7. Murray–Darling Basin

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7. Murray–Darling Basin

7.1 Introduction

This chapter examines water resources in the Murray–Darling Basin region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level and also in more detail at sites for selected rivers, wetlands and aquifers. Information on water use is provided for selected urban centres and irrigation areas. The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a brief description of the region.

Understanding of surface water quality is important to sustainable water resources management; however, it could not be adequately addressed in this assessment. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.
1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

7.2 Key data and information

Figure 7-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the Murray–Darling Basin region. The year was wetter than average for the Murray–Darling Basin region (see Table 7-1) and resulted in above average landscape water yield. Evapotranspiration levels were close to the average level, which allowed soil moisture storage to increase across much of the region. Surface water storage volumes also rose substantially (by 12.4 per cent of accessible storage capacity) during the year providing much needed water for both agricultural and environmental purposes.

Table 7-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.
Table 7-1. Key information on water flows, stores and use in the Murray–Darling Basin region

<table>
<thead>
<tr>
<th>Landscape water balance</th>
<th>During 2009–10</th>
<th>During the past 30 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Region average</td>
<td>Difference from</td>
</tr>
<tr>
<td></td>
<td></td>
<td>long-term mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rank (out of 99)*</td>
</tr>
<tr>
<td>Rainfall</td>
<td>533 mm</td>
<td>+16%</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>428 mm</td>
<td>+2%</td>
</tr>
<tr>
<td>Landscape water yield</td>
<td>45 mm</td>
<td>+30%</td>
</tr>
</tbody>
</table>

Surface water storage (comprising approximately 95% of the region’s total surface water storage)

<table>
<thead>
<tr>
<th>Total accessible capacity</th>
<th>July 2009</th>
<th>June 2010</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total accessible volume</td>
<td>25,210 GL</td>
<td>5,057 GL</td>
<td>20.1%</td>
</tr>
<tr>
<td>% of accessible capacity</td>
<td>8,200 GL</td>
<td>32.5%</td>
<td>+12.4%</td>
</tr>
</tbody>
</table>

Measured streamflow in 2009–10

<table>
<thead>
<tr>
<th>Central-north rivers</th>
<th>Eastern rivers</th>
<th>Southern rivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above average to very much above average</td>
<td>Below average to very much below average</td>
<td>Below average to very much below average</td>
</tr>
</tbody>
</table>

Wetlands inflow patterns in 2009–10

<table>
<thead>
<tr>
<th>Currawinya lakes</th>
<th>Gwydir wetlands</th>
<th>Macquarie marshes</th>
<th>Barmah forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely high summer inflows</td>
<td>Predominantly below average</td>
<td>Predominantly below average</td>
<td>Predominantly below average</td>
</tr>
</tbody>
</table>

Urban water use (Canberra–Queanbeyan)

<table>
<thead>
<tr>
<th>Water supplied 2009–10</th>
<th>Trend in recent years</th>
<th>Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 GL</td>
<td>Steady (low relative to historical levels)</td>
<td>Continued Stage 3 restrictions</td>
</tr>
</tbody>
</table>

Annual irrigation water use in 2009–10 for the natural resource management regions

<table>
<thead>
<tr>
<th>Murrumbidgee</th>
<th>Murray</th>
<th>Goulburn Broken</th>
<th>North Central (Vic)</th>
<th>Border Rivers – Gwydir</th>
</tr>
</thead>
<tbody>
<tr>
<td>585 GL</td>
<td>318 GL</td>
<td>304 GL</td>
<td>363 GL</td>
<td>259 GL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Border Rivers – Maranoa Balonne</th>
<th>Namoi</th>
<th>SA Murray–Darling Basin</th>
<th>Mallee</th>
<th>Lachian</th>
<th>Central West (NSW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Border Rivers – Maranoa Balonne</td>
<td>244 GL</td>
<td>214 GL</td>
<td>288 GL</td>
<td>320 GL</td>
<td>142 GL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>117 GL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower Murray–Darling</th>
<th>Condamine</th>
<th>Western (NSW)</th>
<th>North East (Vic)</th>
<th>In the Wimmera</th>
<th>South West (Qld)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Murray–Darling</td>
<td>86 GL</td>
<td>166 GL</td>
<td>99 GL</td>
<td>28 GL</td>
<td>5 GL</td>
</tr>
</tbody>
</table>

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.
7.3 Description of region

The Murray–Darling Basin region covers more than one million km², one-seventh of mainland Australia, including parts of Queensland, New South Wales (NSW), Victoria and South Australia, and all of the Australian Capital Territory. The Murray–Darling Basin is named after its two major rivers, the River Murray, which drains water from inland areas of southern New South Wales and northern Victoria, and the Darling River, which drains inland southern Queensland and northern NSW. The River Murray and Darling River combine near Wentworth before discharging to the ocean via the Lower Lakes system in South Australia.

The Murray–Darling Basin region is bounded in the south and east by the Great Dividing Range. In the northwest and southwest, the boundaries are much less distinct, particularly in the Wimmera River catchment to the southwest and the border between the Paroo River catchment and the neighbouring Bulloo River catchment which is part of the Lake Eyre Basin region to the northwest. Both of these areas are of low topography and have internal drainage. Elsewhere, areas of low to medium altitude mark the region’s limits, including the Mount Lofty Ranges in the southwest, the Grey and Barrier Ranges in the west, and the Chesterton and Warrego Ranges in the north (Murray–Darling Basin Commission 2006).

The region has a great range of climatic conditions and natural environments, from the rainforests of the cool and humid eastern uplands, the temperate Mallee country of the southeast, the subtropical areas of the northeast, to the hot, dry semi-arid and arid lands of the far western plains.

Most of the region’s landscape is dominated by vast inland plains and large areas of undulating hills, mostly at 200 m above sea level or below. The largest plains are the Darling Plain in the north, drained by the Darling River and its tributaries, and the Riverine Plain in the south, drained by the Murray and Murrumbidgee rivers and their tributaries.

The Darling River (2,740 km), the River Murray (2,520 km) and the Murrumbidgee River (1,600 km) are the three longest rivers in Australia.

Monsoonal events in the north of the basin contribute to a portion of the flow from the north in the Darling River. Higher rainfall along the Great Dividing Range throughout NSW also contributes to flow in the Darling. The flow in the various rivers and tributaries of the River Murray originate from the rainfall run-off or from snowmelt in the south and southeast of the basin. This includes the headwaters of the Murray, Mitta Mitta, Kiewa, Ovens, Broken and Goulburn rivers in the Victorian Alps. The source of the Murrumbidgee River is the Snowy Mountains area of the Kosciusko National Park.

Streamflow volumes at reference sites in the basin are examined in Section 7.5.1.

It is estimated that there are more than 30,000 wetlands in the Murray–Darling Basin region, including 16 wetlands that are listed as internationally important under the Ramsar Convention on Wetlands. In addition, approximately 220 of the wetlands are listed in the Directory of Important Wetlands in Australia.
7.3 Description of region (continued)

Large wetland systems occur along the Darling River and its tributaries, including the Paroo Overflow lakes, Narran lakes, Gwydir wetlands, Macquarie marshes and the Great Cumbung Swamp. The Ramsar designated wetlands of the Lower lakes, Coorong and Murray mouth are at the terminus of the River Murray in South Australia and are important for the breeding and feeding of many species of waterbirds and native fish (Commonwealth Scientific and Industrial Research Organisation 2008). There are major floodplain forests along the River Murray including Barmah–Millewa, Gunbower, Koondrook–Perricoota, Chowilla and the Lindsay–Wallpolla islands. Many of these floodplain wetlands and forests were degraded and some suffered significant loss of area over recent decades due to changes and modifications in flooding regimes and land use (Commonwealth Scientific and Industrial Research Organisation 2008). Recent flows into a selection of wetlands are examined in Section 7.5.2.

The region has a population of over two million (Australian Bureau of Statistics 2010c), approximately ten per cent of Australia’s total population. The largest population centre is Canberra in the Murrumbidgee River basin. Other major centres with populations greater than 25,000 include Queanbeyan, Toowoomba, Bendigo, Albury-Wodonga, Wagga Wagga, Shepparton, Tamworth, Orange, Griffith, Dubbo, Mildura and Bathurst. The water supply to these areas is addressed in Section 7.6.

The Murray–Darling Basin Authority, in cooperation with state authorities, is the principal organisation responsible for integrated management of the water resources in the Murray–Darling Basin. Town centres in the region are supplied water from local systems operated by local or State Government organisations. Of the major urban centres, Canberra is served by a dedicated system of four storages while Toowoomba uses water that is imported from the North East Coast region.

Many of the regional water supply systems in the region supply water for both urban consumption and for irrigation. The River Murray system has a number of significant storages that are used for town water supply, irrigation and securing supply to South Australia and southern Victoria. A large portion of water consumed throughout South Australia is sourced from the Murray–Darling Basin region. In Adelaide, for instance, a major component of water consumed can be diverted from the River Murray.

