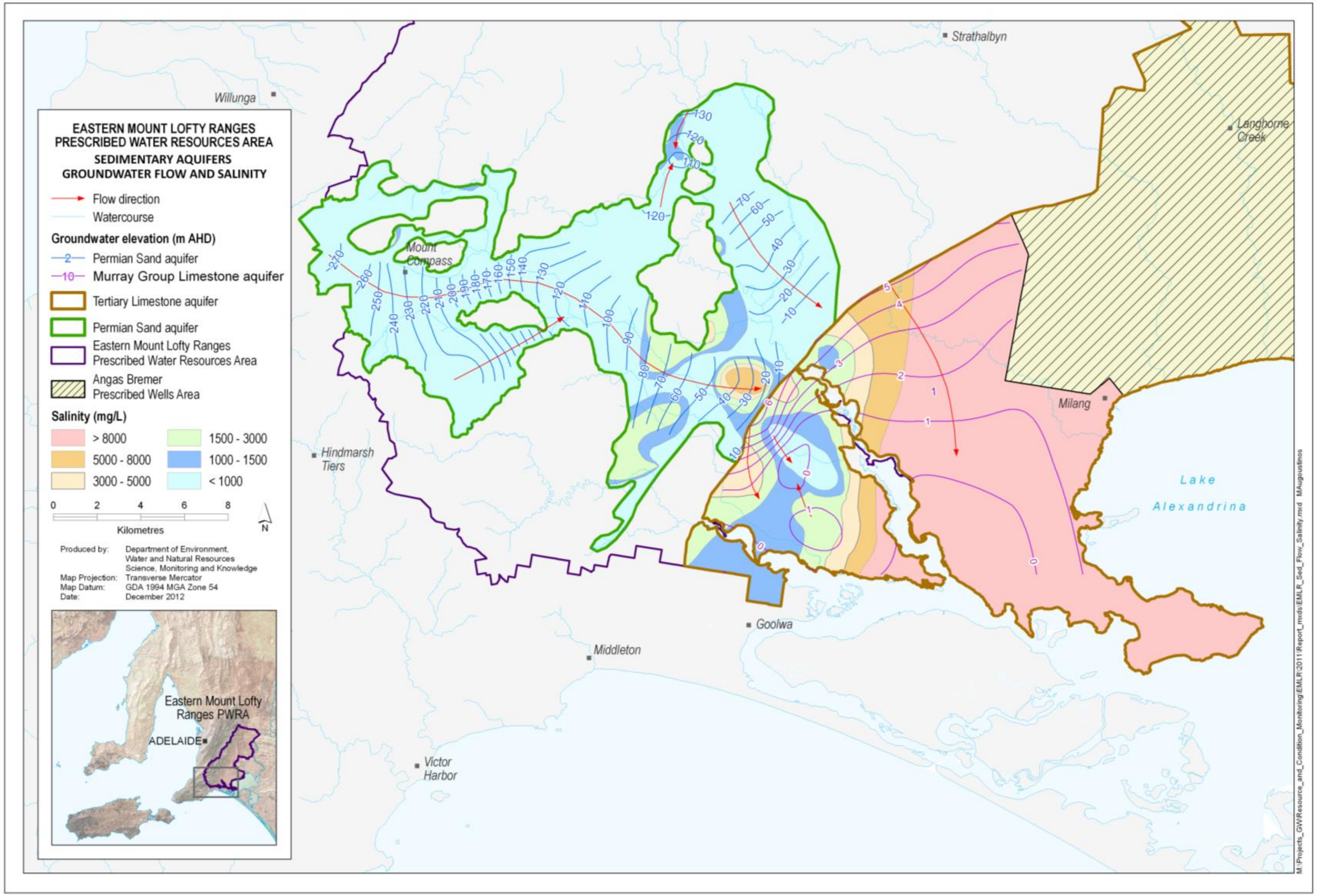

Figure 4. Groundwater flow and salinity distribution of the sedimentary aquifers of the Eastern Mount Lofty Ranges Prescribed Water Resources Area*

* The salinity contours shown in this map are based on groundwater salinity concentrations that have been recorded since 1975 for all drillholes

Groundwater Dependent Ecosystems

Whilst groundwater-dependent ecosystems (GDEs) have not been considered in the assessment of the status of the groundwater resources, it is important to note the presence and ecological characteristics of the GDEs in the EMLR PWRA. 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 water tables less than 10 m below the surface are more likely to support GDEs than deeper water tables. The exception to this is stygofauna (animals that inhabit water-filled cracks and pools below the ground), which can be found at greater depths.

There is strong connectivity between surface water and groundwater resources in the catchments of the EMLR PWRA (Fig. 5). The contribution of groundwater to surface water ecosystems prolongs the existence of aquatic habitats that act as important refugia for aquatic biota during dry periods. These persistent aquatic habitats exist across the EMLR PWRA and include baseflow, in-stream pools and wetlands that support diverse populations of aquatic plants, aquatic macroinvertebrates and fish, many of which have conservation status at the local, state or national scale.

Shallow water tables are likely to support some terrestrial vegetation species (phreatophytes) across the region. One particular example is the red gum swamps located on the Angas and Bremer Plains.

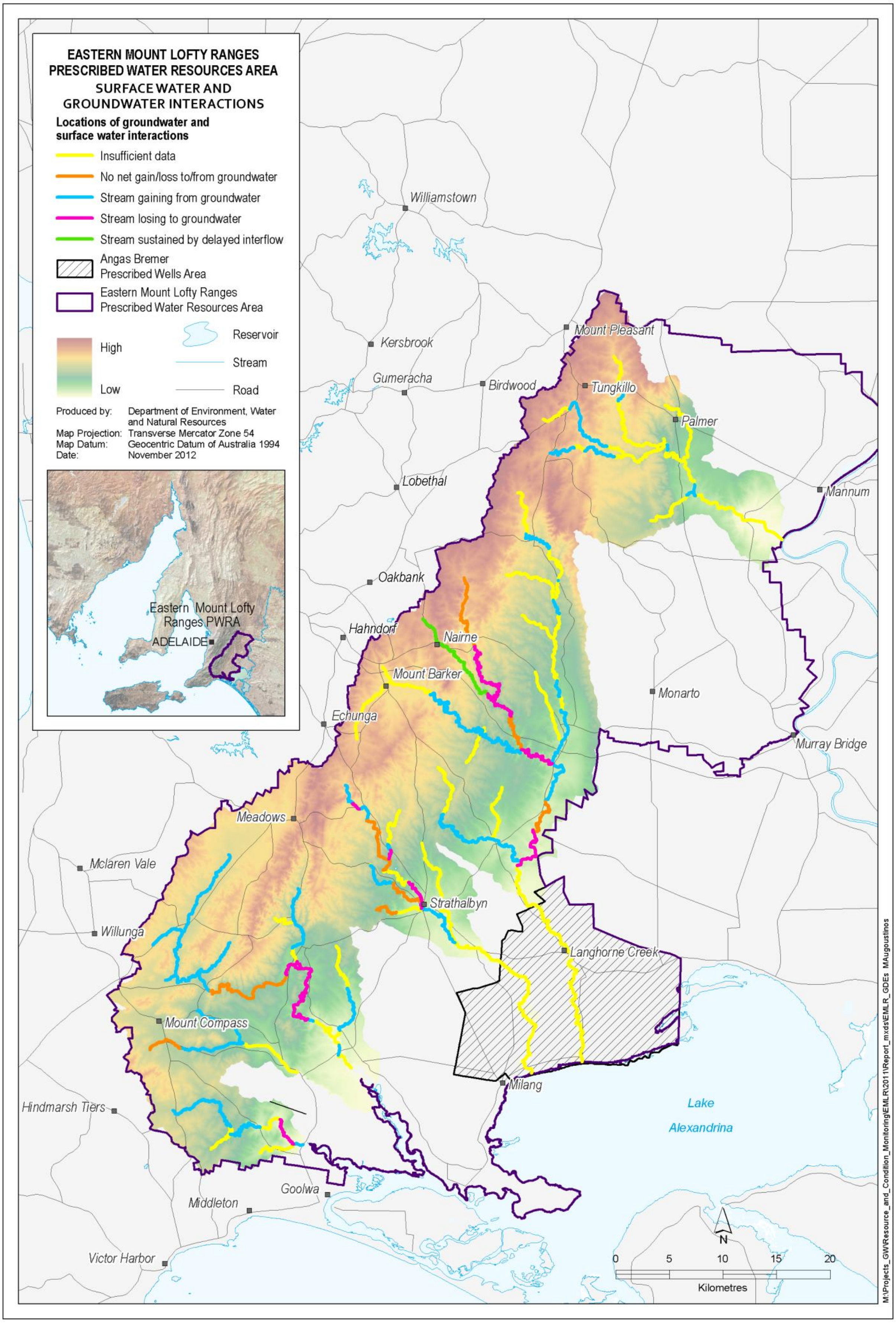

Figure 5. Surface water and groundwater interactions in the Eastern Mount Lofty Ranges Prescribed Water Resources Area

RAINFALL

Rainfall is a very important part of the groundwater balance because it is a source of replenishment or recharge to aquifers by infiltration through the soil, or by percolation from streamflow in drainage lines. The average annual rainfall over the EMLR PWRA is approximately 460 mm, with most rainfall resulting in runoff occurring in winter and early spring.

The eastern slopes of the Mount Lofty Ranges descend to the broad Murray Plains and eventually to the River Murray and the lower lakes of Lake Alexandrina and Lake Albert. The variation in topography found within the EMLR PWRA and the adjacent Western Mount Lofty Ranges PWRA produces a 'rain shadow effect' that is the main reason for the contrast in rainfall within the area. The Mount Lofty Ranges cause westerly winds to rise and cool; if these winds have a high enough moisture content this results in condensation and precipitation along the mountain ranges, predominantly on the western side. The winds continue down the eastern slopes and onto the plains but with much lower moisture concentrations, resulting in comparatively less rainfall on the Murray Plains.

Following the hills from south-west to north-west in the EMLR PWRA, rainfall ranges from approximately 500 to 1000 mm between the Harrogate rainfall station (number 23722) and the Mount Compass rainfall station (number 23735) (Fig. 6). In contrast, the Murray Plains rainfall ranges from less than 300 mm to 500 mm from the north-east to the south-east of the PWRA.

Four rainfall stations, Meadows, Harrogate, Callington and Strathalbyn (Fig. 6), were chosen to examine rainfall trends, with their average annual rainfall over the last 120 years plotted with the annual cumulative deviation (Figs. 7, 8, 9 & 10). The cumulative deviation calculates the difference between the actual measured annual rainfall and the long-term average annual rainfall. An upward trend in the cumulative deviation indicates periods where the rainfall was above average and conversely, a downward trend indicates periods of below-average rainfall.

