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Special Climate Statement 70 update—drought conditions in Australia and impact on water resources in the Murray–Darling Basin

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Cover image: Water storage, New South Wales, 2018 (Photo: Mark Wilgar).

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Summary

- This statement analyses rainfall and hydrological data for the past three years to the end of October 2019, with early November also discussed.
- The past three years have seen dry conditions over much of eastern Australia.
- Rainfall for the 22 months from January 2018 to October 2019, and for the 34 months for January 2017 to October 2019, has been the lowest on record for the Murray–Darling Basin and for New South Wales.
- Rainfall for the northern Murray–Darling Basin for these 22- and 34-month periods was lowest on record by a substantial margin, breaking records originally set during the Federation Drought in 1900−1902.
- In Victoria, West Gippsland and East Gippsland each had their driest 34 months on record to October 2019.
- Cool season rainfall from April to September totalled across 2017 to 2019 was the lowest on record across most of New South Wales as well as in most of subtropical Queensland.
- Root zone soil moisture for October 2019 was below average to very much below average across most of the Murray–Darling Basin, with some areas in the centre and north of the Basin having the lowest soil moisture levels for October on record since 1910.
- Storage volumes in the northern Murray–Darling Basin continue to decline, reaching a combined volume in mid-November of 6.7% of capacity, which is 1.6% lower than at the lowest point during the Millennium Drought.
- Groundwater levels across the Murray–Darling Basin have declined during the prolonged dry period.
- Nationally, Australian rainfall for January to October 2019 was 34% below average, the equal second-lowest on record and the lowest since 1902.
- For January to October 2019, 55.8% of Australia was classified as being in serious or severe rainfall deficiency (below the 10th percentile).
- The dry conditions have taken place in the absence of an El Niño in the Pacific Ocean, but there was a strong positive phase of the Indian Ocean Dipole (IOD) in 2019, which is typically associated with dry conditions in many parts of Australia. This followed two years of relatively cool sea surface temperatures off the northwest coast of Australia, which also likely suppressed rainfall over Australia.

Introduction

The past three years have seen dry conditions over much of eastern Australia, with both 2018 and 2019 being especially dry. This statement provides an update on an earlier summary that was released in late 2018 (Special Climate Statement 66—an abnormally dry period in Eastern Australia), with the dry conditions intensifying in many areas.

This Statement (Special Climate Statement 70) discusses the persistence of dry conditions since then, with an intensification of rainfall deficiencies and a growing impact on water resources in the Murray–Darling Basin (MDB). Much of the included analysis uses data to the end of October 2019, with more recent rainfall in early November also discussed.

The largest rainfall deficiencies over a wide range of timescales have been in New South Wales and adjacent parts of southern Queensland. Rainfall on 2- to 3-year timescales over many parts of this region, particularly in northern inland New South Wales, has been near or below previous record low values, many of them set during the Federation Drought in 1900−1902. These impacts have been exacerbated by record high temperatures, including Australia's hottest summer in 2018–19. The extended nature and timing of the dry conditions means that natural resource management, agriculture, water resources, health, and emergency services organisations have all been significantly impacted.

In addition, rainfall deficiencies on multi-year timescales have affected central and east Gippsland in Victoria, the east coast of Tasmania, and parts of eastern South Australia (extending into the far northwest of Victoria) and southern Western Australia.

There were also long-term rainfall deficiencies from April 2012 to April 2016, primarily affecting two regions—most of inland Queensland (and adjacent border areas of northern New South Wales), and central and western Victoria. The most significant long-term rainfall deficiencies currently being experienced are in those areas affected by both the 2012–2016 and 2016–2018 dry periods. In these areas, below-average rainfall has prevailed for most of the last seven years, interrupted only briefly by wet conditions in mid-2016.

A major rain event in northern Queensland in February 2019 resulted in extensive flooding,[1] but largely missed those regions to the south with the largest long-term rainfall deficiencies.

In 2019, dry conditions have become more extensive. While the most extreme departures from average have been in northeastern New South Wales and southern Queensland, the only parts of Australia that have experienced significantly above average rainfall in 2019 are areas of western Tasmania, the Pilbara coast in the region approached by tropical cyclone *Veronica* in March, and those areas of central and northern Queensland affected by the early 2019 floods.

This Statement includes analysis of the severe hydrological impacts of below average rainfall in the MDB. There is a focus on the northern MDB, where consistent low inflows to major catchments have resulted in storage levels lower than those witnessed during the Millennium Drought (2001–2009) and long periods of low flows. This analysis includes a look at trends that extend beyond the duration of the current drought and can be explored more deeply at www.bom.gov.au/water.

[1] See Special Climate Statement 69—An extended period of heavy rainfall and flooding in tropical Queensland

1. Rainfall deficiencies

1.1. Multi-year rainfall deficiencies

The most prominent rainfall deficiencies in this event have occurred at timescales ranging from around 18 months to three years. Rainfall in most of the Murray–Darling Basin has been substantially below average in each of 2017, 2018 and 2019, a situation not previously seen in rainfall records, with very dry conditions in the April to September period (see section 1.3) followed by only a limited recovery in the October to December period in 2017 and 2018. This has led to record low rainfalls over various multi-year periods.