There are 47 major storages in the region which have accessible storage capacity of more than 10 GL. The largest storages are Lake Eldon (accessible capacity of 3,200 GL) on the Goulburn River, and Lake Dartmouth (accessible capacity of 3,800 GL) and Lake Hume (accessible capacity of 3,000 GL) on the upper River Murray.

On the south eastern boundary of the region lies the Snowy Mountains Hydro-electric Scheme, one of the most complex integrated water and hydro-electric power schemes in the world. It provides a net transfer of water from the South East Coast (Victoria) region into the Murray–Darling Basin region. The scheme collects and stores water from the Snowy Mountains that would normally flow east to the coast and diverts it inland through trans-mountain tunnels and power stations to the Murray and Murrumbidgee rivers.

The mix of land use in the Murray–Darling Basin region is illustrated in Figure 7-2. Agriculture is the dominant economic activity in the region. Pasture, predominantly for livestock production, particularly dryland sheep and cattle production, accounts for 75 per cent of the land area of the basin. Important cropping activities include cereals (particularly wheat, barley and rice), oilseed, cotton, and horticulture (particularly citrus, stone and pome fruits, grapes and vegetables). Irrigated agriculture occupies a relatively small proportion of the region (two per cent) but is the major water user in the basin. More than half of all irrigation in Australia takes place in the region, which supports an agricultural industry worth more than $9 billion per annum (Australian Government Department of Sustainability, Environment, Water, Population and Communities 2011).

In 2005–06, it was estimated that the region contained 65 per cent of Australia’s irrigated land with a gross value of agricultural production of $15 billion (Australian Bureau of Statistics 2006). Pasture for dairying was traditionally the main irrigation industry in terms of water use. The largest irrigation areas are located in the Murrumbidgee, Murray, Lachlan, Goulburn, Broken, Loddon and Lower Murray basins to the south of the region, and the Condamine, Border, Gwydir, Namoi and Macquarie basins to the north of the region. Water supply to the Coleambally and Murrumbidgee irrigation districts in the Murrumbidgee basin is described in Section 7.7.
Figure 7-2. Key landscape and hydrological features of the Murray–Darling Basin region (land use classes based on Bureau of Rural Sciences 2006)
7.3 Description of region (continued)

As shown in Figure 7-3, the region is divided into three broad hydrogeological subdivisions (Murray–Darling Basin Commission 2008), namely:

- the basinal aquifers in sedimentary deposits (Murray Basin and Great Artesian Basin) within the flatter landscapes
- the fractured rock aquifers in areas where the basement rock outcrops
- valley-fill alluvium (including the Mid-Murrumbidgee and Upper Namoi) in the highlands bordering the basin.

The Great Artesian Basin is the largest groundwater basin in Australia and underlies the northern portion of the region. It consists of a complex, multi-layered system of water bearing sandstones separated by mostly shale and mudstone confining beds (Murray–Darling Basin Commission 2008). It underlies the sand and clay sequences of the Murray–Darling Basin region that were laid down over the past 50 million years. The Great Artesian Basin provides vital water resources for domestic and town water supply, for stock use by the pastoral industry and water supplies for the operations of the mining and petroleum industries and associated communities.

The sedimentary aquifers within the region cover the main depositional areas of the Murray Geological Basin and the Darling River basin, including upstream reaches of other major rivers such as the Murrumbidgee and Lachlan rivers. The major aquifers within or at the margins of the Murray Geological Basin include the Shepparton, Calivil, Parilla–Loxton Sands, Murray Limestone and Renmark Group aquifers, and the upland alluvium of the Cowra and Lachlan formations. The important alluvial sediments of the Darling River basin include the Gunnedah and Narrabri aquifers.

Fractured rock aquifers occur in the highland areas around the margins of the region. Generally, the groundwater in fractured rock aquifers exhibits a response in level consistent with changes in local climatic conditions (Murray–Darling Basin Commission 2008). In fractured rock aquifers, groundwater is stored in the fractures, joints, bedding planes and cavities of the rock mass. Although fractured rock aquifers are found over a large area, they hold a much lower groundwater volume than sedimentary aquifers. Due to the difficulty in obtaining high yields, the volume of groundwater extracted from any one bore and in a given area is relatively low.

Figure 7-4 shows the salinity of the watertable aquifer in the Murray–Darling Basin region as fresh (less than 3,000 mg/L) and saline (greater than 3,000 mg/L). Generally, the shallow groundwater in the flatter, lower altitude areas of the region is saline, while fresh groundwater resources occur at depth. Groundwater in the deeper sub-systems is typically fresher than the watertable. Watertable aquifer salinity levels have risen significantly since European settlement, following the clearing of native vegetation, irrigation development and the consequent increase in recharge to groundwater systems (Barnett et al. 2004).
Figure 7-3. Watertable aquifer groups in the Murray–Darling Basin region (Bureau of Meteorology 2011e)
Figure 7-4. Watertable salinity classes within the Murray–Darling Basin region (Bureau of Meteorology 2011e)
7.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 7-5 shows that for the Murray–Darling Basin (the Basin) region, 2009–10 started with much lower than the median rainfall in July and August 2009, followed by approximately median monthly rainfall up to November 2009. These relatively dry conditions were followed by a wetter than usual summer of 2009–10. The wetter than average summer was due in large part to the wetter than normal December 2009 in the northern part of the Basin, and February 2010, the wettest February averaged across the Basin since 1976. The above average rainfall was due to two significant rainfall events in the first half of February. The first major rainfall event was associated with ex-tropical cyclone Olga, which produced falls across the north western parts of the Basin in early February. Following this, on 13–14 February 2010 a major rain event produced large falls. March 2010 was also a wet month, largely due to a monsoonal low event, that resulted in high rainfall in the north of the region. February and March 2010 experienced their fourth and third highest monthly rainfall respectively in the long-term record (July 1911 to June 2010).

Monthly evapotranspiration was below normal levels between October and December 2009 as a result of the relatively dry start to the year. Following the very high rainfall events of December, February and March, higher than normal monthly totals were experienced until April 2010, as water availability no longer acted as a constraint to evapotranspiration, particularly across the wetter north of the region.

Modelled landscape water yield for the region is on average low throughout the year as a consequence of relatively high evapotranspiration losses relative to rainfall inputs, particularly during the generally wetter summer months. Landscape water yield for 2009–10 shows significant responses to the higher than normal rainfall in December 2009, February and March 2010. Modelled landscape water yield for March 2010 represents the record highest March total in the long-term record (July 1911 to June 2010).

![Figure 7-5. Monthly landscape water flows for the Murray–Darling Basin region in 2009–10 compared with the long-term record (July 1911 to June 2010)](image)
7.4.1 Rainfall

Rainfall for the Murray–Darling Basin region in 2009–10 was estimated to be 533 mm, which is 16 per cent above the region’s long-term (July 1911 to June 2010) average of 458 mm. Figure 7-6 (a) shows that during 2009–10, rainfall was highest in the alpine areas of the southeast of the region, but also relatively high in the central-east and northwest. Rainfall deciles for 2009–10, shown in Figure 7-6 (b), indicate annual rainfall was above average across much of the region, particularly in the north and west. Below average to very much below average rainfall was experienced in the northeast.

Figure 7-7 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual rainfall ranged from 305 mm (2002–03) to 615 mm (1988–89). The annual average for the period was 465 mm. The data show that 2009–10 was the first year since 2000–01 to experience annual rainfall above the 30-year average.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 7-7 (b). This graph shows annual rainfall for the region is roughly equally distributed between winter and summer. The moving average for winter in particular reflects the prolonged period of below average winter rainfall experienced since 2000–01. Summer rainfall has increased over recent years while winter rainfall has remained low.

![Maps of annual rainfall totals in 2009–10 and their decile rankings](image)
Figure 7-7. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the Murray–Darling Basin region.
7.4.1 Rainfall (continued)

Figure 7-8 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The summer period analysis shows generally increasing trends in rainfall across much of the region, particularly in the north. The winter period analysis highlights reductions in rainfall across almost the entire region with the strongest negative trends observed to the south and southeast.

Figure 7-8. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the Murray–Darling Basin region. The statistical significance of these trends is often very low.
7.4.2 Evapotranspiration

Evapotranspiration for the Murray–Darling Basin region for 2009–10 was estimated to be 428 mm, which is approximately equal to the region’s long-term (July 1911 to June 2010) average of 422 mm. Figure 7-9 (a) shows that during 2009–10, evapotranspiration across the region was closely related to the distribution of rainfall (see Figure 7-6 [a]). Highest values were in the southeast and east, decreasing to the southwest of the region. Evapotranspiration deciles for 2009–10, shown in Figure 7-9 (b), indicate above average values across much of the centre, west and far southeast of the region. Lower than average values are apparent in the northeast and also to the east and south.