The graphs for the Harrogate and Meadows stations represent the rainfall trends recorded in the hills area of the PWRA. The Meadows station experienced predominantly below-average annual rainfall since 1974 with the exception of a few wet years in 1979, 1981 and 1992. Whereas the Harrogate station experienced predominantly above-average annual rainfall since 1967, with the exception of a few dry periods in 1975–76, 1993–94, 2001 and 2005–07. Above-average rainfall was recorded at the Harrogate station in 2011, which was preceded by wet years in 2009 and 2010. At the Meadows station, 2011 was a below-average rainfall year following above-average annual rainfall in 2010.

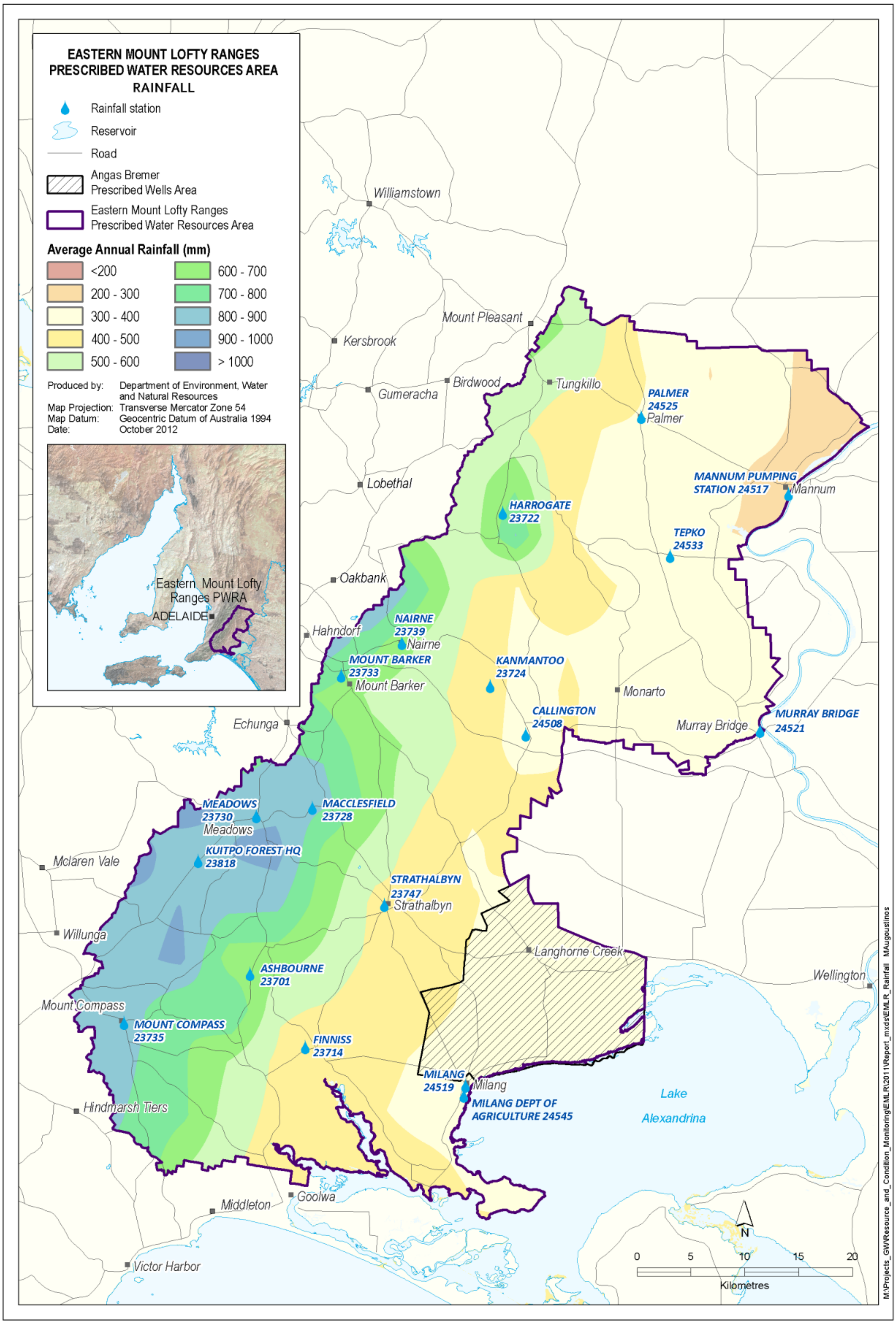

Figure 6. Average annual rainfall and the location of rainfall stations in the Eastern Mount Lofty Ranges Prescribed Water Resources Area

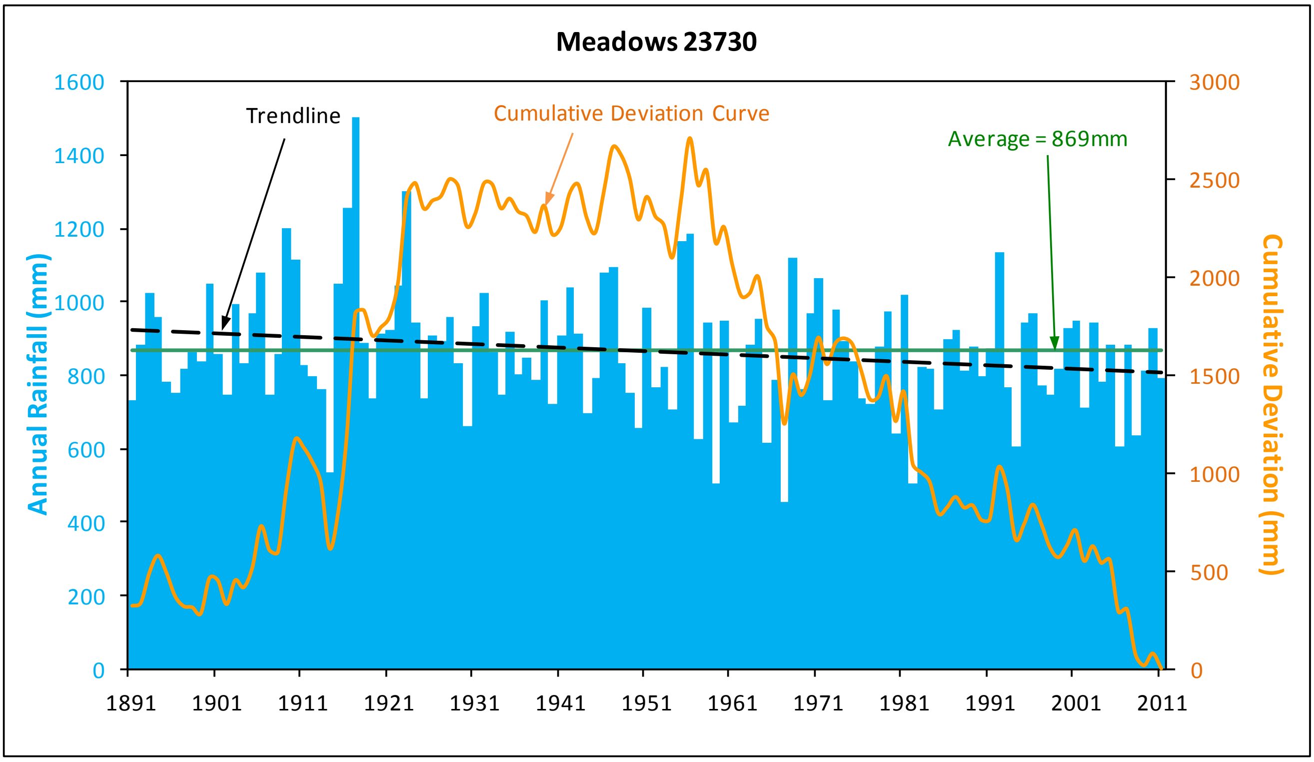

Figure 7. Annual rainfall and the cumulative deviation from average annual rainfall for the Meadows rainfall station (number 23730)

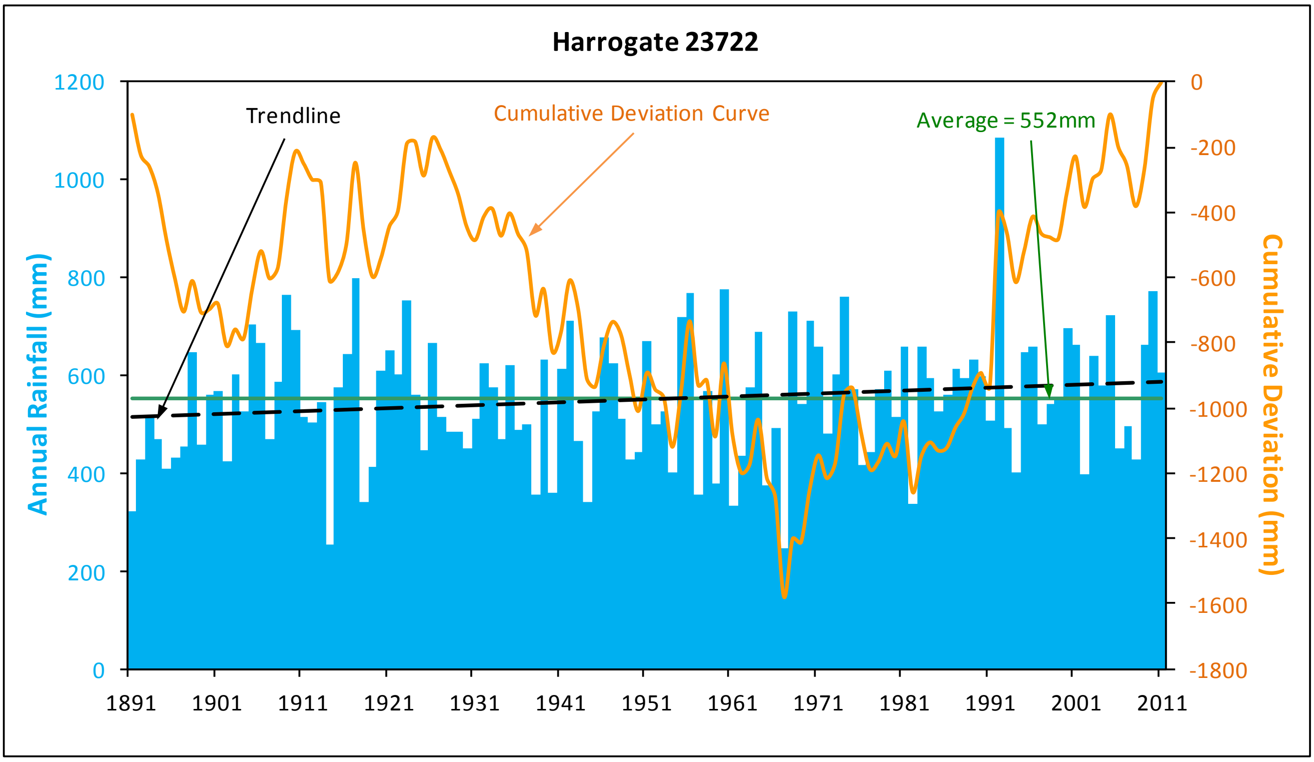

Figure 8. Annual rainfall and the cumulative deviation from average annual rainfall for the Harrogate rainfall station (number 23722)