For periods beginning in calendar years, rainfall, for the 22 months from January 2018 to October 2019, and for the 34 months for January 2017 to October 2019, has been the lowest on record for the Murray–Darling Basin and for the State of New South Wales. But more generally, rainfall for all periods ranging from 16 to 36 months ending in October 2019 has been either lowest on record or second-lowest on record for both New South Wales and the Murray–Darling Basin.

The most extreme rainfall deficiencies over multi-year periods have occurred in the northern half of New South Wales (see Figure 1). For example, rainfall for the northern Murray–Darling Basin, which covers that part of the catchment which drains into the Darling River, has been 40% below the 1961−1990 average for the 34 months from January 2017 to October 2019, and 50% below average for the 22 months from January 2018 to October 2019. Both of these are record lows by substantial margins, breaking records set during the Federation Drought in 1900−1902. Conditions have been very dry, but less extreme, in the southern Murray–Darling Basin, where 34- and 22-month rainfall has been 29% and 39% below average respectively (third-lowest and lowest on record).

Most of the individual catchments within the northern Murray–Darling Basin have also experienced record low rainfalls at the 22- and 34-month timescales (Table 3). Records have been set for the 34 and 22 months ending in October 2019 for the Border Rivers, Moonie, Gwydir, Namoi-Peel, Castlereagh, Macquarie-Bogan, Paroo and Lower Darling catchments, with records also set at the 22-month timescale in the Condamine-Culgoa and Lower Murray catchments. Records have been broken by especially large margins at the 22-month timescale; for this period, rainfall from January 2018 to October 2019 has been 10 to 25% below previous record lows in several New South Wales districts, including the Far Northwest, the southern and northern Central Western Plains, the western and eastern Northwest Plains, the northern and southern Northwest Slopes, and the western Northern Tablelands.

Another notable area with multi-year rainfall deficiencies is the central and eastern Gippsland region in eastern Victoria, particularly the area from Sale to Lakes Entrance. 2019 has been the third successive year of below-average rainfall in this area, and whilst it has not been as dry as 2017 and 2018, the continuing below-average rainfall has allowed multi-year deficits to accumulate. Both the West and East Gippsland districts had their driest 34 months on record. The east coast of Tasmania has also had substantial rainfall deficits over this period, although these were eased slightly by heavy rain in September.

In South Australia, rainfall was near average in 2017, but has been well below average in 2018 and 2019. As a result, rainfall for the 22 months from January 2018 to October 2019 was at, or near, record low levels over many parts of the State, apart from the far west and Lower South East. Record low totals have been set for this period for the Upper North and Northeast region and for the Adelaide region (although not for central Adelaide itself). Two successive dry years have also resulted in well below average 22-month rainfall in southern agricultural areas of Western Australia, with some record low rainfall totals around Ravensthorpe and Jerramungup.

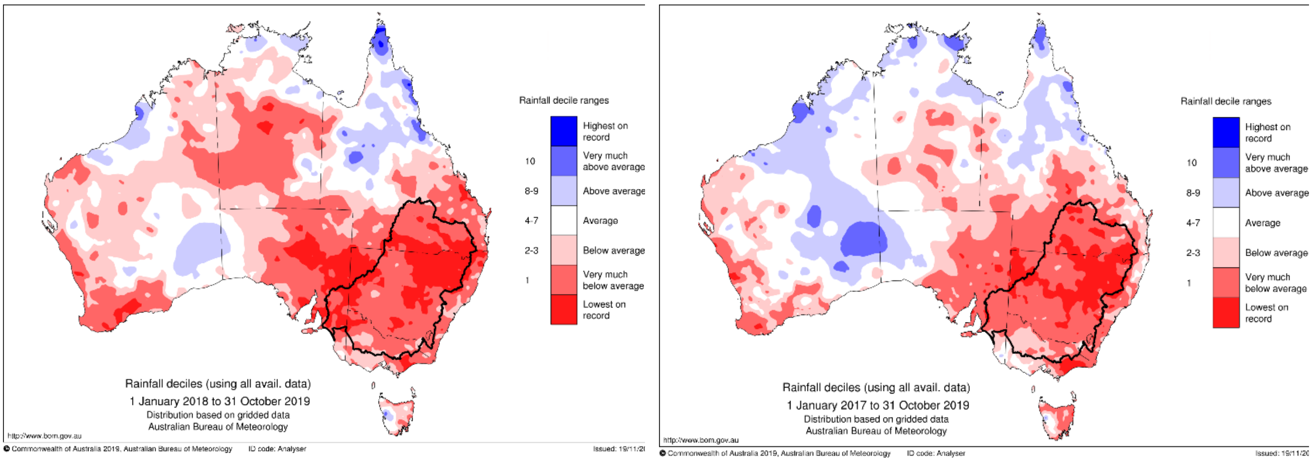


Figure 1. Australian rainfall deciles for the 22 months from January 2018 to October 2019 (left), and 34 months from January 2017 to October 2019 (right) (based on all years since 1900). The boundary of the Murray–Darling Basin is marked in black.