Figure 7-10 (a) shows annual evapotranspiration for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 315 mm (1982–83) to 517 mm (1983–84). The annual average for the period was 423 mm.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 7-10 (b). Evapotranspiration over the region in summer is consistently higher than in the winter period. The moving average for summer reflects low average evapotranspiration between 2002–03 and 2006–07, which was constrained by low rainfall during these years.
Figure 7-10. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the Murray–Darling Basin region.
7.4.2 Evapotranspiration (continued)

Figure 7-11 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The summer period analysis shows some areas of increasing evapotranspiration across the northwest and centre of the region, with decreasing trends in the northeast and around the foothills of the Great Dividing Range in the southeast. The winter period analysis shows no particularly strong positive or negative trends in any part of the Basin.

Figure 7-11. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the Murray–Darling Basin region. The statistical significance of these trends is often very low.
7.4.3 Landscape water yield

Landscape water yield for the Murray–Darling Basin region for 2009–10 was estimated to be 45 mm, which was 30 per cent above the region’s long-term (July 1911 to June 2010) average of 35 mm. Figure 7-12 (a) shows water yield for 2009–10 was highest in the New South Wales and Victorian alps in the far southeast of the region. Relatively high levels of landscape water yield were also estimated to have occurred in the river basins of the central-east and northwest.

Landscape water yield deciles for 2009–10, shown in Figure 7-12 (b), indicate very much above average yield values across much of the centre and north of the region. Below average values occurred in the northeast and along much of the southeastern and southern boundaries of the region.

Figure 7-13 (a) shows annual landscape water yield for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 13 mm (2006–07) to 61 mm (1993–94). The annual average for the period was 37 mm. The high level of interannual variability in annual totals relative to the average reflects the sensitivity of the region’s landscape water yield to variations in both rainfall and evapotranspiration.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 7-13 (b). The graph shows that landscape water yield was estimated to be higher for winter than for summer until the early 1990s. Since 2002–03, landscape water yield has been a little higher for the summer period than in the winter. The moving average for summer also shows a clear increase at the end of the 30-year record.
Figure 7-13. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the Murray–Darling Basin region.
7.4.3 Landscape water yield (continued)

Figure 7-14 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The summer period shows only slight trends, both positive and negative, with the most apparent increasing trends in the north of the region. Decreasing trends are identified in the far southeast of the region, particularly at the top of the Murrumbidgee River basin in the New South Wales alpine areas near Canberra.

The winter period analysis shows strong negative trends in landscape water yield across the far southeast of the region. The reductions observed across the south-eastern areas are noticeably high relative to average winter landscape water yield over the 30-year period. This area represents the main streamflow generating headwater catchments of a number of important rivers in the region, including the Murray, Murrumbidgee, Kiewa, Ovens, Goulburn and Broken rivers.

Figure 7-14. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the Murray–Darling Basin region. The statistical significance of these trends is often very low.
7.5 Rivers, wetlands and groundwater

The 80 stream gauges with at least 30 years of records across 20 geographically representative river basins were selected for examination of regional streamflow in this report (see Figure 7-15). Streamflow at these gauges in 2009–10 was analysed in relation to the flow record. Additionally, seven gauges were selected for analysis of wetland river inflow for the region.

Groundwater use in the region is extensive. Total groundwater use in 2008–09 was 1,273 GL, which was more than 30 per cent of the surface water diversion in the region (Murray–Darling Basin Authority 2010). This level of use is reflected in the large number (95) of groundwater management areas in the region. The large number of groundwater management units were created to identify areas with significant groundwater resources and to provide a boundary within which resource management can be focused. Groundwater extraction and intensity of use in many units is controlled through a range of planning mechanisms. The Bureau’s Interim Groundwater Geodatabase contains information for 95 groundwater management units within the region.

Figure 7-16 shows some major groundwater management units within the region where total groundwater allocation is typically larger than 30 GL/yr. Groundwater management units in the Lower Murray–Darling Basin are also shown. The boundary and name of the Eastern Downs groundwater management unit in Queensland will be updated in the future but currently represents the groundwater management area in the Condamine valley.

The units selected for analysis represent fresh groundwater resources associated with:

- the Murray Group within the Murray Basin
- major alluvial/transitional sediments at the margin of the Murray Geological Basin or overlying the Great Artesian Basin
- alluvial-fill upland paleovalleys
- fractured rock basalt.

In other groundwater management units, except for the Great Artesian Basin, groundwater is often saline or of poor yield, and used for local stock and domestic water supply.

7.5.1 Streamflow and flood report

Figure 7-17 presents an analysis of river flows over 2009–10 relative to annual flows for the past 30 years at 80 monitoring sites throughout the Murray–Darling Basin region. Gauges are selected according to the criteria outlined in the Technical supplement. Annual river flows for the 2009–10 are colour-coded relative to their decile rank over the 1980 to 2010 period at each site.

With regard to total annual discharge in 2009–10, Figure 7-17 shows that observations from monitoring gauges across the south and east of the region reflect the below average to very much below average modelled landscape water yield results shown in Figure 7-12 (b). Very much above average modelled yields in the river basins of the northwest of the region, and in the Bogan River basin, are also reflected in gauge results in these areas. Above average modelled yields in lower parts of river basin areas in the centre and west of the region (Figure 7-12 [b]) do not contribute enough streamflow (in total volume) to significantly raise streamflow levels in these areas. The magnitude of streamflow at these rivers is largely determined by yields in upper catchment areas to the south and east, and to some extent by releases and spills from on-river storages. Figure 7-17 shows two dominant patterns:

- below average to very much below average streamflow in the southern and eastern rivers in the region
- above average to very much above average streamflow in the northern river basins including the Paroo, Warrego and Condamine–Culgoa river basins.

With regard to lower basin streamflow in the region in 2009–10:

- the lower Darling River recorded average streamflow, suggesting high flows in the northern river basins were largely averaging out their streamflow amounts of high flows in the northwest and low flows in the east
- streamflow in the lower River Murray upstream of the Darling River junction was very much below average, consistent with the below to very much below average upstream flow totals
- streamflow downstream of the River Murray and Darling River junction was very much below average despite the average inflow from the Darling River.
Figure 7-15. Stream gauges selected for analysis in the Murray–Darling Basin region.
Figure 7-16. Major groundwater management units in the Murray–Darling Basin region (Bureau of Meteorology 2011e)
7.5.1 Streamflow and flood report (continued)

Through flood monitoring partnership arrangements, data were available for a number of flood gauges allowing reporting on flood occurrence and severity at those sites. The 23 gauges selected as indicative stations for the Murray–Darling Basin region are situated on rivers in the Basin from the Condamine River in the north to the River Murray in the south (Table 7-2). The stations were also selected on the basis of data quality and coverage for the 2009–10 year.

In 2009–10, there was major flooding in many of the inland river valleys of New South Wales and Queensland. The first major flood event resulted from former tropical cyclone Laurence that tracked across the continent from Western Australia and developed into a slow moving low, which on Christmas Day 2009 was located on the New South Wales–Queensland border. Up to 200 to 300 mm of rain was recorded at official gauges, which caused significant overland flooding between Bourke and Brewarrina and in the lower Namoi Valley, and moderate flooding along the Paroo and Warrego rivers. Record major flooding occurred along the lower Culgoa River from heavy local rainfalls, with up to 480 mm being reported from unofficial gauges in the area. As the low moved further west another 60 to 130 mm of rain fell over the Castlereagh Valley, which resulted in major flooding at Coonamble.

Rainfall associated with ex-tropical cyclone Olga was recorded in a wide area across Queensland during the first ten days of February 2010. Moderate to heavy rainfall produced fast stream rises over already saturated catchments. Olga crossed the coast north of Cairns initially on 24 January 2010 and, once re-formed in the Gulf, crossed again around Normanton on 29 January. The system then weakened into a rain depression within hours of making landfall and tracked steadily southeast. By 3 February 2010, the system was located over the far northeast corner of South Australia. It then moved eastwards along the Queensland–New South Wales border and during this time produced areas of moderate to heavy rainfall and flooding in the Paroo, Warrego, Condamine and Balonne rivers. The former tropical cyclone reached southeast Queensland on 7 February 2010 then moved westward, producing more areas of moderate to heavy rainfall and flooding on already saturated catchments before finally exiting Queensland on 9 February 2010.

In March 2010, a low, which began in the Northern Territory, tracked eastward to southwest Queensland resulting in widespread rainfall across a large area of southern Queensland. This caused record major flooding in the Condamine–Balonne rivers as well as major flooding in the Warrego and Paroo rivers. The floodwaters from Queensland caused major flooding along the Culgoa, Bokhara, Birrie and Narran rivers in New South Wales, and the flows from the Paroo River reached the Darling River upstream of Wilcannia for the third time in the past 200 years.

7.5.2 Inflows to wetlands

This section looks at water flows into a selection of wetlands important to the Murray–Darling Basin region. Four internationally recognised Ramsar wetland sites across the region (Currawinya Lakes, Gwydir Wetlands, Macquarie Marshes and the Barmah Forest) were selected for examination.

Seven reference gauges were selected for analysis of the pattern of wetland inflows for the four wetlands (Figure 7-15.). Figure 7-18 presents a comparison of 2009–10 monthly flows with flow deciles over the 30-year period 1980–81 to 2009–10 for each of these gauges.