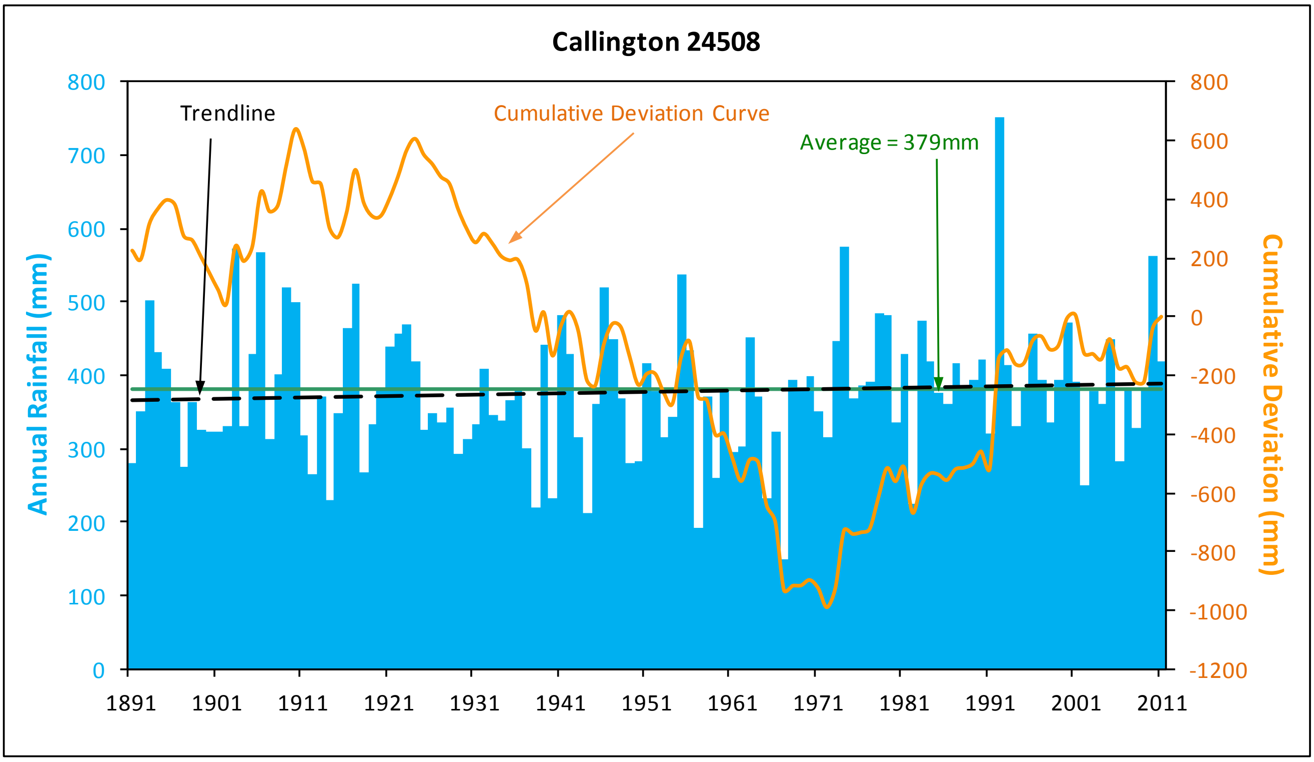

Figure 9. Annual rainfall and the cumulative deviation from average annual rainfall for the Callington rainfall station (number 24508)

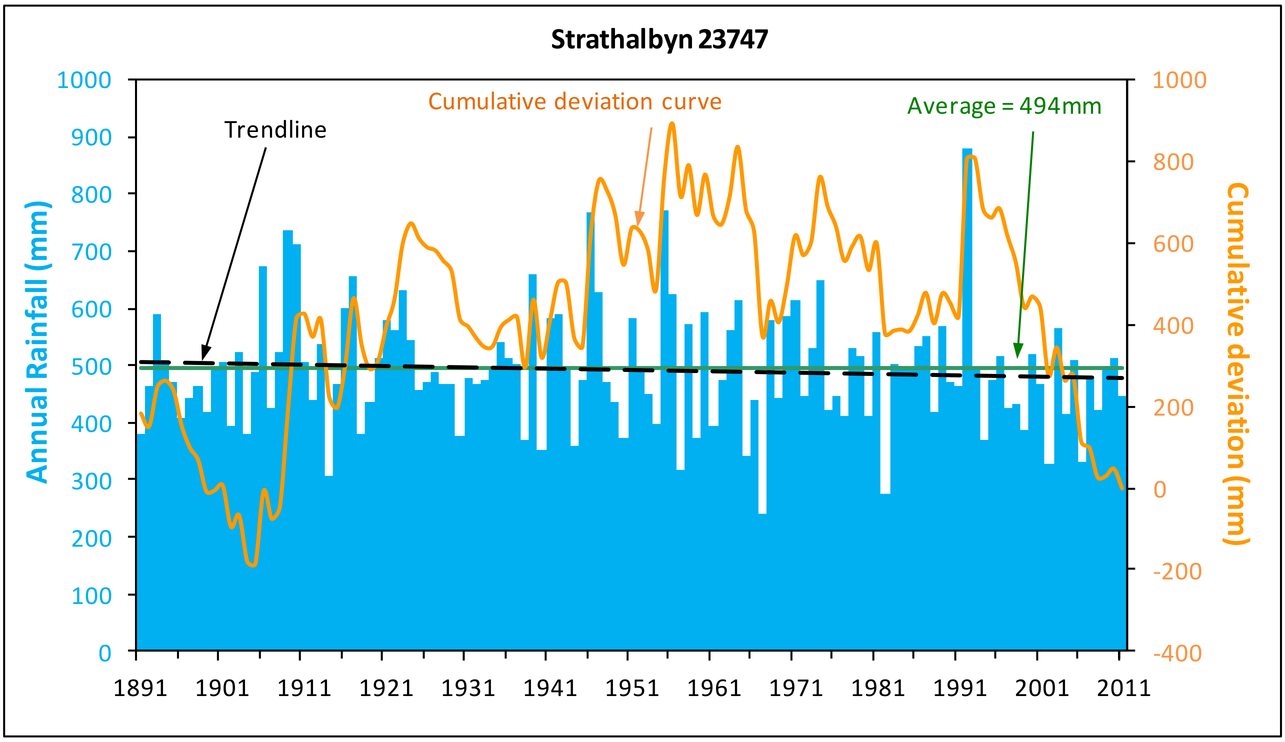

Figure 10. Annual rainfall and the cumulative deviation from average annual rainfall for the Strathalbyn rainfall station (number 23747)

The Callington and Strathalbyn rainfall stations are located on the Murray Plains of the EMLR PWRA. The rainfall trends of these two stations show significant differences over the last 120 years. The annual cumulative deviation curve of the Callington station indicates predominantly above-average rainfall as of 1972, with the exception of a few dry years in 1982, 2001, 2005 and 2007. The rainfall trends observed at the Callington station are similar to that of the Harrogate station, probably due to the proximity of the stations. However the magnitude of the average annual rainfall at the Callington station is much less than that of the Harrogate station. For example, the Callington station experienced its highest average annual rainfall in 1992, as did Harrogate (also due to very high rainfall in December of that year), however, Callington received only 751 mm as opposed to 1085 mm at Harrogate, demonstrating the significant impact that the rain shadow effect has on the rainfall patterns of the EMLR PWRA.

The Strathablyn station also experienced the highest annual average rainfall for the last 120 years in 1992. The average annual rainfall recorded at the Strathalbyn station gradually decreased over the 120 year period, with a particularly dominant trend of below-average annual rainfall since 1992, with the exception of a few, slightly above-average rainfall years in 1995, 2000, 2002, 2005 and 2010.

It is worth noting an incidence of wetter conditions in South Australia in the 2009 to 2011 period. The state experienced its third wettest summer on record in 2010–11, with many individual locations in the Mount Lofty Ranges setting summer and daily rainfall records. High summer rainfall is particularly relevant as it may lead to significantly reduced demand from groundwater users and thus lower drawdown of the aquifers over the dry months of the year.

All rainfall data used in this report is sourced from the SILO Patched Point Dataset, which is an online database of approximately 120 years of continuous daily weather records. The SILO Patched Point Dataset uses original Bureau of Meteorology daily rainfall measurements for a particular meteorological station, but missing data are filled ("patched") with interpolated values. The means of interpolation of the data can be further explained by viewing the SILO website: (http://www.longpaddock.qld.gov.au/silo).

GROUNDWATER USE

Groundwater is extracted from the aquifers of the EMLR PWRA for a range of purposes, such as irrigation of crops or for stock and domestic purposes. Water taken for irrigation practices will be managed through a water licensing system, however, water taken for stock and domestic purposes is exempt from this requirement. Although extensive meter data is not yet available for licensable groundwater extractions, it is estimated that approximately 30 122 ML is taken each year from the aquifers of the EMLR PWRA. This estimation is based on land-use surveys of agricultural properties and the theoretical irrigation requirements for various crops. Please note that this is an estimation and actual current use may be different.

Most of the groundwater is used for the irrigation of pasture (40.4%) and lucerne (18.2%). Irrigation of various food crops including olives, vegetables, potatoes, berries and orchards utilise 7.5% or less each, with viticulture using 10.3% of the groundwater extracted (Fig. 11).

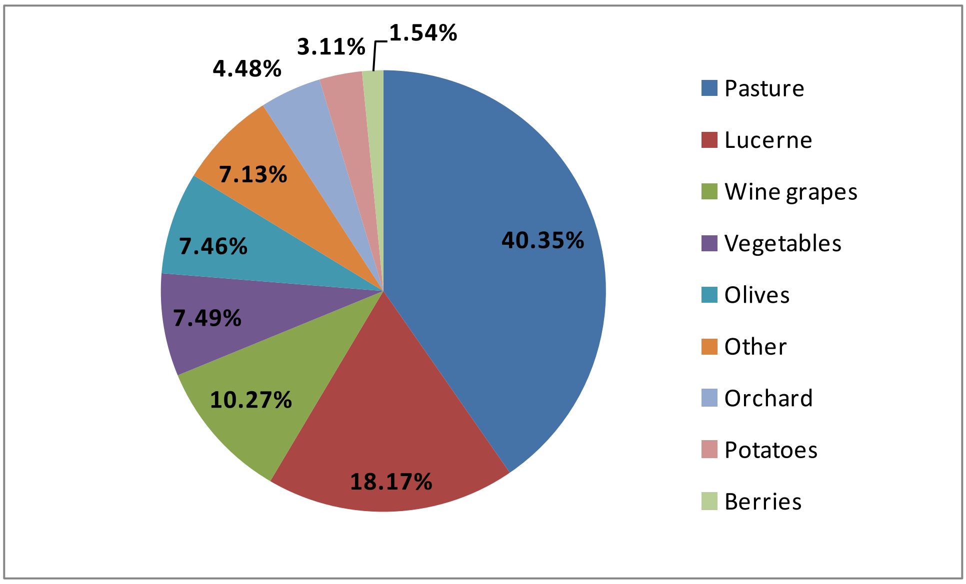

Figure 11. Estimated groundwater use by purpose

The estimated demand is below the calculated sustainable yield of 42 791 ML/y for the entire EMLR PWRA. However, at a local scale the estimated demand may exceed the sustainable yield, such as where the MGL aquifer is within the Currency Limestone management zone and the Permian Sand aquifer is within the Tookayerta Permian management zone (Fig. 13).