1.2. Low rainfall in 2019

Rainfall for January to October 2019 was below average over many parts of Australia (Figure 2). Rainfall was well below average in most tropical areas of Western Australia and the Northern Territory in the 2018−19 wet season, with the Kimberley region (37% below average) and the western Northern Territory Top End (20% below average) having their driest October−April since 1991−92. There was also a marked lack of penetration of tropical moisture into desert regions of Australia, except for Queensland and eastern border areas of the Northern Territory.

Punctuating the dry conditions, northern and western Queensland had two significant rainfall events in the first half of 2019. In late January and early February, a monsoon trough remained near stationary, resulting in some sites in tropical Queensland having their wettest February day on record or their highest total February rainfall on record.[2] In March, severe tropical cyclone *Trevor* produced widespread moderate to heavy falls over western and central Queensland. However, these heavy rain events largely missed the areas of long-term rainfall deficiencies in the MDB.

January to April 2019 was very dry in many parts of southern Australia, including southern Western Australia, South Australia, Victoria and much of Tasmania. Regular rainfall returned to the southern coastal fringe from May onwards, but it remained dry further inland. January and February were exceptionally dry in the eastern subtropics on both sides of the New South Wales−Queensland border; a near-normal March was then followed by very dry conditions from April onwards.

The consistently low rainfall has resulted in some extreme, below average rainfall anomalies for the year to date (January to October 2019), especially in northern New South Wales and southern Queensland. In this region, rainfall has been 70 to 80% below average in places, and far below previous records. Several locations, including Stanthorpe, Tenterfield and Texas, have experienced January−October rainfall more than 30% below previous record lows, and in some parts more than 40% below. The western Northern Tablelands district as a

[2] Further information in Special Climate Statement 69—An extended period of heavy rainfall and flooding in tropical Queensland

whole has had rainfall 65% below average, and 36% below the previous record low set in 1965. In the January to September period, 12 of the 14 rainfall stations in the western Northern Tablelands with 50 years or more of data had their driest January−September on record, with seven stations breaking previous records by more than 30%.

Record low rainfalls have also occurred over many parts of inland central and western Australia. Many parts of outback South Australia have had less than 30 mm for the year so far, with Marree only receiving 9.4 mm to the end of October. Record low rainfalls have also occurred in some parts of eastern Western Australia (e.g. 19.6 mm at Warburton and 30.2 mm at Forrest) and in the central and western Northern Territory (20.0 mm at Yulara, 31.4 mm at Tennant Creek). Tennant Creek's total is less than one-tenth of their long-term average (91% below average). An additional area of extreme low rainfalls has been in a region centred on Renmark and Mildura, near the Victoria−South Australia border, and adjacent areas of far southwest New South Wales, with some records set.

Across southern Australia, rainfall deficits have been less extreme in most of Victoria, Tasmania (away from the east coast) and southeast South Australia, but only in small pockets has rainfall for 2019-to-date approached the long-term average.

October rainfall was below to very much below average across most of Australia, including most of New South Wales, Victoria, South Australia, and Tasmania. For southern Australia (south of 26°S), it was the driest October on record.

The widespread nature of the dry conditions is further illustrated by the fact that 55.8% of Australia is classified as being in serious or severe rainfall deficiency (in the lowest 10%) for the period from January to October 2019, and in total 88.3% of Australia has had rainfall totals below the median.