While streamflow observations from the seven selected reference gauges do not represent the total volume of freshwater inflows to the wetlands under study, the reference gauge discharges are assumed to be representative of the variation of actual freshwater inflows to the wetlands.
Figure 7-17 Annual and summer streamflow volumes (ML/day) for selected gauges for 2009–10 and their decile rankings over the 1980 to 2010 period in the Murray–Darling Basin region.
Table 7-2. Weekly flood classifications for key flood gauging sites within the region (flood classes are derived in consultation with emergency services and local agencies, the peak height for the year is also included)

<table>
<thead>
<tr>
<th>River Name</th>
<th>Jul-10</th>
<th>Aug-10</th>
<th>Sep-10</th>
<th>Oct-10</th>
<th>Nov-10</th>
<th>Dec-10</th>
<th>Jan-10</th>
<th>Feb-10</th>
<th>Mar-10</th>
<th>Apr-10</th>
<th>May-10</th>
<th>Jun-10</th>
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<td>Ginninderra River</td>
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Figure 7-18. Monthly discharge hydrographs for 2009–10 compared with the period of 1980 to 2010 for reference gauges on rivers flowing into selected wetland sites of the Murray–Darling Basin region.
7.5.2 Inflows to wetlands (continued)

With this in mind, the following may be observed with respect to water supply to these wetlands in 2009–10 relative to the 30-year record:

- In the arid northern part of the region, the Paroo River inflow to the Currawinya Lakes (gauge 1) experienced a very much above average late summer flow peak. In contrast, the 2009–10 winter flows were very low and closer to the 30-year average.
- For the Gwydir Wetlands on the Gwydir River in the northeast of the region (gauge 2), the normally high inflows during summer were below average to very much below average in 2009–10.
- Inflows to the Macquarie Marshes on the Macquarie River in the central north of the region (gauge 3) were below average in all months of 2009–10 except for February, when inflows were average.
- Inflows to the southern Barmah Forest wetlands from the River Murray (gauge 4) were generally below average or very much below average in most months of 2009–10 including the normally high inflow months during winter and spring.
- In the Edward River (gauge 5), feeding the Barmah Forest wetlands in the north, flows were mostly average over early summer but generally below average at other times.
- The Gulpa Creek (gauge 6) streamflow into the Barmah Forest wetlands was very much below average for most months of 2009–10 with only the three summer months of December 2009 to February 2010 experiencing average flows.
- The Broken Creek, a smaller inflow to the southern part of the Barmah Forest (gauge 7), showed below average to very much below average flows throughout 2009–10.

Figure 7-19 explores the pattern of changing wetland river inflows through the 30 years between 1980 and 2010. A five-year moving window was applied over daily streamflow data to produce the 10th, 50th and 90th flow percentiles for each of the seven reference gauges. The 10th, 50th and 90th flow percentiles were selected to approximate patterns of low, median and high flows, respectively. Low flows are associated with base level environmental inflow needed to ensure a minimum level of ecological function over the long-term. Median river flows sustain basic wetland hydrology and ecological function whereas high flows and extreme events are associated with wetland flooding and floodplain inundation, and are necessary for reproduction and recruitment of flora and fauna.

Note that any variability in the flow percentiles of Figure 7-19 can be a result of changing climatic conditions as well as human activity. However, the purpose of the graphs is not to analyse the cause of the variability and, in addition, the 10th percentiles (low flow) are sometimes estimated to be 0 ML/day and therefore are shown as the minimum plotted value for a gauge in Figure 7-19.

With respect to the 30-year period, Figure 7-19 indicates:

- The ephemeral Paroo River had variable median and high inflows to the Currawinya Lakes, with substantial periods of negligible flow over the 30-year record (gauge 1).
- Low, median and high inflows into the Gwydir Wetlands and Macquarie Marshes (gauges 2 and 3) show a cyclic pattern with a decline over the 30-year period.
- The especially high flows of the River Murray upstream of the Barmah Forest wetland (gauge 4) show a slight decline in volume over the 30-year record, suggesting that less frequent flooding occurs and flood volumes decrease.
- High, median and low flows in the Edward River (gauge 5) were steady for most of the 30-year period, with low flows dropping substantially in volume in the mid-1990s and remaining at relatively low levels thereafter.
- Gulpa Creek (gauge 6) displayed little variation in the pattern of low, median and high flows into the Barmah Forest wetland over the 30-year record, with only a slight, but steady decline in flow volumes after 1993.
- Low, median and high flows into the Barmah Forest wetlands from the Broken Creek (gauge 7) all increased in the late 1980s and early 1990s but then progressively declined to historically low levels by the end of the 30 year period.
Figure 7-19. Daily flow percentiles extracted from a five-year moving window at reference gauges on rivers flowing into selected wetland sites of the Murray–Darling Basin region.
Figure 7-20. Groundwater aquifer subsystems in the Murray–Darling Basin region
7.5.3 Groundwater status

The status of groundwater levels in the Murray–Darling Basin region is evaluated for the most productive aquifers associated with major groundwater management units (Figure 7-20). Status is assessed by estimating trends in groundwater levels from 2005 to 2010. This period follows the Murray–Darling Basin Commission Groundwater Status Report for the period of 2000–05 (Murray–Darling Basin Commission 2008).

The trends in groundwater levels from 2005–10 are evaluated in the following way using a 20 km grid across an aquifer:

- a linear trend in groundwater levels is evaluated for each bore with at least 20 level measurements since 2005
- the linear trend in groundwater levels for a 20 km grid cell is assessed as:
  - decreasing (where more than 60 per cent of the bores have a negative trend in levels lower than -0.1 m/year)
  - stable (where the trend is lower than 0.1 m/year and higher than -0.1 m/year for more than 60 per cent of the bores)
  - increasing (where more than 60 per cent of the bores have a positive trend in levels higher than 0.1 m/year)
  - variable (where there is no dominant trend in groundwater levels amongst the bores within a 20 km grid cell).

Bore data used in this assessment are derived from New South Wales, Queensland and South Australia; Victorian data were not ready for inclusion in this report. Example bore hydrographs are presented for each aquifer over the 1990–2010 period and trends are discussed with a focus on the 2005–10 period. Where possible, the bore hydrographs presented are for the same bores used in the Groundwater Status Report 2000–05 (Murray–Darling Basin Commission 2006).

Condamine Alluvium Subsystem

The map in Figure 7-21 illustrates the spatial and temporal trends in groundwater levels in the Condamine Alluvium Subsystem from 2005–10. Many of the 20 km grid cells are shown as ‘variable’ indicating that, within a grid cell, no clear majority of bores has a specific trend. In other cells, groundwater levels are declining or stable.

Selected bores 1, 2 and 4 show a linear decline in groundwater levels over the 2005–10 period. Groundwater salinity data are not available for many bores in the Condamine, but for bore 2 electric conductivity values are less than 1,000 μS/cm (approximately 600 mg/L) and are relatively constant. The fluctuations in water level observed in bore 3 are likely to be caused by groundwater extraction in nearby bores. Bore 6 shows an upward trend in water level observed in areas near the upper tributaries of the Condamine River.

Narrabri and Gunnedah Subsystems

Figure 7-22 illustrates the spatial and temporal trends in the Narrabri Subsystem and the associated underlying Gunnedah Subsystem. The water levels in bores within Narrabri Subsystem are generally falling, with some areas showing variable or stable levels within the 20 km grid cells from 2005–10.

Bore 1 is located in the upper reaches of the Border Rivers groundwater management unit in Queensland. The hydrograph indicates a drop in groundwater level of about 30m since 1990 and high annual fluctuations in the groundwater level that may be caused by nearby groundwater extractions. Bore 2 is located in the Lower Namoi groundwater management unit. The hydrograph shows that water levels in 2005–10 continued their gradual long-term decline. Bore 3 is located in the Cox’s Creek region of the Upper Namoi groundwater management unit. The groundwater levels show a very gradual rate of decline with little annual fluctuation indicating that the bore is remote from the influence of groundwater extraction. Bore 4 is located in the Gwydir catchment and shows a very stable water level over the measurement period.

The groundwater levels in the more permeable Gunnedah Subsystem, like the Narrabri, indicate a declining trend overall. There are a small number of cells that show stable or increasing trends in water levels.

Bore 1 is located in the Lower Namoi groundwater management unit and shows a slight increase in the water level, but is generally stable. Bore 2 is located at the western margin of the Lower Namoi groundwater management unit and is stable. Bore 3 and 4 are at the eastern (upstream) end of the Lower Namoi groundwater management unit and are located in an area of groundwater extraction. Both show a decline in the groundwater level and possible interference from local groundwater extraction.
Figure 7-21. Spatial distribution of trends in groundwater levels for the Condamine Alluvium Subsystem for 2005–10, with selected hydrographs showing groundwater levels (blue line) and salinity (red dots)
Figure 7-22. Spatial distribution of trends in groundwater levels for the Narrabri and Gunnedah Subsystems for 2005–10, with selected hydrographs showing groundwater levels (blue line) and salinity (red dots).
7.5.3 Groundwater status (continued)

Cowra and Lachlan Subsystems

Figure 7-23 illustrates the spatial and temporal trends in the Cowra and the underlying Lachlan Subsystems. Generally the Cowra and Lachlan Subsystems show declining levels, with a few cells in the Cowra Subsystem indicating variable trends in water levels for 2005–10.