GROUNDWATER OBSERVATION NETWORKS

WATER LEVEL NETWORK

There are 12 groundwater level observation networks operating within the EMLR PWRA which encompass 170 observation wells (Table 2). These wells are completed in the sedimentary aquifers (103 wells) and in the FRAs (45 wells) (Figs. 12 & 13). The groundwater level observation networks are listed in Table 2, with the corresponding aquifers that are monitored, the number of wells monitoring these aquifers and the frequency of the monitoring. If a network, or wells within a network, correspond to the Currency Limestone management zone or the Tookayerta Permian management zone this is identified in Table 2 and Fig. 12.

Table 2. Groundwater level observation networks within the Eastern Mount Lofty Ranges Prescribed Water Resources Area

Observation network	Aquifer and Management Zone (where applicable)	Number of wells	Monitoring frequency (monthly)
Ashbourne	Kanmantoo Group Permian Sand	2 16	6
Tungkilo (Dryland Salinity Network)	Quaternary Kanmantoo Group	11 3	6
Currency Creek	Kanmantoo Group Murray Group Limestone (all wells except ALX 1 are within the Currency Limestone MZ) Permian Sand (NGK 35, 63 & 64 are within the Tookayerta Permian MZ) Quaternary Unnamed	4 18 9 5 2	6
Lower Lakes	Quaternary	4	1
Macclesfield	Kanmantoo Group Normanville Group	9 7	6
Mannum Marina	Quaternary Murray Group Limestone	12 2	As required
Mount Lofty Ranges Recharge investigation sites	Fractured Rock (specific formation not identified) Adelaidean sediments	4 4	3
Mobilong and Toora reclaimed swamps	Quaternary	5	1
Mount Barker	Adelaidean sediments	5	6

Observation network	Aquifer and Management Zone (where applicable)	Number of wells	Monitoring frequency (monthly)
Mount Compass	Barossa Complex	3	6
	Kanmantoo Group	3	
	Permian Sand (Tookayerta Permian MZ)	19	
Murray Basin-Western Margin	Renmark Group (Tertiary)	1	12

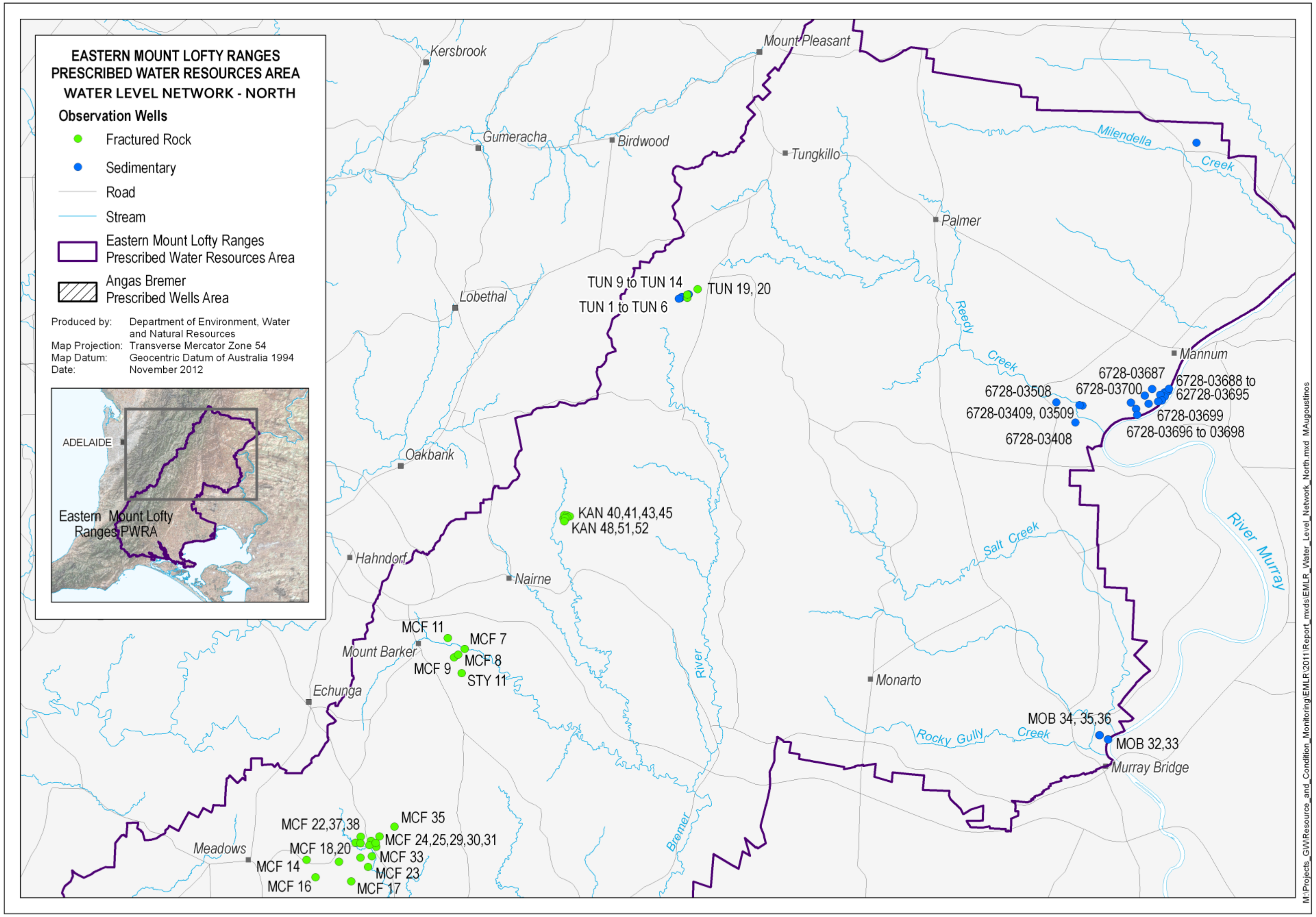

Figure 12. Location of water level observation wells in the North of the Eastern Mount Lofty Ranges Prescribed Water Resources Area

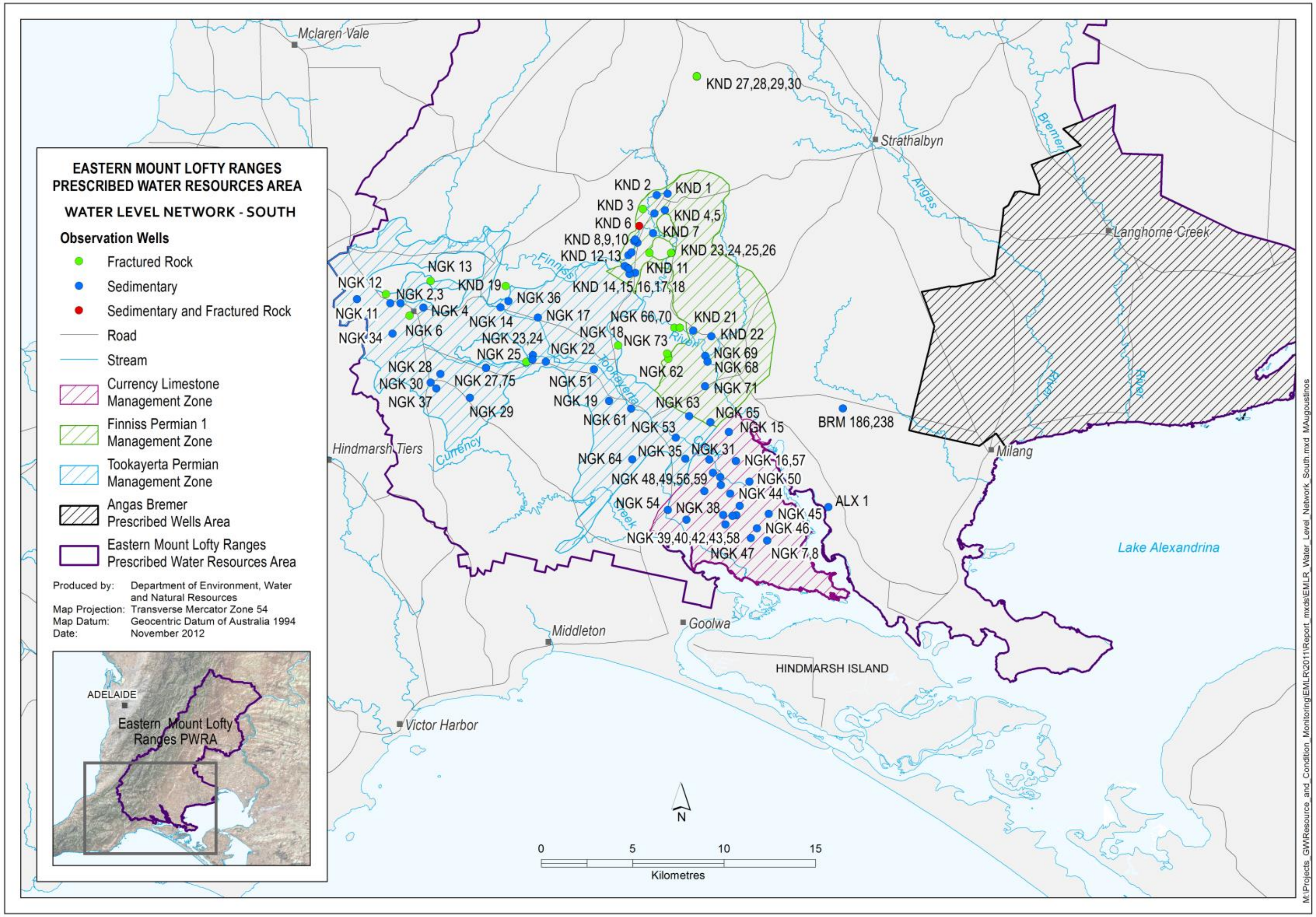

Figure 13. Location of water level observation wells in the South of the Eastern Mount Lofty Ranges Prescribed Water Resources Area

SALINITY NETWORK

There are five salinity observation networks operating within the EMLR PWRA (Table 3). These include the Mobilong and Toora Reclaimed Swamps network, Mount Barker network, Macclesfield network and the Currency Creek network. These networks consist of 30 wells, comprising 14 wells in the FRAs and 16 wells in the sedimentary aquifers (Fig. 14).

Table 3 lists the name of aquifer, the total number of current wells for each networks and the current monitoring frequency. The MGL aquifer salinity observation wells of the Currency Creek salinity observation network correspond with the Currency Limestone management zone as identified in Table 3 and Fig. 14.