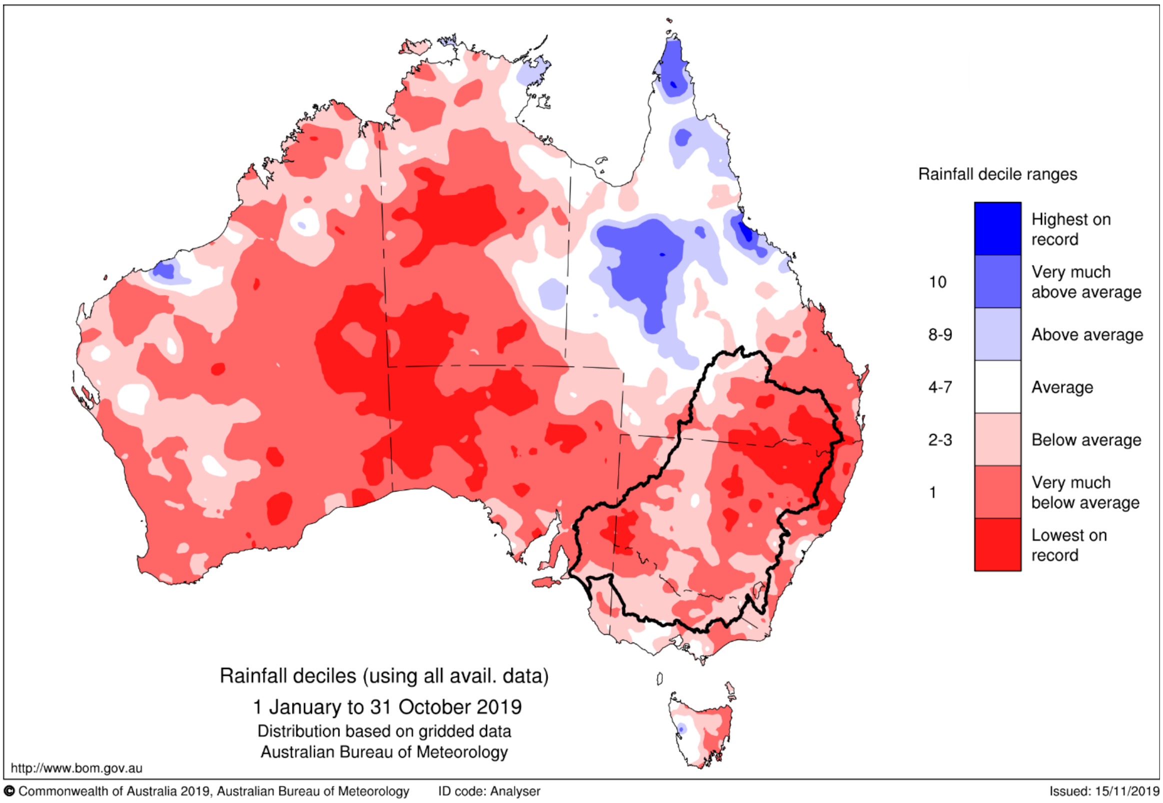


Figure 2. Australian rainfall deciles for January to October 2019 (based on all years since 1900). The boundary of the Murray–Darling Basin is marked in black.

1.3. Eastern Australian rainfall deficits especially extreme for the April to September periods

A notable feature of the rainfall deficits of the last three years is that they have been especially concentrated in the cooler seasons. Rainfall for the April to September period was far below average in all three of the years 2017, 2018 and 2019 in most of New South Wales, and Queensland south of the Tropic of Capricorn.

All three April−September periods ranked in the ten driest on record for the Murray–Darling Basin and for New South Wales; for New South Wales, 2017 was the eighth-driest April−September on record, 2018 the third-driest and 2019 the fifth-driest. Many of the northern New South Wales rainfall districts had rainfall at least 50% below average in all three April−September periods. In the northern and southern Central Western Slopes regions, all three years had April−September rainfall in the five driest years on record, whilst the northern Central Western Plains region had less than one-third of their average rainfall in all three periods—in this region, the total April−September rainfall across the three years 2017, 2018 and 2019 was only 17 mm more than that received in the single month of June 2016.

April−September rainfall totalled across the three years was the lowest on record across almost all New South Wales, apart from some coastal areas and parts of the far west, as well as in most of subtropical Queensland (see Figure 3). All three years had seasonal rainfall below 125 mm for New South Wales; there is no previous instance of two consecutive years below 125 mm, or three consecutive years below 175 mm. Total April−September rainfall for the three years was 324.9 mm, far below the previous record low of 486.6 mm set in 1927−29. In the northern Murray–Darling Basin, all three years had April−September rainfall below 75 mm, the first instance of three consecutive years below 100 mm.

Although cool-season precipitation has been well below average in Alpine regions, the snowpack at higher elevations was above average in all three years. Peak natural snow depths at Spencers Creek in the Snowy Mountains exceeded 200 cm in 2017, 2018 and 2019, only the second time (after 1990−92) that there have been three consecutive years above 200 cm since records began in 1954. Despite the low precipitation, there was a lack of melting during the season due to an almost complete absence of winter rain at high elevations (almost all the precipitation that did fall was snow), and a relative lack of extreme warm events during the peak of the snow season; Cabramurra did not reach 10 °C in August in 2017, 2018 or 2019, whereas it had done so in 13 of the 20 Augusts between 1997 and 2016, including readings above 15 °C in 2005 and 2007.