Bores 1a, 2a and 3a represent groundwater levels in the Cowra Subsystem while bores 1b, 2b and 3b represent groundwater levels in the Lachlan Subsystem. These bores are nested and the hydrographs indicate hydraulic connection between the Lachlan and overlying Cowra Subsystem. Annual variations in groundwater level in the deeper Lachlan Subsystem are most likely due to the effects of groundwater extraction from this aquifer. In the mid-Murrumbidgee (bores 1 and 2), a steady decline in groundwater levels is noticeable from 1994 onwards. The single bore hydrograph in the Lachlan valley (bore 3) suggests that a decline in levels begins around the year 2000.

Shepparton Subsystem

Generally the water level fluctuation for the Shepparton Subsystem over the past five years shows declining levels. Bore levels most likely respond to groundwater extraction in the main groundwater management units as well as to comparatively low rainfall.

Hydrographs of two bores located within the Shepparton Subsystem are presented in Figure 7-24. Bore 1 is located southwest of Deniliquin in the Lower Murrumbidgee groundwater management unit of New South Wales. The hydrograph indicates an increasing water level overall, with a slight decline in levels since 2007. Bore 2 is located west of Griffith in the Lower Murrumbidgee groundwater management unit of New South Wales. The water level trends over 2005–10 indicate a decline, which appears to be increasing over the period. This decline is consistent with a response to pumping in the Lower Murray groundwater management unit further to the east. Bore 3 is located near Deniliquin in the Lower Murray groundwater management unit of New South Wales. The hydrograph shows considerable fluctuation in groundwater levels due to drawdown associated with groundwater extraction during the irrigation season and subsequent recovery when the extraction ceases in winter. There is a falling trend in groundwater level from the mid-1990s.

Calivil Subsystem

The trend analysis indicates that groundwater levels within the Calivil Subsystem are predominantly decreasing. This decline is likely to be the result of groundwater extraction in groundwater management units and comparatively low rainfall (and associated low groundwater recharge) over the period.

Hydrographs of groundwater levels in three bores located near the southern and western margins of the Calivil Subsystem are presented in Figure 7-24. Bore 1 is located at the western (downstream) end of the Lower Murrumbidgee groundwater management unit. The hydrograph shows relatively stable groundwater levels since 1990. Bore 2 is located on the River Murray, north of Barham in New South Wales. The water level trends over 2005–10 indicate a decline, which appears to be increasing over the period. This decline is consistent with a response to pumping in the Lower Murray groundwater management unit further to the east. Bore 3 is located near Deniliquin in the Lower Murray groundwater management unit of New South Wales. The hydrograph shows considerable fluctuation in groundwater levels due to drawdown associated with groundwater extraction during the irrigation season and subsequent recovery when the extraction ceases in winter. There is a falling trend in groundwater level from the mid-1990s.

Murray Group Subsystem

The groundwater levels mostly decreased within the Murray Group from 2005–10 (using monitoring bore data in South Australia only and including data from bores outside the Murray–Darling Basin region). This is clearly illustrated in Figure 7-25.

Bore 1 shows a high annual fluctuation in the water levels due to pumping at nearby wells and has a declining water level overall. Bores 2 and 4 are outside the region and the groundwater level is shallow and declining with fluctuations due to the effects of pumping. Bore 3 located east of Murray Bridge indicates a stable water level for 1990–2010.

Renmark Subsystem

The spatial and temporal trends in the Renmark Subsystem are also shown in Figure 7-25, which indicate that the water levels in the Renmark Subsystem over the past five years are mainly declining. The groundwater bores that are used in this analysis are relatively evenly distributed in the east with usually only one bore per reference cell.

The hydrograph of bore 1 shows slightly decreasing groundwater levels from 1990 onwards. Bore 2 is located in the centre of groundwater pumping influences of the Lower Murrumbidgee groundwater management unit. The groundwater water level data is available up to 2007. During the period of 2005–07, the levels responded dramatically to the seasonal groundwater extraction cycle. There is also a declining trend in groundwater levels since the mid-1990s.
Figure 7-23. Spatial distribution of trends in groundwater levels for the Cowra and Lachlan Subsystems for 2005–10, with selected hydrographs showing groundwater levels.
Figure 7-24. Spatial distribution of trends in groundwater levels for the Shepparton and Calivil Subsystems for 2005–10, with selected hydrographs showing groundwater levels.
Figure 7-25. Spatial distribution of trends in groundwater levels for the Murray Group Subsystem and for the Renmark Subsystem for the 2005–10 period, with selected hydrographs showing groundwater levels.
### 7.6 Water for cities and towns

The main urban centres of the Murray–Darling Basin region are sparsely distributed throughout the region, with most centres located on the western slopes of the Great Dividing Range and along the River Murray as shown in Figure 7-26. The major cities and towns of the region (those with a population greater than 25,000) are shown in Table 7-3 together with the river basin in which they are located and their main urban water supply sources.

The Canberra and Queanbeyan conurbation is the largest urban centre in the region. The Corin and Googong reservoirs represent 93 per cent of the total storage capacity for this centre. Figure 7-26 shows the accessible storage in the Corin and Googong reservoirs from 1980 to 2010 and during 2009–10.

### Table 7-3. Cities and their water supply sources in the Murray–Darling Basin region

<table>
<thead>
<tr>
<th>City/town</th>
<th>Population*</th>
<th>River basin</th>
<th>Major supply sources</th>
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</thead>
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<tr>
<td>Canberra</td>
<td>350,000</td>
<td>Murrumbidgee</td>
<td>Cotter, Bendora and Googong reservoirs and Murrumbidgee River</td>
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<td>Toowoomba</td>
<td>128,000</td>
<td>Condamine–Culgoa</td>
<td>Cooby Creek, Cressbrook and Perseverance reservoirs</td>
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<td>Albury–Wodonga</td>
<td>100,000</td>
<td>Murray–Riverina and Kiewa</td>
<td>River Murray</td>
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<td>Bendigo</td>
<td>89,000</td>
<td>Loddon</td>
<td>Lake Eppalock and Malmmsbury and Upper Coliban reservoirs</td>
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<td>Wagga Wagga</td>
<td>58,000</td>
<td>Murrumbidgee</td>
<td>Murrumbidgee River and groundwater</td>
</tr>
<tr>
<td>Queanbeyan</td>
<td>51,000</td>
<td>Murrumbidgee</td>
<td>Cotter, Bendora and Googong reservoirs and Murrumbidgee River</td>
</tr>
<tr>
<td>Mildura</td>
<td>50,000</td>
<td>Mallee</td>
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<td>Goulburn–Broken</td>
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<td>25,700</td>
<td>Murrumbidgee River</td>
<td>Murrumbidgee River via irrigation canals</td>
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</tbody>
</table>

* Australian Bureau of Statistics (2010b)
Figure 7-26. Urban areas and supply storages in the Murray–Darling Basin region
7.6.1 Canberra and Queanbeyan

The Canberra and Queanbeyan water supply area is located 150 km inland to the east of the nearby Brindabella Ranges. The area has a population of over 400,000 (Australian Bureau of Statistics 2010b).

Urban water infrastructure and management in Canberra and Queanbeyan

ACTEW Corporation is the ACT Government-owned statutory body that owns and manages the Canberra water supply system. ACTEW controls surface water diversions, operates water treatment plants, maintains Canberra’s reticulation system and delivers water to Queanbeyan where the infrastructure is managed and maintained by Queanbeyan City Council.

Figure 7-28 illustrates the major components of the Canberra and Queanbeyan urban water supply system. The key components of the system are four water storages, two water treatment plants and four wastewater treatment plants. Water is sourced from three catchments: the Cotter River catchment, the Murrumbidgee River catchment and the Queanbeyan River catchment.

Canberra and Queanbeyan (Corin) *

The Mount Stromlo water treatment plant receives water from the Corin, Bendora and Cotter reservoirs, all located on the Cotter River, as well as water from the Murrumbidgee River at the Cotter pump station. Water taken from Googong Reservoir receives treatment at the Googong water treatment plant. Excess treated water can be released into the Googong Reservoir for storage (ACTEW 2007).

Intense bushfires in the Cotter River catchment in January 2003 resulted in poor water quality in the Cotter River system, requiring the Mount Stromlo water treatment plant to be upgraded to ensure adequate treatment whilst the Cotter catchment recovered. The upgraded plant was commissioned in 2004.

In 2005 and 2006, bathymetric surveys were conducted on the four water storages. As a result, the total accessible storage capacity of the system was down-rated from 215 GL to 212 GL (ACTEW 2007).