Table 3. Salinity observation networks within the Eastern Mount Lofty Ranges Prescribed Water Resources Area

Observation network	**Aquifer**	**Number of wells**	**Monitoring frequency (monthly)**
Mount Barker	Adelaidean sediments	4	As required
Macclesfield	Normanville Group	6	12
	Kanmantoo Group	4	
Currency Creek	Tertiary Limestone (Currency Limestone MZ)	11	6–12
Mobilong and Toora Reclaimed Swamps	Quaternary	5	As required

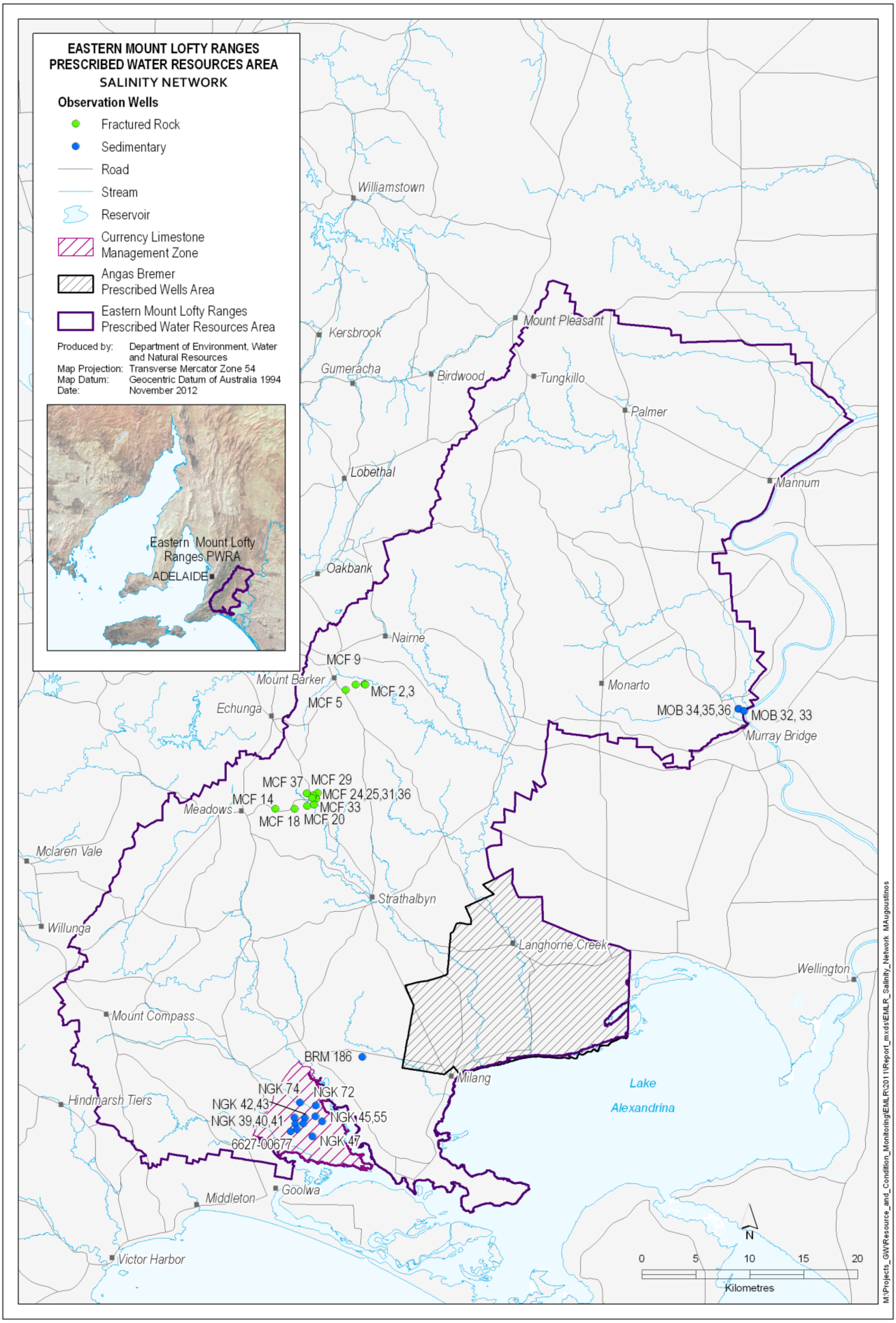

Figure 14. Location of salinity observation wells of the Eastern Mount Lofty Ranges Prescribed Water Resources Area

GROUNDWATER LEVEL TRENDS

Barossa Complex

Observation well NGK006, from the Mount Compass observation network, displays seasonal fluctuations but a relatively stable groundwater level trend, with low-level periods from 1997 to 2000 and 2006 to 2009 (Fig. 15). Observation well NGK012 shows some significant seasonal fluctuations (up to 15 m) due to extraction between 1996 and 2001. Both wells show a reduction in seasonal variations since 2001.

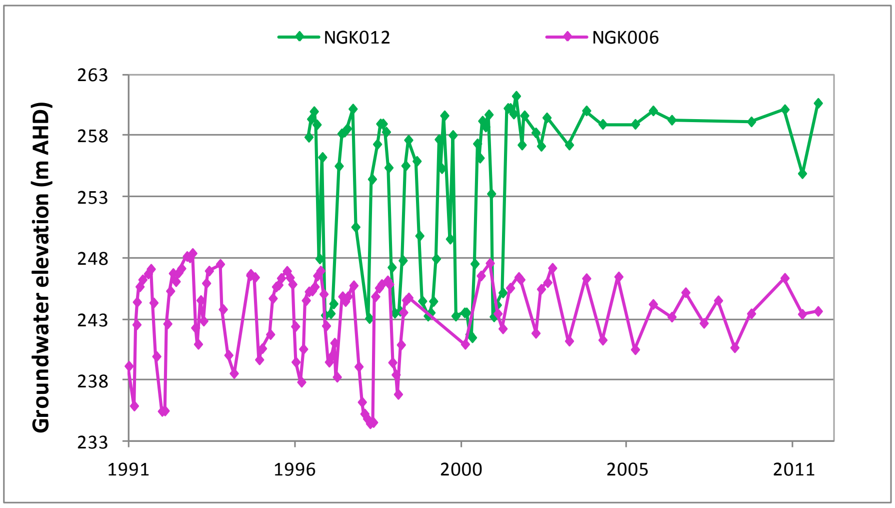

Figure 15. Groundwater level trends of the Barossa Complex fractured rock aquifer monitored in the Mount Compass observation network

Adelaidean sediments

Observation wells from the Mount Barker observation network show a similar trend of lower levels between 1997 and 2000 and, to a lesser extent, from 2006 to 2009 (Fig. 16). This coincides with periods of below-average rainfall recorded at the Mount Barker rainfall station. There appears to be an overall stabilisation in levels and reduction in seasonal variation in all three wells from 2002 to 2011 despite below-average rainfall and may be due to a decrease in irrigation caused by the urban expansion of Mount Barker.

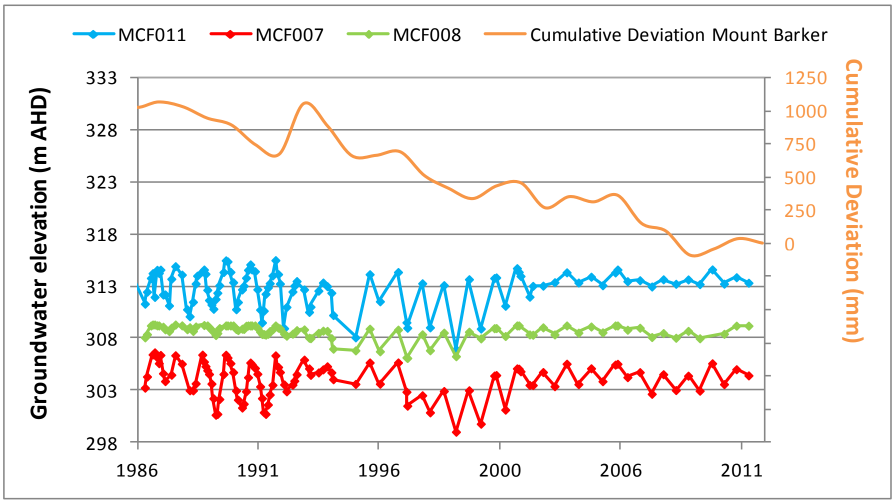

Figure 16. Groundwater elevation of the Adelaidean sediments fractured rock aquifer monitored in the Mount Barker observation network

Kanmantoo Group

Groundwater level monitoring of the Kanmantoo Group FRA in the Ashbourne observation network indicates significant seasonal variations over the last 15 years (Fig. 17). Observation wells KND003 and KND011 display the same low-level period between 1997 and 2000, while the second low-level period commences in 2004 rather than 2006. The groundwater level in KND011 also displays a gradual overall decline.

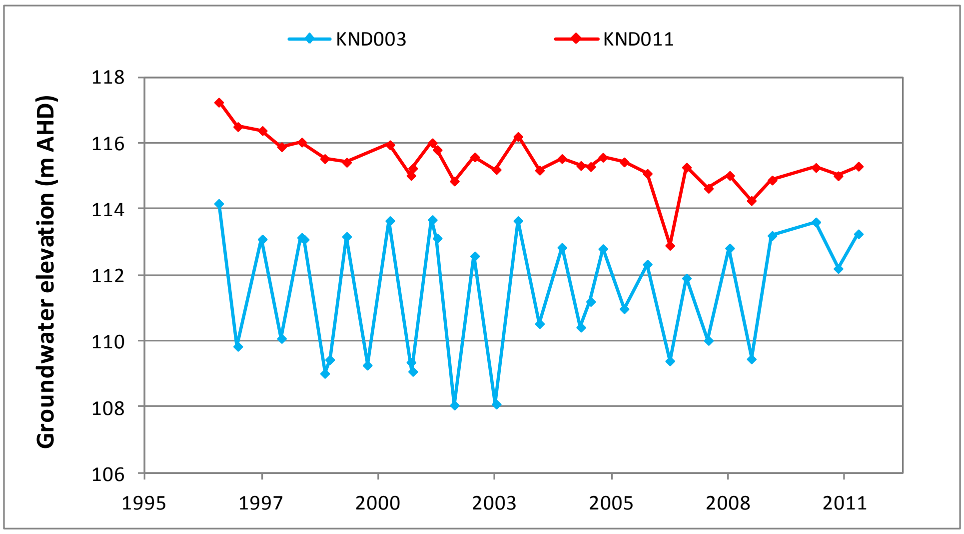

Figure 17. Groundwater elevation of the Kanmantoo Group fractured rock monitored in the Ashbourne observation network

Groundwater level observation wells in the Tungkillo network show both stable and decreasing groundwater level trends over the last 20 years (Fig. 18). Observation wells TUN012 and TUN014 show relatively stable groundwater level readings in 2011.