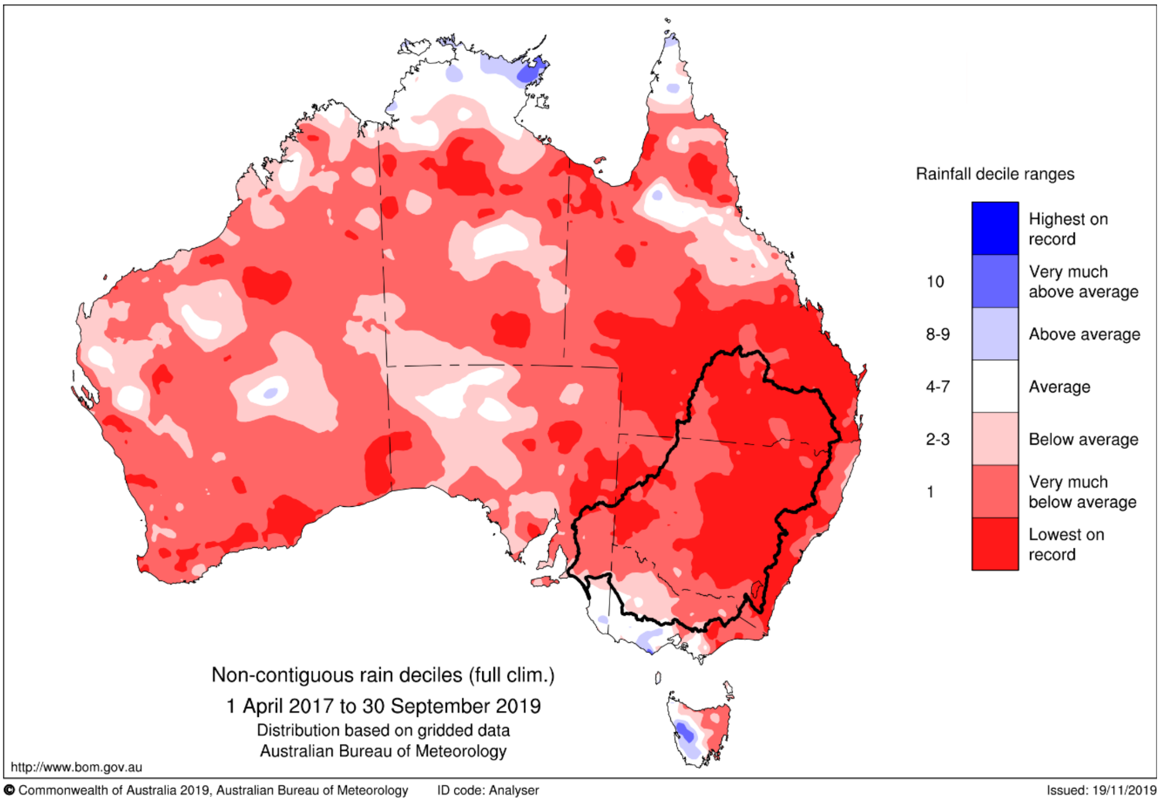


Figure 3. Australian rainfall deciles for the combined three-year 2017, 2018, and 2019 April to September periods (based on all years since 1900). The boundary of the Murray–Darling Basin is marked in black.

1.4. Rainfall in early November

Rain and scattered thunderstorms associated with a slow-moving trough and cold front in the first days of November brought some very welcome rainfall across areas of eastern Australia. Through some areas of inland Queensland and central to western New South Wales, this event brought the first significant rainfall since early May. However, eastern New South Wales and southeast Queensland missed out on the heaviest falls (see Figure 4). Even in the regions that received significant rainfall in November, the longer-term January to November rainfall totals remain below average.

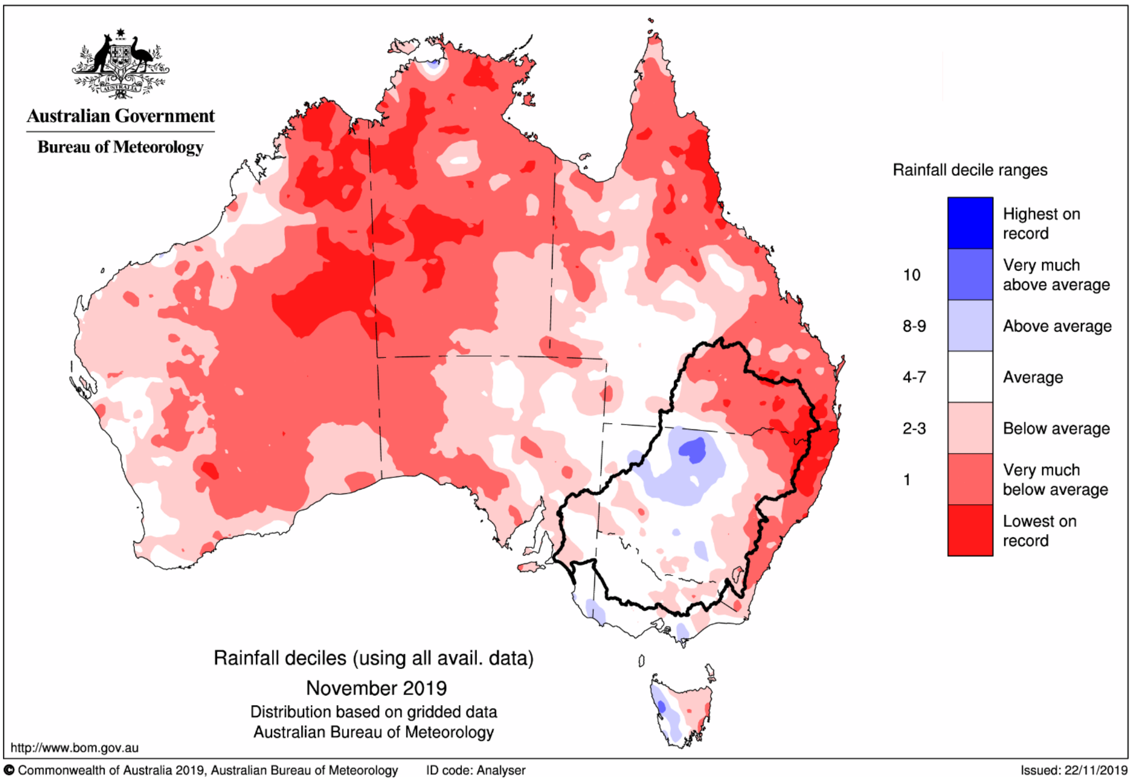


Figure 4. Australian rainfall deciles for 1–22 November 2019 (based on all years since 1900). The boundary of the Murray–Darling Basin is marked in black.