Canberra and Queanbeyan (Googong) *

* Note that the percentage of accessible capacity was calculated using the 2010 total accessible capacity. It ignores the transitional change of accessible volume, which reduced the capacity of both storages. The capacity of Googong Reservoir had a phased change from 1975 to 2006, while the Corin Reservoir capacity had a phased change from 2003 to 2006. These changes cause the percentage of capacity shown to exceed 100 per cent prior to 2006. The total volume can also exceed 100 per cent capacity during periods of high inflow.

Figure 7-27. Variation in the amount of water held in storage over recent years (light blue) and over 2009–10 (dark blue) for Canberra and Queanbeyan
Figure 7-28. Water supply schematic for Canberra and Queanbeyan.
7.6.1 Canberra and Queanbeyan (continued)

In order to secure water resources for Canberra and Queanbeyan’s future, two main projects are in progress. The most significant is the enlargement of the Cotter Reservoir from 3.9 GL to 78 GL total accessible storage capacity. Construction of the new dam wall commenced in late 2009 (ACTEW 2011). The second project is a 13 km underground pipeline that will transfer water from the Murrumbidgee River at Angle Crossing to Burra Creek, where it will flow into the Googong Reservoir. Construction on the pipeline commenced in January 2011 (ACTEW 2011).

The Lower Molonglo Water Quality Control Centre is the largest wastewater treatment plant in Canberra. The plant treats more than 90 ML/day of wastewater before discharging it to the Molonglo River or providing it for irrigation purposes at nearby vineyards and golf courses. The Fyshwick wastewater treatment plant collects and treats industrial and domestic sewage from Fyshwick and surrounding suburbs. Treated wastewater from this plant is then discharged back into the sewer or delivered to the North Canberra Water Reuse Facility where it undergoes secondary treatment before it is used for irrigation purposes. A sewer mining facility at Southwell Park also supplies recycled wastewater for irrigation purposes. Wastewater treated at the Queanbeyan sewage treatment plant is discharged to the Molonglo River with only a small fraction used for on-site irrigation purposes.

Surface storage levels and volumes in recent years

Figure 7-29 shows the combined accessible storage volume of the Corin and Googong reservoirs between 1980 and 2010 and for 2009–10. The Corin and Googong reservoirs have a combined accessible storage of 190 GL, which constitutes 93 per cent of Canberra and Queanbeyan’s total system accessible storage. The accessible storage volumes of individual reservoirs are given in Figure 7-27.
7.6.1 Canberra and Queanbeyan (continued)

Throughout much of the 1980s and 1990s the combined storage of the Corin and Googong reservoirs remained above 80 per cent of capacity, with only a few significant draw-downs due to low rainfall in isolated years. In contrast, the combined storage volume was greatly reduced in the 2000s due to prevailing drought conditions. As a result, the combined storage volume of the Corin and Googong reservoirs has been below 80 per cent since January 2002, rarely exceeding 60 per cent of the combined accessible storage capacity.

Two significant draw-downs in the 2000s can be observed in Figure 7-29 (top). The first occurred during the 2001–03 period and the second from the start of 2006 to mid-2007. Both were a result of El Niño events causing exceptionally warm and dry weather during a period of prolonged low rainfall conditions from 2002–09. As a result of the draw-down in 2006, the combined water storage volume dropped to just above 25 per cent in early 2007.

Figure 7-29 (bottom) shows that the combined storage volume of the Corin and Googong reservoirs increased by 12 per cent over 2009–10. This increase was assisted by significant snow melt in spring 2009 and two major rainfall events in the summer of 2009–10.

Water restrictions in recent years

ACTEW manages decisions about water restrictions for the ACT, with Queanbeyan City Council applying the same decisions for Queanbeyan residents. Restrictions imposed in Canberra and Queanbeyan from 1999–2010 are shown against combined storage volumes in Figure 7-30. The different stages of the restrictions are defined in the Utilities (Water Conservation) Regulation 2006 under the ACT’s Utilities Act 2000.

![Graph showing urban water restriction levels for the ACT since 1999 against combined accessible water volume of Googong and Corin reservoirs](image)

Figure 7-30. Urban water restriction levels for the ACT since 1999 shown against the combined accessible water volume of Googong and Corin reservoirs
7.6.1 Canberra and Queanbeyan (continued)

Until November 2002, Canberra had not experienced water restrictions since 1969 when the population of the ACT was approximately 120,000 (Commonwealth Bureau of Census and Statistics 1969). The ACT’s population grew to an estimated 321,800 (Australian Bureau of Statistics 2002) by November 2002 and the onset of drought caused water storage volumes to diminish significantly. Voluntary Stage 1 water restrictions were introduced in November 2002 but were quickly replaced by mandatory Stage 1 water restrictions when storage volumes dropped below 55 per cent capacity. In October 2003, several factors including climatic conditions, consumption patterns, low storage volumes and bushfires resulted in the introduction of Stage 3 water restrictions, surpassing Stage 2 (ACTEW 2003). Restrictions were relaxed to Stage 2 in March 2005 and in November that year a four-month trial of Stage 1 water conservation measures was introduced.

Permanent Water Conservation Measures were introduced in March 2006 and approximately 18 per cent savings were achieved during the four-month trial (ACTEW 2006). The Permanent Water Conservation Measures include basic water saving practices that are designed to remain in place when water restrictions are not required.

Stage 2 water restrictions were introduced in November 2006 due to extremely low storage inflows. They were quickly moved to Stage 3 restrictions in December 2006 as warm and dry weather conditions persisted. Stage 4 restrictions were nearly implemented in May 2007. Stage 3 water restrictions continued for the rest of 2009–10.

Source and supply of urban water in recent years

Water supplied to Canberra and Queanbeyan comes from surface water and recycled water. Figure 7-31 (National Water Commission 2011a) shows the total water supplied from both sources for 2005–06 to 2009–10. During the past five years, the greatest volume sourced for Canberra and Queanbeyan’s water supply was in 2005–06. During that year, Stage 2 water restrictions were replaced with Permanent Water Conservation Measures.

During 2006–07 and 2007–08, the volume of water supplied decreased as a result of Stage 2 and Stage 3 water restrictions being introduced. Stage 3 water restrictions remained in place until the end of 2009–10, which resulted in a relatively constant volume of water being sourced.

![Figure 7-31. Total urban water sourced for Canberra and Queanbeyan from 2005–06 to 2009–10](image-url)
7.6.1 Canberra and Queanbeyan (continued)

The use of recycled water increased over the period shown in Figure 7-31, being supplied primarily for commercial, municipal and industrial uses. Recycled water use doubled from 2.1 GL in 2005–06 to 4.2 GL in 2009–10.

Figure 7-32 (National Water Commission 2011a) shows the total volume of water delivered between 2002–03 and 2009–10 to residential, commercial, municipal and industrial customers in Canberra only. Queanbeyan consumption data were not available at the time of publication of this report. The figure shows that water consumption dropped in the eight-year period, although the population grew steadily.

The consumption pattern is a response to the water restrictions outlined above. In 2002–03, when Stage 1 water restrictions were in place, the Canberra consumption was 60 GL. During 2003–04, Stage 3 water restrictions were introduced and consumption dropped approximately 20 per cent to 48 GL. When restrictions were eased and replaced by Permanent Water Conservation Measures in 2005–06, the consumption increased approximately nine per cent, but returned to 48 GL during 2006–07, when Stage 2 followed by Stage 3 water restrictions were introduced. Stage 3 water restrictions continued through to 2009–10 and Canberra’s water consumption remained steady at approximately 41 GL.

The proportion of water use per sector remained steady during 2002–03 to 2009–10. Residential water consumption was approximately 65 per cent; commercial, municipal and industrial sector use approximately 25 per cent and the remaining water supplied for other uses.

Canberra and Queanbeyan’s per capita water use decreased significantly between 2002–03 and 2009–10. In 2002–03, the unrestricted water consumption was 461 litres/person/day (L/p/d), which decreased to 360 L/p/d by 2004–05 due to the introduction of water restrictions. The easing of water restrictions meant consumption increased to 386 L/p/d in 2005–06. From 2005–06 to 2009–10, water restrictions and increasing awareness of water conservation caused consumption to reduce from 349 to 288 L/p/d.
7.7 Water for agriculture

Agriculture is the dominant economic activity in the Murray–Darling Basin region. Land uses related to agriculture comprise nearly 80 per cent of the area of the region. Cropping is mostly rain-fed and includes cereals, oilseed, cotton, horticulture and vegetables. Although irrigated agriculture covers less than two per cent of the basin, it uses a considerable amount of water. Increasing groundwater use in the region is primarily due to the expansion of irrigated agriculture combined with prolonged periods of drought.

7.7.1 Soil moisture

Upper soil moisture content during the summer (November–April) of 2009–10 was above average to very much above average in most dryland agricultural areas in the region in response to average or above average rainfall from December 2009 to April 2010. Below average upper soil moisture conditions were modelled in parts in the east of the region, however, particularly in the Gwydir River basin (Figure 7-33).