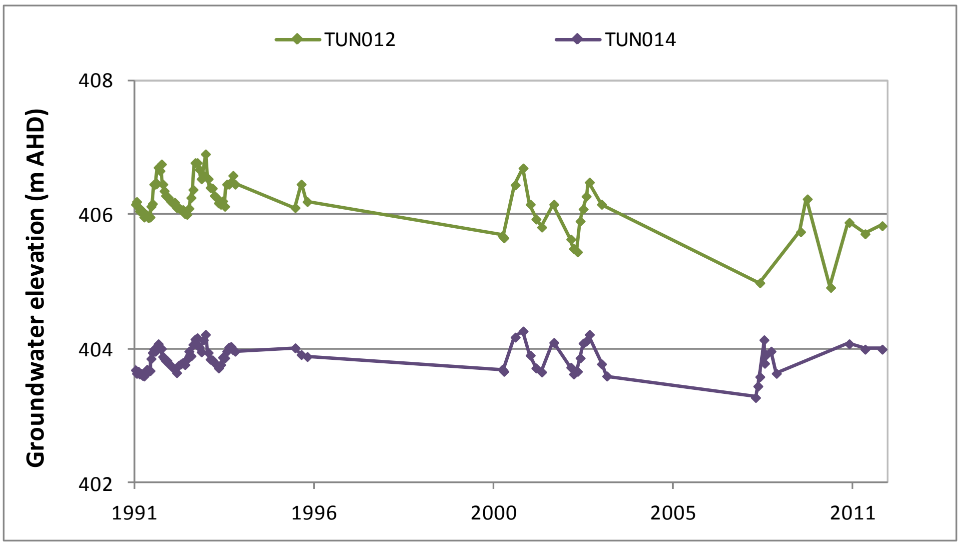

Figure 18. Groundwater elevation of the Kanmantoo Group fractured rock aquifer monitored in the Tungkillo observation network

The wells monitored in the Macclesfield network, such as MCF033 and MCF023, show a slightly decreasing trend over the last 20 years, again with low-level periods from 1997 to 2000 and 2006 to 2009 (Fig. 19). Water levels recorded in April 2011 were higher than those recorded in April 2012.

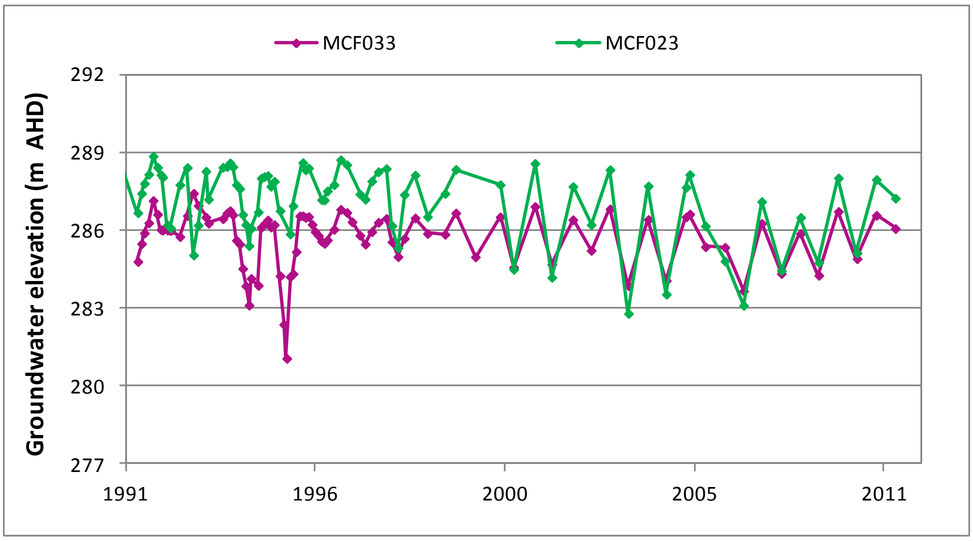

Figure 19. Groundwater elevation of the Kanmantoo Group fractured rock aquifer monitored in the Macclesfield observation network

Observation wells of the Mount Compass network such as NGK025 and KND019 show a fluctuating trend over the last 12 years with some evidence of the low-level period between 2006 and 2009 (Fig. 20). There has been some recovery to groundwater levels in 2010 and 2011.

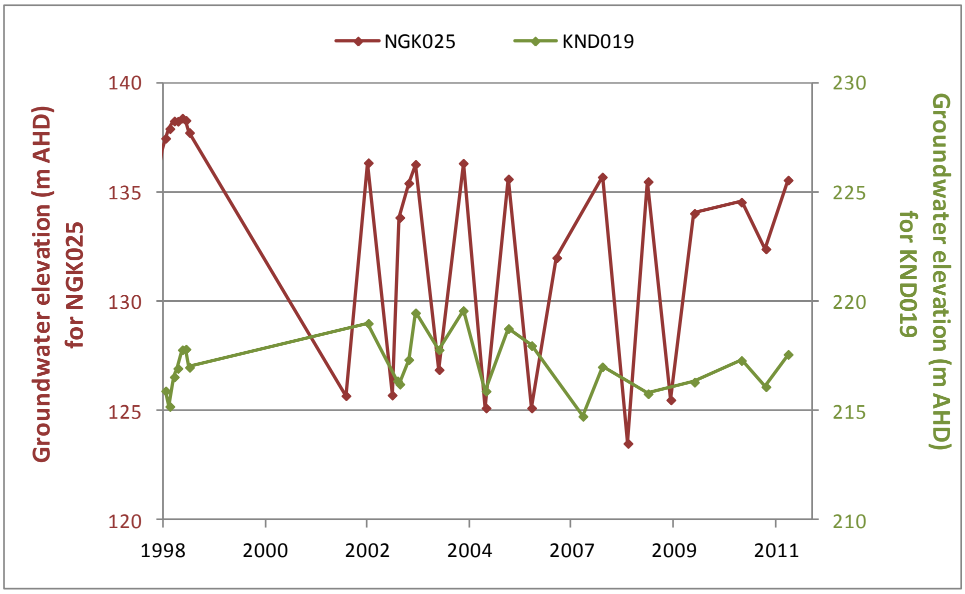

Figure 20. Groundwater elevation of the Kanmantoo Group fractured rock aquifer monitored in the Mount Compass observation network

Normanville Group

Overall, the recovered groundwater levels of the FRA monitored by the Macclesfield observation network have remained relatively stable, with seasonal fluctuations evident. The low-level periods of 1997 to 2000 and 2006 and 2009 are also evident in observation wells MCF037 and MCF038. During 1994–95, the seasonal fluctuation was exaggerated in these wells, however this is known to have resulted from an aquifer test undertaken at the time (Fig. 21). In 2011, both wells show a comparative rise in groundwater level based on the groundwater levels measured during the irrigation season.

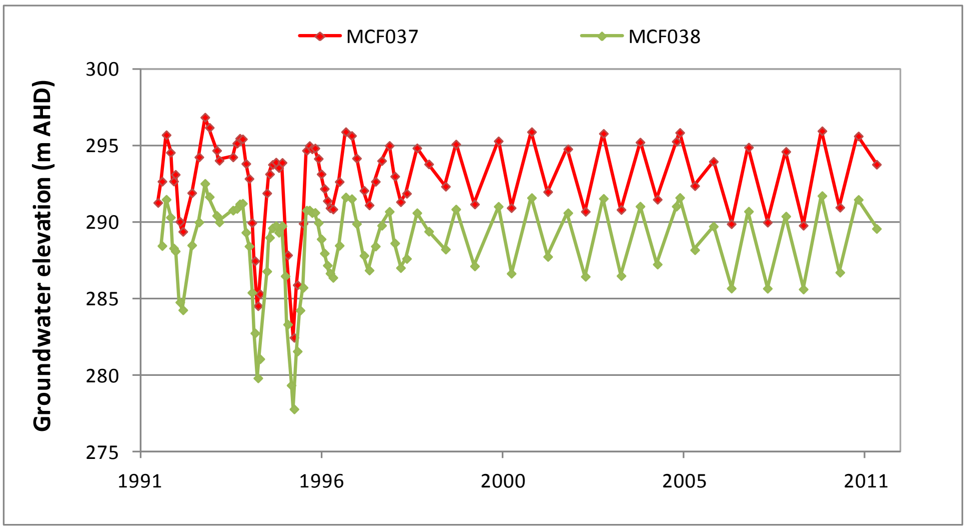

Figure 21. Groundwater elevation of the Normanville Group fractured rock aquifer monitored in the Macclesfield observation network

Permian Sand

The Permian Sand aquifer observation wells of the Currency Creek observation network display some fluctuations over the last six years (Fig. 25). Groundwater levels show overall gradual declining trends and observation well NGK068 displays a similar low-level period between 2006 and 2008 as the one seen in the fractured rock aquifers. Well NGK068 also recorded a slight increase in 2011 compared to 2010 measurements, as does NGK035, which may be due to the above-average rainfall recorded at the Finnis rainfall station.

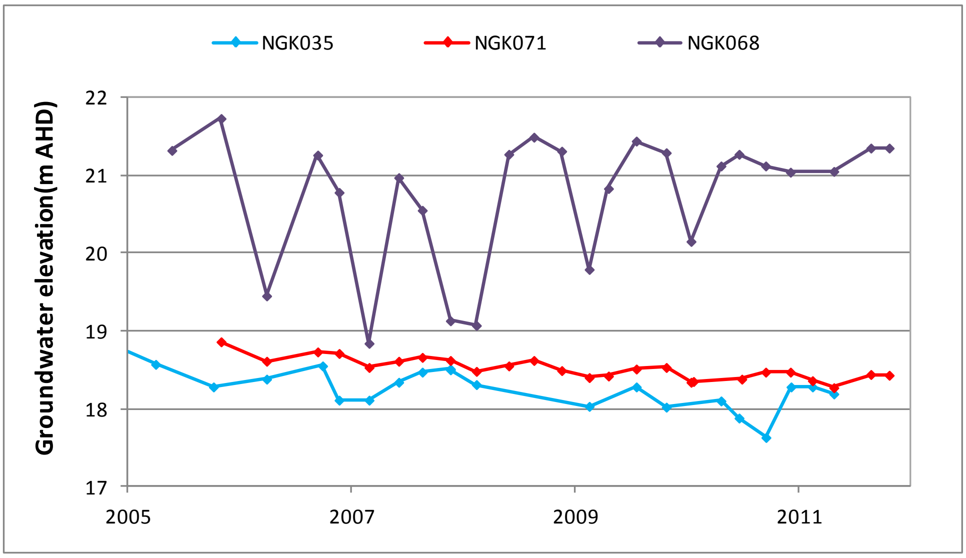

Figure 25. Groundwater level trends of the Permian Sand aquifer in the Currency Creek observation network

The Permian Sand aquifer displays seasonal variations in groundwater levels due to groundwater extraction based on the observation records of the Ashbourne network (Fig. 26). Well KND018 displays an overall slight decline in water level measurements over the last 15 years, which coincides with a period of decreasing average annual rainfall recorded at the Ashbourne rainfall station (number 23701). Wells KND013 and KND004 also display lower levels between 2006 and 2009. Some recovery of levels in 2011 may be due to the unusually wet summer of 2010–11.