2. Temperature and evaporation

The dry conditions experienced over the past two years were exacerbated by record-high temperatures. Unusually warm temperatures have dominated Australia's climate in recent years, and particularly so in the drought affected regions. Mean temperatures in 2017 (+1.53 °C) were the highest on record for the MDB to that point, with the record being broken in 2018 with an anomaly of +1.66 °C above the 1961–1990 average. 2019 is on course to approach or break the 2018 record, with an anomaly of +1.79 °C for the period from January to October. While droughts are often associated with above average temperatures, these values are typically 1 °C or more above values for previous drought years such as 1972, 1982, and 1994. High temperatures increase the stress on landscapes affected by rainfall deficiencies and add to water demand.

Summer 2018–19 was Australia's warmest summer on record. The national mean temperature for summer was 2.14 °C warmer than the 1961–1990 average, exceeding the previous record (+1.28 °C in 2012–13). Daytime and night-time temperatures were both warm, with the mean maximum temperature 2.60 °C above average (almost a degree higher than the previous record of +1.64 °C in summer 2012–13). The mean minimum temperature broke the record by a smaller, but still substantial, margin at 1.67 °C warmer than average (previous record was +1.09 °C in summer 2017–18). March 2019 was Australia's warmest March on record.

Temperatures have been less extreme from April onwards but have still been above average in every month, extending a sequence of consecutive above-average months that goes back to November 2016 (a 35-month sequence, which breaks the previous record of 32 months, from August 2012 to March 2015). It has been particularly warm in the western interior, much of which has experienced its warmest January to October on record (see Figure 5).

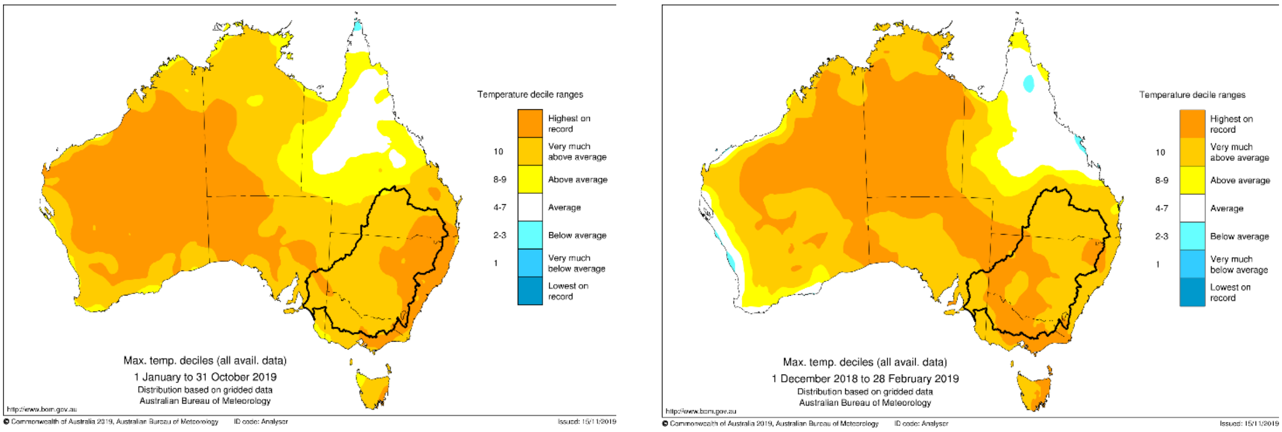


Figure 5. Maximum temperature deciles for January to October 2019 (left) and summer 2018–19 (right). Deciles are calculated with respect to the whole period from 1910. The boundary of the Murray–Darling Basin is marked in black.

Modelled and observed evaporation shows the impact of the warm temperatures and drier than average conditions in the northern half of the Murray–Darling Basin, which saw highest on record summer potential evaporation for the most recent 30-year period. Potential evaporation (evaporative demand) and pan evaporation was well above average over most of Australia leading up to and during winter 2018. Averaged over Australia, pan evaporation for June to August 2018 was the third highest on record (446.8 mm), just below the record of 452.8 mm set in 1977. South Australia and Queensland had their highest winter seasonal evaporation on record, with New South Wales ranking second.

Estimated potential evaporation is also examined in the modelled data to look at the impacts of the below average rainfall, reduced cloudiness, and increased temperatures. April to June 2018 saw highest on record potential evaporation (Figure 6). The actual evaporation varies from these numbers, being dependent on how much water remains in the landscape and plant water use efficiency.