Upper soil moisture content for winter (May–October) of 2010 was above average to very much above average for most dryland agricultural areas of the region, particularly in central and northern river basins (Figure 7-33). Dryland agricultural areas in the far south of the region were estimated to have average upper soil moisture conditions.

7.7.2 Irrigation areas

The largest irrigation areas in the Murray–Darling Basin region are located in the Murrumbidgee, Murray, Lachlan, Goulburn, Broken, Loddon and Lower Murray basins in the south of the region, and the Condamine, Border, Gwydir, Namoi and Macquarie river basins to the north of the region (Figure 7-34).

A comparison of annual irrigation water use (from surface and groundwater) across the Murray–Darling Basin from 2005–06 to 2009–10 is shown in Figure 7-35 and Figure 7-36 by natural resource management region. Data were sourced from the Water Use of Australian Farms reports (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011).

The figures also indicate that the average water use for 2005–10 was highest in the Murrumbidgee River basin, which contains the Murrumbidgee and Coleambally irrigation areas. Water resource conditions and use in the Coleambally and Murrumbidgee irrigation areas in the Murrumbidgee River basin are considered in more detail in Sections 7.7.3 and 7.7.4.

Figure 7-33. Deciles rankings over the 1911–2010 period for modelled soil moisture in the winter (May–October) and summer (November–April) of 2009–10 for the Murray–Darling Basin region
Figure 7-34. Context map of irrigation areas and infrastructure in the Murray–Darling Basin region
Figure 7.35. Average annual irrigation water use per natural resource management region for 2005–06 to 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)
7.7.3 Murrumbidgee River basin

Overview of the region

The Murrumbidgee River basin has a diverse climate and distinct physical characteristics. The basin is an 84,000 km² area, about 17 per cent of which is covered by native vegetation. Land use varies from sheep and cattle grazing, conservation reserves and residential areas in the upper catchment to irrigated agriculture, horticulture, dryland cropping, grazing and forestry in mid to lower areas of the catchment. Some important sites of international ecological significance are located in the Murrumbidgee River basin, including the Fivebough and Tuckerbil swamps and the Lowbidgee wetlands. The Murrumbidgee River basin is one of the most densely populated regions in rural Australia – over 520,000 people with a growth rate of 1.5 per cent per annum (CRC for Catchment Hydrology 2004).

The region uses over 22 per cent of the total surface water diverted for irrigation and urban use in the Murray–Darling Basin region. Over 24 per cent of the groundwater use in the region occurs in the Murrumbidgee River basin. The irrigation industry provides 25 per cent of fruit and vegetable production in New South Wales, 42 per cent of the State’s grape production, and half of Australia’s rice production (Murrumbidgee Catchment Management Authority 2010).

Water supply

The region’s rivers are regulated by multiple storages including those of the Snowy Mountains Hydro-electric Scheme, the ACT Water Supply System and the major New South Wales irrigation storages of Blowering (on the Tumut River) and Burrinjuck (on the Murrumbidgee River). Most of the groundwater is extracted from alluvial aquifers in the central Murrumbidgee and lower Murrumbidgee groundwater management units (Commonwealth Scientific and Industrial Research Organisation 2008).

Figure 7-37. Coleambally and Murrumbidgee irrigation areas in the Murrumbidgee catchment
7.7.3 Murrumbidgee River basin (continued)

The Murrumbidgee and Coleambally irrigation areas in the lower Murrumbidgee catchment are the two most important irrigation areas in the region (Figure 7-37). The management of water in the two districts was privatised in the late 1990s. They are supplied with water from Burrinjuck and Blowering reservoirs through more than 10,000 km of irrigation channels. Burrinjuck Reservoir has a catchment area of about 13,000 km² with a total accessible capacity of 1,023 GL. Blowering Reservoir has an accessible storage capacity of 1,600 GL and catchment area of 1,600 km².

As a result of persistent drought, surface water diversions within the Murrumbidgee River basin declined substantially from a peak of around 2,600 GL in 1996–97 to 450 GL in 2007–08 (Figure 7-38). In 2009–10, the inflows to the Burrinjuck and Blowering reservoirs were the lowest on record and the storages were at less than half of their full capacity (Figure 7-39, Figure 7-40 and Figure 7-41). Diversions over the whole of the river basin in 2009–10, however, were higher than in the previous two years and close to 2006–07 levels (Figure 7-38).

Irrigation water management

Water Sharing Plans define water sharing arrangements between the environment and water users in the regulated Murrumbidgee River basin. There are a number of categories of water licences, which are assigned different priorities based on the intended use of water (New South Wales Office of Water 2011). An Available Water Determination (AWD) is set at the start of each financial year in terms of megalitres per share. The total number of shares held by a licence holder multiplied by the ML/share announced gives the volume of water credited to that licensee’s account, in addition to carry over provisions.

Figure 7-38. Surface water use in Murrumbidgee (from Murray–Darling Basin Commission Water Audit Reports 1996 to 2009), with the dashed line showing the overall trend in total diversions
7.7.3 Murrumbidgee River basin (continued)

The majority of the water entitlements held within the Murrumbidgee River basin are general security entitlements. Priority is given to high security entitlements primarily used for horticultural and grape production. Annual water availability has a significant influence on the volume of water used for summer and winter crop production.

Table 7-4 lists licence category priorities and share components in the regulated Murrumbidgee River determined on 30 June 2010 (NSW Office of Water 2011). Water was actively traded both within the river basin and with the neighbouring River Murray region.

Table 7-4. Murrumbidgee Regulated River share components determined on 30 June 2010

<table>
<thead>
<tr>
<th>Access licence category</th>
<th>AWD priority</th>
<th>Total share component (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Security</td>
<td>Low</td>
<td>1,888,070</td>
</tr>
<tr>
<td>High Security</td>
<td>High</td>
<td>377,435</td>
</tr>
<tr>
<td>Murrumbidgee Irrigation Conveyance</td>
<td>Low</td>
<td>243,000</td>
</tr>
<tr>
<td>Coleambally Irrigation Conveyance</td>
<td>Low</td>
<td>130,000</td>
</tr>
<tr>
<td>Regulated River Conveyance</td>
<td>Low</td>
<td>2,968</td>
</tr>
<tr>
<td>Supplementary</td>
<td>Lowest</td>
<td>198,779</td>
</tr>
<tr>
<td>Domestic and Stock</td>
<td>Very high</td>
<td>35,939</td>
</tr>
<tr>
<td>Local Water Utility</td>
<td>Very high</td>
<td>23,586</td>
</tr>
</tbody>
</table>

Figure 7-39. Monthly discharge hydrographs compared to discharge deciles at reference gauges for inflows to the Burrinjuck and Blowering reservoirs
Figure 7-40. Water storage volumes available for irrigation at the Burrinjuck Reservoir since 1980 (top) and during 2009–10 (bottom).

Figure 7-41. Water storage volumes available for irrigation at the Blowering Reservoir since 1980 (top) and during 2009–10 (bottom).
7.7.4 Murrumbidgee and Coleambally Irrigation Areas

The Murrumbidgee Irrigation Area occupies an area of approximately 3,620 km². It covers around 160,000 ha of intensive irrigation and 3,320 ha of landholdings. The area is located on the northern side of the Murrumbidgee River, between Leeton and Griffith and is fed by two canals receiving diverted water from the Murrumbidgee River: the Main Canal and the Sturt Canal.

The Main Canal receives water diverted at Berembed Weir to serve the Yanco, Leeton and Griffith areas and can accommodate flows of up to 6,500 ML/day. The Sturt Canal receives water diverted at Gogeldrie Weir to supply the Whitton and Benerembah areas and can accommodate flows of up to 1,700 ML/day.

River diversions for the 2009–10 irrigation season were 505,000 ML of which 368,000 ML was delivered to irrigators (Murrumbidgee Irrigation Ltd 2010). Total irrigated area in 2009–10 was 79,000 ha of which 28,000 ha was allocated to winter crops, 29,000 ha to horticultural crops and 8,000 ha to rice.

The Coleambally Irrigation District is located between Darlington Point and Jerilderie. The Coleambally Irrigation Co-operative Limited is the provider of water to the area, which contains 79,000 ha of irrigated land. Water is sourced from the Murrumbidgee River which is diverted into the Coleambally Main Canal upstream of Gogeldrie Weir, near Darlington Point. Water supplies are regulated from two major Snowy River Scheme storages: Burrinjuck and Blowering. The supply system is gravity fed and consists of 41 km of canal from the Murrumbidgee River, 477 km of supply channels and a further 734 km of drainage channels.

In 2009–10, total water diversion into the area was 157,700 ML out of which 39,800 ML was channel losses and 117,900 ML was delivered to irrigators. The general security allocation was 27 per cent. Groundwater usage was 96,700 ML. The total irrigated crop area was 46,400 ha, including 19,800 ha of summer crops, 26,600 ha of winter crops and 3,700 ha of rice.