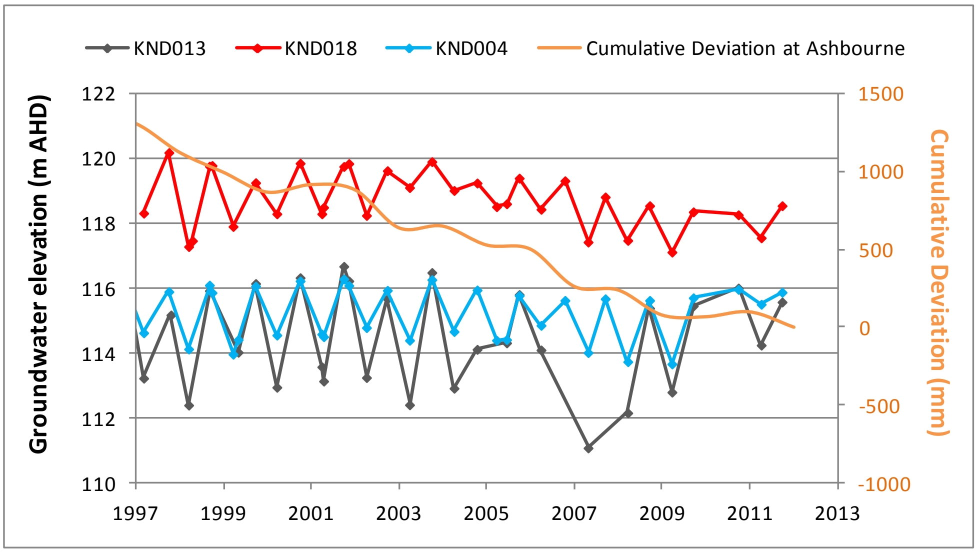

Figure 26. Groundwater level trends of the Permian Sand aquifer monitored in the Ashbourne observation network

The Permian Sand aquifer wells monitored in the Mount Compass network, within the Tookayerta Permian management zone, show slightly decreasing trends over the last 15 years (Fig. 27). Groundwater elevation in well NGK023 shows major seasonal fluctuations over this period. In comparison well NGK017 shows a decreasing trend with less seasonal fluctuation. In 2011, these wells show a slight increase in water level despite overall below-average rainfall recorded at Mount Compass rainfall station (number 23735) and may be due to the unusually wet summer of 2010–11.

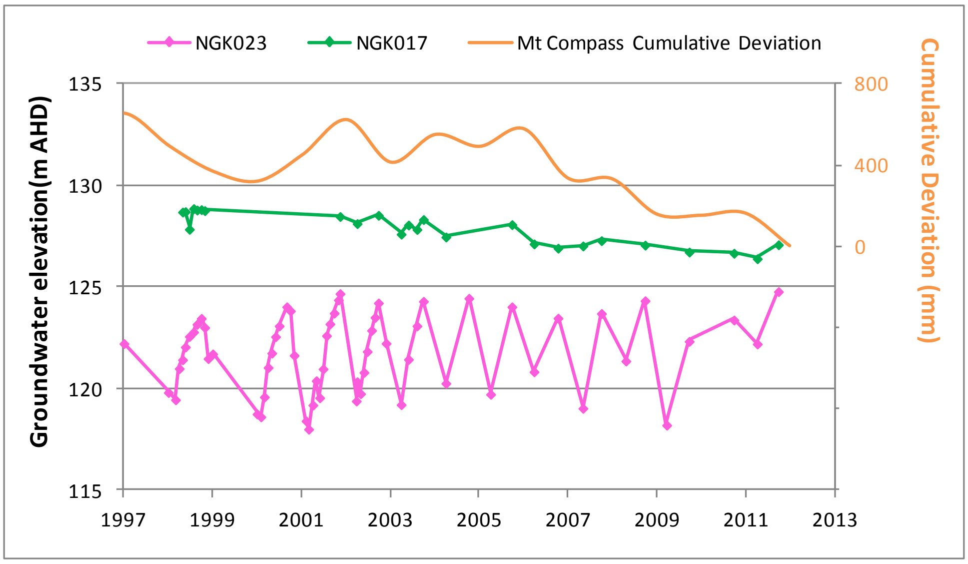

Figure 27. Groundwater level trends of the Permian Sand aquifer monitored in the Mount Compass observation network

Murray Group Limestone

Groundwater levels of the MGL aquifer monitored as part of the Currency Creek network display seasonal variations due to groundwater extraction (Fig. 24). The groundwater levels of wells NGK031 and NGK015 show a continuous decline from late 2004 to 2010, however there is a slight recovery evident during 2011. The recovered groundwater level in October 2011 is about half a metre more than at that time in 2010. This may be due to the period of above-average rainfall recorded at the Finniss rainfall station (number 23714) from 2009 to 2011 (Fig. 24), resulting in a reduction in extractions.

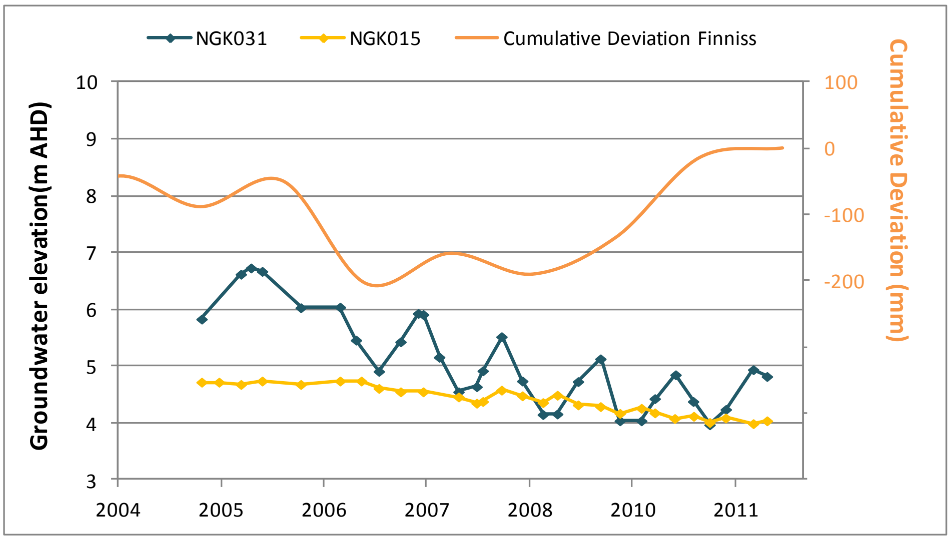

Figure 24. Groundwater level trends of the Murray Group Limestone aquifer monitored in the Currency Creek observation network

Quaternary

Groundwater levels of the unconfined Quaternary aquifer are monitored as part of the Currency Creek, Mobilong and Tungkilo networks. The trends observed in wells MOB032 (Mobilong) and NGK007 (Currency Creek) are examples of the groundwater level monitoring results recorded in these networks (Fig. 22). Well NGK007 shows a decrease in water level followed by a period of recovery in response to extractions from the underlying MGL aquifer, and is located near the Finniss rainfall station (number 23714) (Fig. 6). Well MOB032 is located on the River Murray floodplain and is influenced by the fall in river level following the 2006 drought.

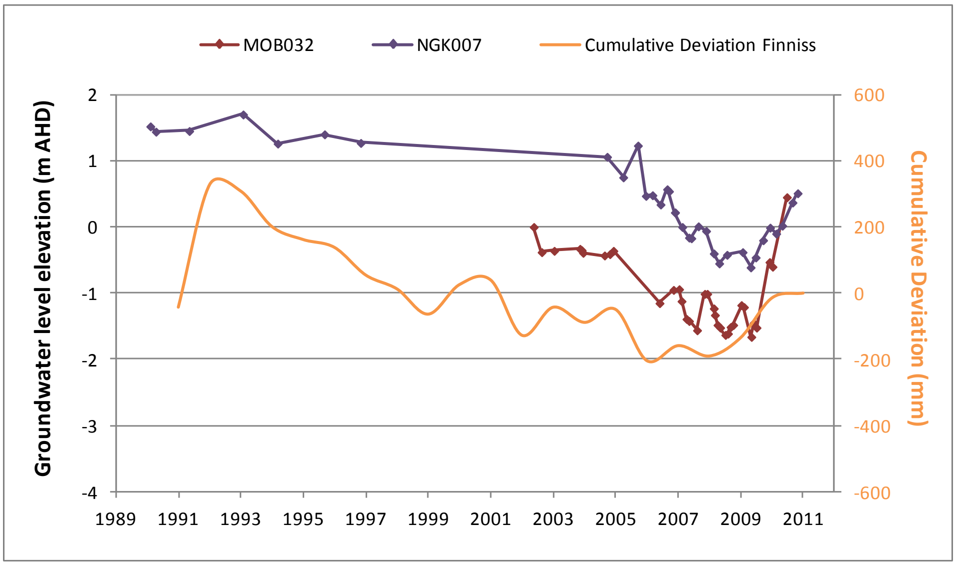

Figure 22. Groundwater level trends in the Quaternary aquifer monitored in the Eastern Mount Lofty Ranges PWRA

Wells TUN001 and TUN002 are examples of the water level monitoring occurring in the unconfined Quaternary aquifer in the Tungkilo observation network which was established to observe trends in areas affected by dryland salinity (Fig. 23). These wells are relatively shallow with TUN001 at 4.8 m depth and TUN002, which is further downhill, reaching a depth of 1.4 m. The overall trend of these wells is relatively stable without significant increases or decreases in water level, however the influence of seasonal recharge and evaporative discharge from the shallow watertable is evident during periods of more intensive monitoring. The latest monitoring results indicate only minor declines in 2011. The rainfall observations of the Harrogate rainfall station (number 23722) have a subdued relationship with these water level observation wells. In particular since 2009 the above-average rainfall may have influenced the slight increase in water level in 2010 and the decrease in rainfall experienced in 2011 could be the cause for the decrease in water level observed.

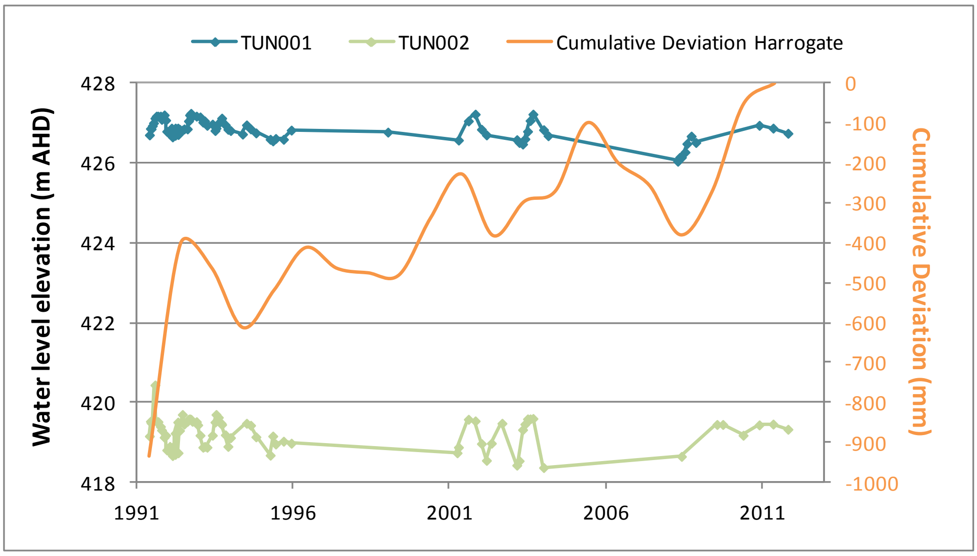

Figure 23. Groundwater level trends in the Quaternary aquifer monitored in the Tungkilo (Dryland Salinity) observation network

GROUNDWATER SALINITY TRENDS

Barossa Complex

The Barossa Complex FRA is not monitored for salinity as it typically has low salinity concentrations. The lack of salinity monitoring is also due to the very few extraction wells completed in this formation, most likely due to the low yields experienced with this aquifer.