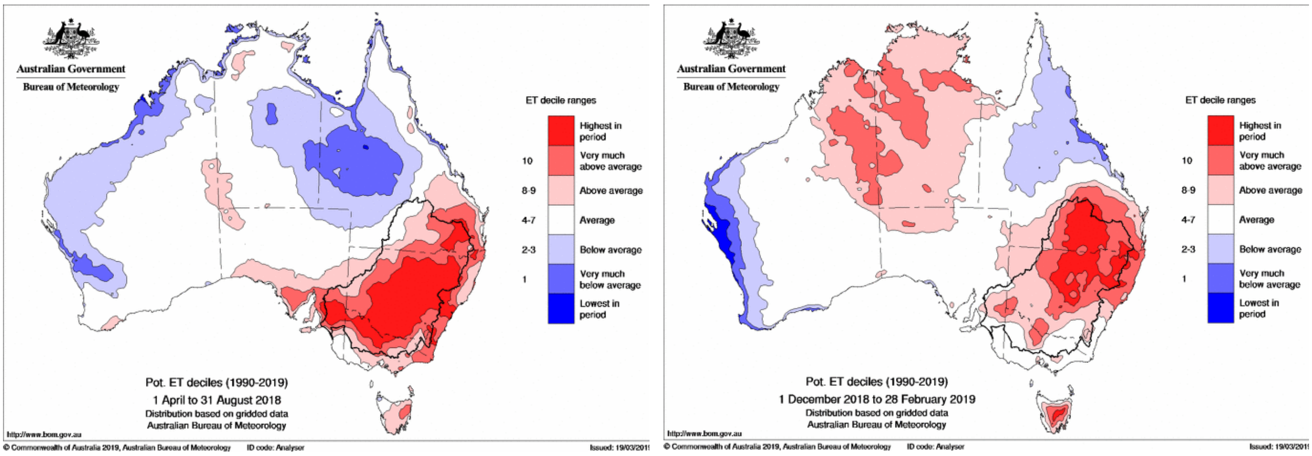


Figure 6. Potential evapotranspiration from the Australian Landscape Water Balance (AWRA-L) version 6 model for April to August 2018 (left) and summer 2018–19 (right). Deciles are calculated with respect to the most recent 30-year period from 1990.

3. Water resources in the Murray–Darling Basin

Water resources are greatly influenced by the occurrence and frequency of rainfall across the landscape, and further by temperature and consumptive water use. Given the historic low rainfalls and high temperatures, water availability in the soil, major storages, rivers and groundwater across the Murray–Darling Basin is low. Key aspects of water resources availability are described below.

3.1. Soil moisture

In line with rainfall patterns, October root zone soil moisture was below average to very much below average across most of the Murray–Darling Basin, with some areas in the central and north having the lowest soil moisture levels for October on record (Figure 7). The only major exceptions to these lower than average soil moistures were average conditions in the far south and northwest of the Basin. These values provide an indication of the moisture stress experienced by vegetation and the severity of agricultural drought, which has been ongoing for three years in some areas.