Groundwater in the Coleambally Irrigation Area

For the purpose of this report, the Coleambally Irrigation Area was selected as an example for the discussion of groundwater use in an irrigation area in the Murray–Darling Basin region. More than 40 per cent of the total water used for irrigation in the Coleambally Irrigation Area is groundwater. During 2009–10 the total metered groundwater use in the area was 117,937 ML. Prolonged dry conditions between 2002 and 2010 and subsequent reductions in surface water availability are generally responsible for the increased contribution of groundwater to irrigation in the area (Coleambally Irrigation Co-operative Limited 2010).

The Coleambally Irrigation Area is located in the eastern part of the Murray Geological Basin and overlies the Lower Murrumbidgee alluvial aquifer system which starts downstream of Narrandera and consists of unconsolidated alluvial deposits of sands, silts, clays and peat. The alluvial system is comprised of three main units: the unconfined shallow Shepparton subsystem, and the confined intermediate Calivil and deep Renmark subsystems. These last two subsystems are often in hydraulic continuity.

The lowermost Renmark Subsystem consists of Palaeocene to late Miocene fluvial clays, silts and gravels overlying the basaltic bedrock. In the eastern part of the Murrumbidgee catchment, the Renmark Subsystem has an average thickness of about 280 m (Lawson & Webb 1998).

Overlying the Renmark Subsystem are the late Miocene to Pliocene sands of the Calivil Subsystem. They were deposited by, and are thickest in, the ancestral drainage channels of modern-day rivers. It typically consists of 50 to 70 per cent coarse quartz sand with lenses of pale grey to white kaolinitic clay. The Calivil Subsystem varies in thickness from about 50 to 70 m and can extend to depths greater than 150 m. Of the three regional aquifer systems, the Calivil is the most productive.

The uppermost unit is the Shepparton Subsystem, which is typically 20 to 60 m thick. The Shepparton Subsystem comprises a series of fluvio–lacustrine clays, sands and silts that were deposited during the late Tertiary to Quaternary period. These sediments are laterally discontinuous and form a highly heterogeneous unconfined aquifer system. In the Coleambally Irrigation Area, the Shepparton Subsystem can be clearly divided into two parts, the upper (0–12 m deep) and lower Shepparton (12–60 m deep).
Recharge to and discharge from the shallow Shepparton Subsystem occurs across the area and its heterogeneity and low overall hydraulic conductivity can inhibit lateral flow. Water movement through the deep aquifers is generally from east to west; however, groundwater flow directions near the production bores around Darlington Point are complex. Movement occurs under gentle gradients and is therefore very slow with estimated flow rates of around 7–10 m/yr (Lawson and Webb 1998). Recharge to deep aquifers occurs mainly from the Murrumbidgee River downstream of Narrandera and from vertical leakage from the Shepparton Subsystem.

Figure 7-42. The Coleambally Irrigation Area with groundwater bore sites, including a location map of the Murrumbidgee River catchment.
### 7.7.4 Murrumbidgee and Coleambally Irrigation Areas (continued)

During the 1960s, irrigation began in the Coleambally Irrigation Area with water diverted from the Murrumbidgee River upstream of Gogeldrie Weir near Darlington Point (Figure 7-42). Irrigated agriculture often leads to recharge of regional groundwater systems at rates greater than those the systems can absorb, resulting in the development of shallow watertables and causing salinity and waterlogging. Prior to irrigation, watertable levels were at depths of 15–20 m. However, due to recharge to the groundwater from inefficient irrigation practices, leaky channels and recharge from rainfall, a significant proportion of the area had watertables within two meters of the soil surface by the late 1990s (Coleambally Irrigation Co-operative Limited 2004). These have since subsided due to recent below average rainfall and reduced water allocations. A return to normal seasonal conditions will most likely bring back the high watertables.

Fluctuations in shallow groundwater levels in the upper Shepparton are shown in Figure 7-43. A declining trend in groundwater levels is visible from 2002 onwards. Water levels are relatively stable between 1996 and 2002. To investigate the drivers of the groundwater level trends, fluctuation in shallow groundwater levels are compared to the rainfall residual mass at the Coleambally Irrigation station and to the monthly discharge of the Murrumbidgee River at Darlington Point (see Figure 7-42).

![Graph of shallow groundwater levels](image)

**Figure 7-43.** Shallow groundwater levels between 1996 and 2009 averaged by sub-areas (Coleambally Irrigation Co-operative Limited 2004, top panel) compared to cumulative rainfall residual mass at Coleambally Irrigation station 74249 (middle panel) and Murrumbidgee River discharge at Darlington Point station 410021 (lower panel)
7.7.4 Murrumbidgee and Coleambally Irrigation Areas (continued)

The rainfall residual mass curve is given as the cumulative sum of the actual rainfall for each month minus the average rainfall for that month. Periods in which the cumulative rainfall residual mass curve rises indicate wetter than average conditions. Periods with a falling trend indicate drier than average conditions. As shown, river discharge near the off-take for irrigation, and in minor part rainfall, is correlated with the observed trends in groundwater levels. Some peaks in surface water discharge and in the rainfall residual mass curve correspond to peaks in groundwater. The most striking feature is the decline in groundwater levels driven by reduced irrigation and low rainfall (and hence less recharge) and low surface water diversions.

Groundwater level status

Groundwater level measurements are an important source of information about hydrological and anthropological influences on groundwater in an area, including recharge. Figure 7-44 shows groundwater levels recorded at two regional nested sites within the Coleambally Irrigation Area reaching all three subsystems. Groundwater level fluctuations at bore 36040 are similar in the Calivil and Renmark subsystems, indicating that the two are hydraulically connected. Fluctuation in groundwater levels show the effect of pumping during the irrigation season and the subsequent recovery during the winter months when pumping ceased. Since 1996, a clear downward trend is visible, indicating the groundwater resource is under stress.

Figure 7-44. Groundwater levels between 1980 and 2010 recorded at two nested bore sites (bore 36040, top and bore 36372, bottom), reaching all three subsystems: Shepparton, Calivil and Renmark
7.7.4 Murrumbidgee and Coleambally Irrigation Areas (continued)

The Shepparton Subsystem at this location (bore 36040) seems disconnected from the deeper subsystems. The groundwater levels in the Shepparton Subsystem also show an increasing trend since 1990 due to irrigation accession and a minor decline since 2002 linked to the decline in surface water allocation and, therefore, water available for irrigation. At this location, the hydraulic gradient, and therefore groundwater flow, is downward and increased in recent years. This may pose a greater risk to fresh groundwater at depth if the shallow groundwater is saline.

Groundwater levels at bore 36372 show that the lower Shepparton Subsystem is hydraulically connected to the Calivil Subsystem and both are influenced by pumping. In particular, there is a clear declining trend since the mid-1990s illustrating that these two aquifers are under stress. Similarly, the underlying Renmark Subsystem shows some effects of pumping, with the groundwater levels not recovering to previous levels of 2002. It appears that there is a weak hydraulic connection between the Remark and Calivil subsystems. The hydraulic gradient between the Shepparton and Calivil Subsystems is downward at this location and increased in recent years.

Figure 7-45 shows ranges of groundwater depth in upper Shepparton, lower Shepparton, Calivil and Renmark groundwater bores in the Coleambally Irrigation Area, and the ranking of 2008–09 median groundwater levels compared to annual median groundwater levels since 1996. The bores used are part of a network of bores that are monitored approximately monthly and regional bores monitored by the NSW Office of Water less frequently. The analysis was carried out for 2008–09 rather than for 2009–10 due to the paucity of data in the latter period.

Groundwater levels in the Calivil and Renmark subsystems are all deeper than 10 m. Importantly, groundwater levels in the upper Shepparton and lower Shepparton subsystems are all deeper than 2.5 m. This indicates that the risk of groundwater salinisation from shallow watertables is low.

Median groundwater depths in 2008–09 are mostly in the lowest decile range of recorded levels since 1996 (Figure 7-46), indicating that groundwater levels are on average the deepest of the past 13 years in all aquifers. This is consistent with the trend in groundwater levels shown in the above sections and with the climatic conditions experienced and the reduction of surface water allocations.

**Groundwater salinity status**

Salinity in the Calivil and Renmark subsystems is relatively low and generally increases from east to west from Narrandera to Hay along the Murrumbidgee River. In contrast, the shallow Shepparton Subsystem is often very saline especially under irrigation areas.

Irrigation-induced salinity is a well known problem in many mature irrigation areas across Australia and internationally. The consequences of salinity in irrigation areas include production losses, increased production costs and damage to environmental and infrastructure assets in the region. The Coleambally Irrigation Area is experiencing such salinity problems. Unfortunately, no time-series data on groundwater salinity are currently available for further analysis.
Figure 7-45. Median groundwater depth for the Coleambally area in 2008–09 compared to the upper and lower Shepparton, Calivil and Renmark subsystems.
Figure 7-46. Decile rank of median groundwater depth for the 2008–09 period compared to the reference period 1996–2009 for the upper and lower Shepparton, Calivil and Renmark subsystems.