Adelaidean sediments

Groundwater salinities of the Adelaidean sediments, monitored by the Mount Barker observation network, display some fluctuations over the last 26 years (Fig. 28). Two wells, namely MCF005 and MCF003 show an overall increase in salinity from 1986 to 1996, after which they both show relatively stable trends possibly as a result of reduced irrigation. In 2011, wells MCF005 and MCF003 have recorded a slight decline in salinity, whereas well MCF009 shows an increase in salinity for this year.

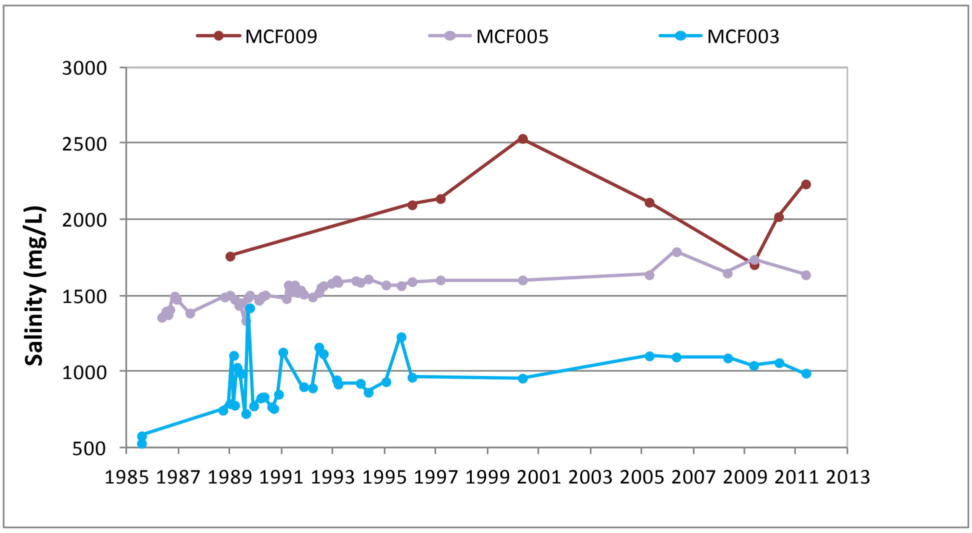

Figure 28. Salinity trends of the Adelaidean sediments formation monitored in the Mount Barker observation network

Kanmantoo Group

Groundwater salinity of the Kanmantoo Group as monitored through the Macclesfield observation network show little variation since monitoring began. In well MCF029, salinity rose during 1976–81 and after that period, it has continued to rise slightly up until 1991. Salinity levels have declined since this time except for a few periods of increase in 2006 and 2009–10 (Fig. 29). In general, the two other wells in Figure 29 (MCF031 and MCF036) show slight fluctuations over the past 30 years but generally display stable trends.

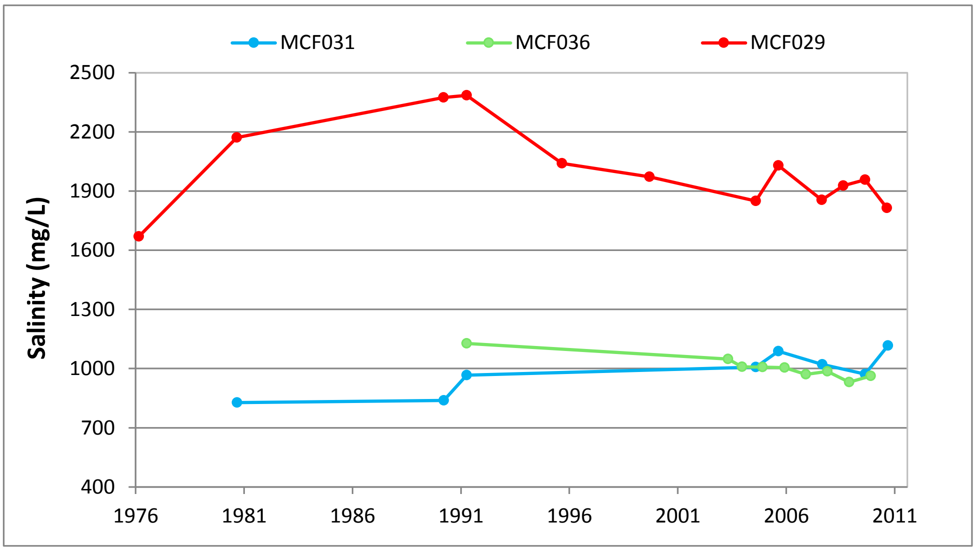

Figure 29. Salinity trends of the Kanmantoo Group monitored in the Macclesfield observation network

Normanville Group

The Normanville Group is recognised as typically having lower salinities due to the secondary porosity of this formation, which enables more recharge. While wells MCF014 and MCF037 (Macclesfield network) display the low salinity concentrations typical of this formation, they do display a slight increasing trend over the past 27 years. In 2011, well MCF037 displays a decline in salinity concentration while well MCF014 shows a similar salinity compared to the previous year (Fig. 30).

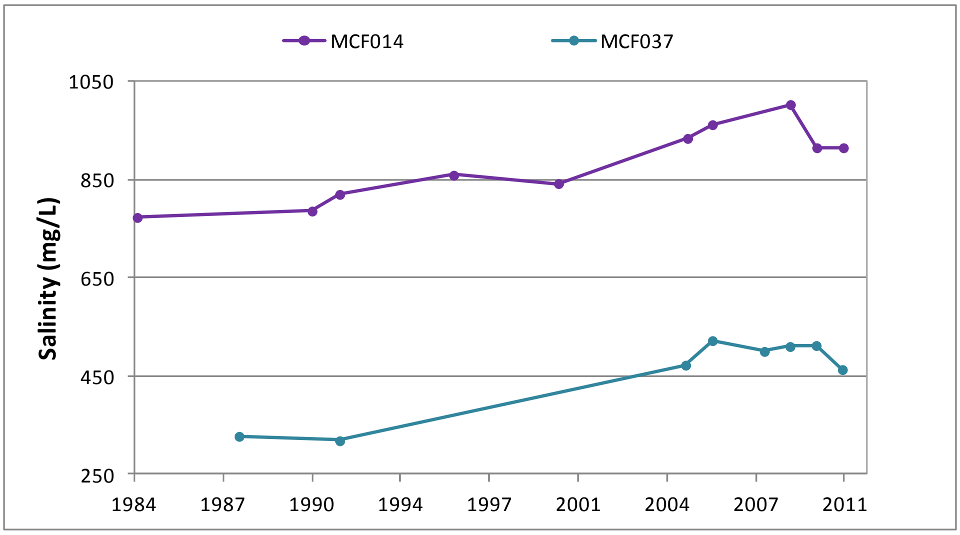

Figure 30. Salinity trends of the Normanville Group monitored in the Macclesfield observation network

Permian Sand

Groundwater salinity is not monitored for the Permian Sand aquifer. The salinity concentration throughout most of the Permian Sand aquifer is typically less than 1000 mg/L and the priorities for salinity monitoring are the aquifers that typically are of a higher initial salinity (i.e. closer to the 1500 mg/L tolerance level for crops) and have had increasing salinity trends observed.

Murray Group Limestone

Within the Currency Limestone management zone, the groundwater salinity of the MGL aquifer is a concern, as the area of suitable low salinity water for agricultural practices (less than 1500 mg/L) is not being replenished by current recharge. It is believed that this region of good quality water resulted from recharge that occurred 8000 years ago. Extraction from this region of good quality groundwater encourages lateral flow of more saline water towards this zone from within the aquifer and from the brackish water of the overlying Quaternary aquifer due to downward leakage. This occurs when the groundwater elevation of the Quaternary aquifer is greater than that of the MGL aquifer.

Most of the MGL aquifer salinity observation wells of the Currency Creek network have recorded overall rising trends since they have been monitored. An example of this is displayed in Figure 31 by the salinity records of wells NGK042, NGK055 and NGK072.

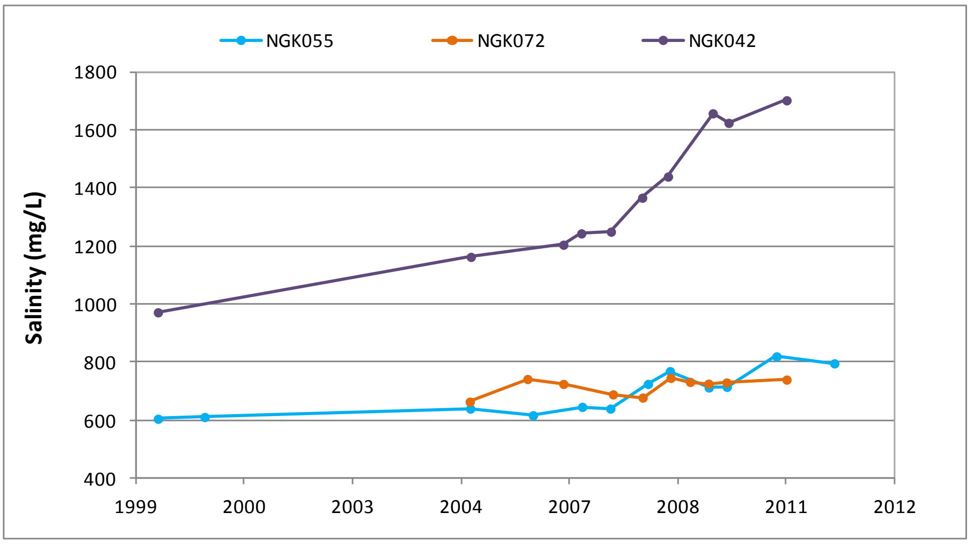

Figure 31. Salinity trends of the Murray Group Limestone aquifer monitored in the Currency Creek observation network

Quaternary

Groundwater levels of the unconfined Quaternary aquifer are monitored as part of the Currency Creek, Mobilong and Tungkilo networks. There is no significant extraction from the Quaternary aquifers at present. This is largely due to the salinity of the aquifer being between 7000 mg/L to 10 000 mg/L. As such, the salinity monitoring of the Quaternary aquifer is not undertaken in the majority of the Quaternary aquifer monitoring locations.