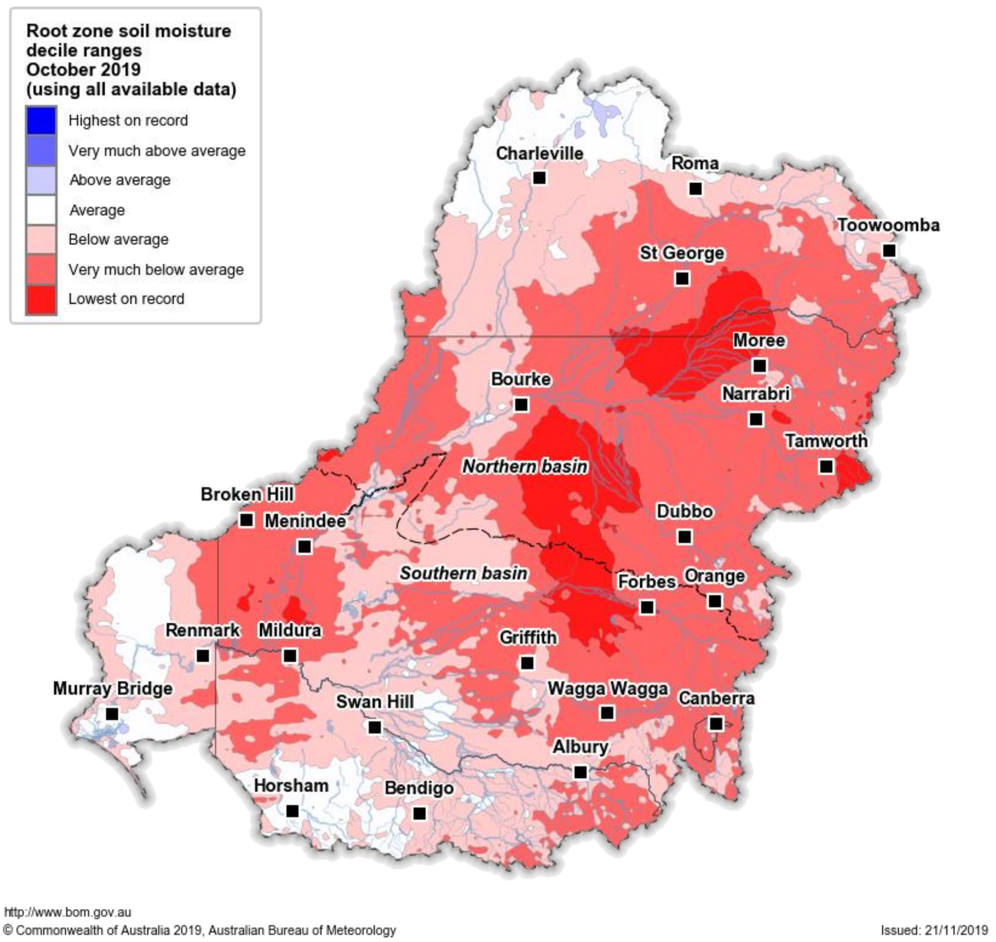


Figure 7. October soil moisture deciles in the root zone soil moisture (top 100 cm of the soil profile) across the Murray–Darling Basin from the AWRA-L version 6 model.

The current dry conditions in many areas began in January 2017 and by considering how this 34-month period compares to other 34-month periods, since records began in 1911, this period can be placed in context. Mean root zone soil moisture levels for the past 34 months (January 2017–October 2019) set new low records in parts of the Murray–Darling Basin, particularly in the east of the Basin (Figure 8). The river catchments that experienced lowest on record soil moisture for this period (Table 1) represent major water source catchments for the Darling River in particular. These records mean that there may have been shorter periods that were drier, or less dry periods that lasted longer, but there has not been a period of this average dryness that has lasted this long (34-months) in over 100 years.

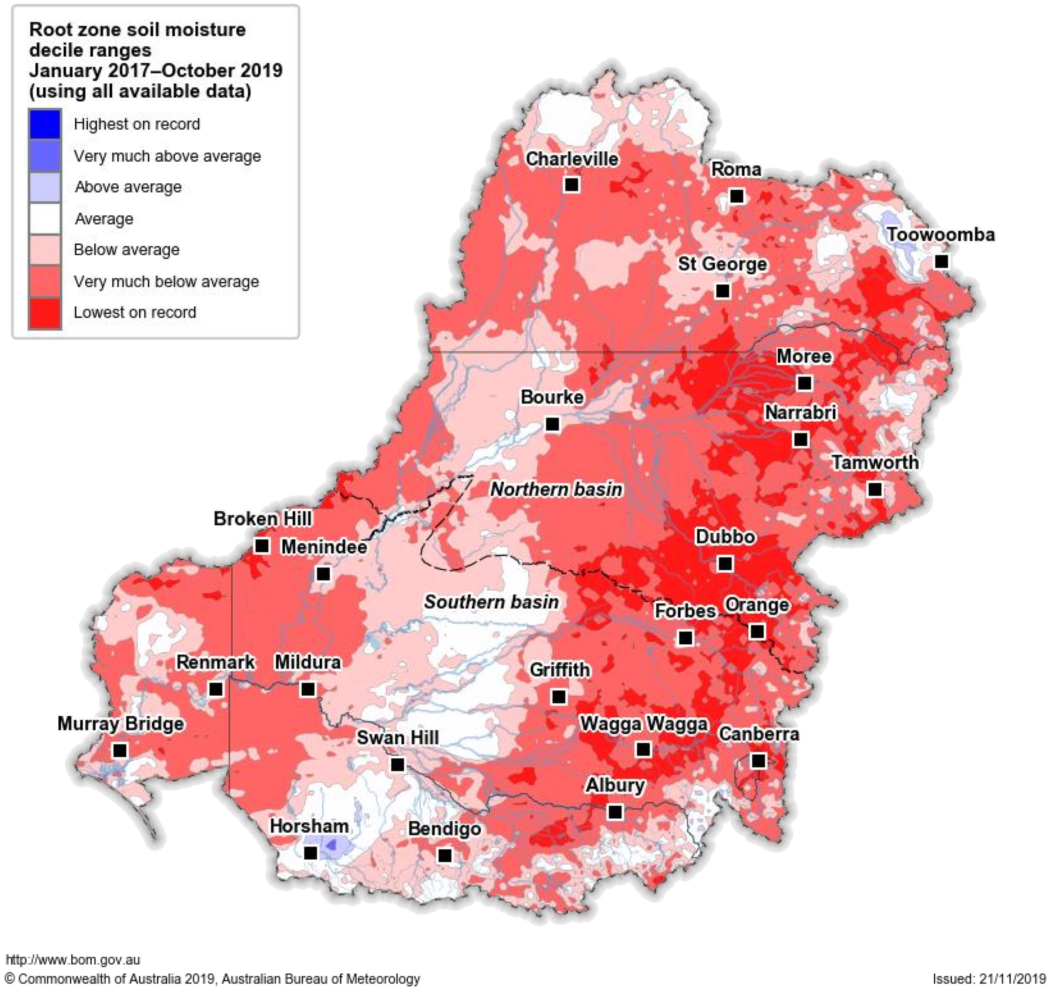
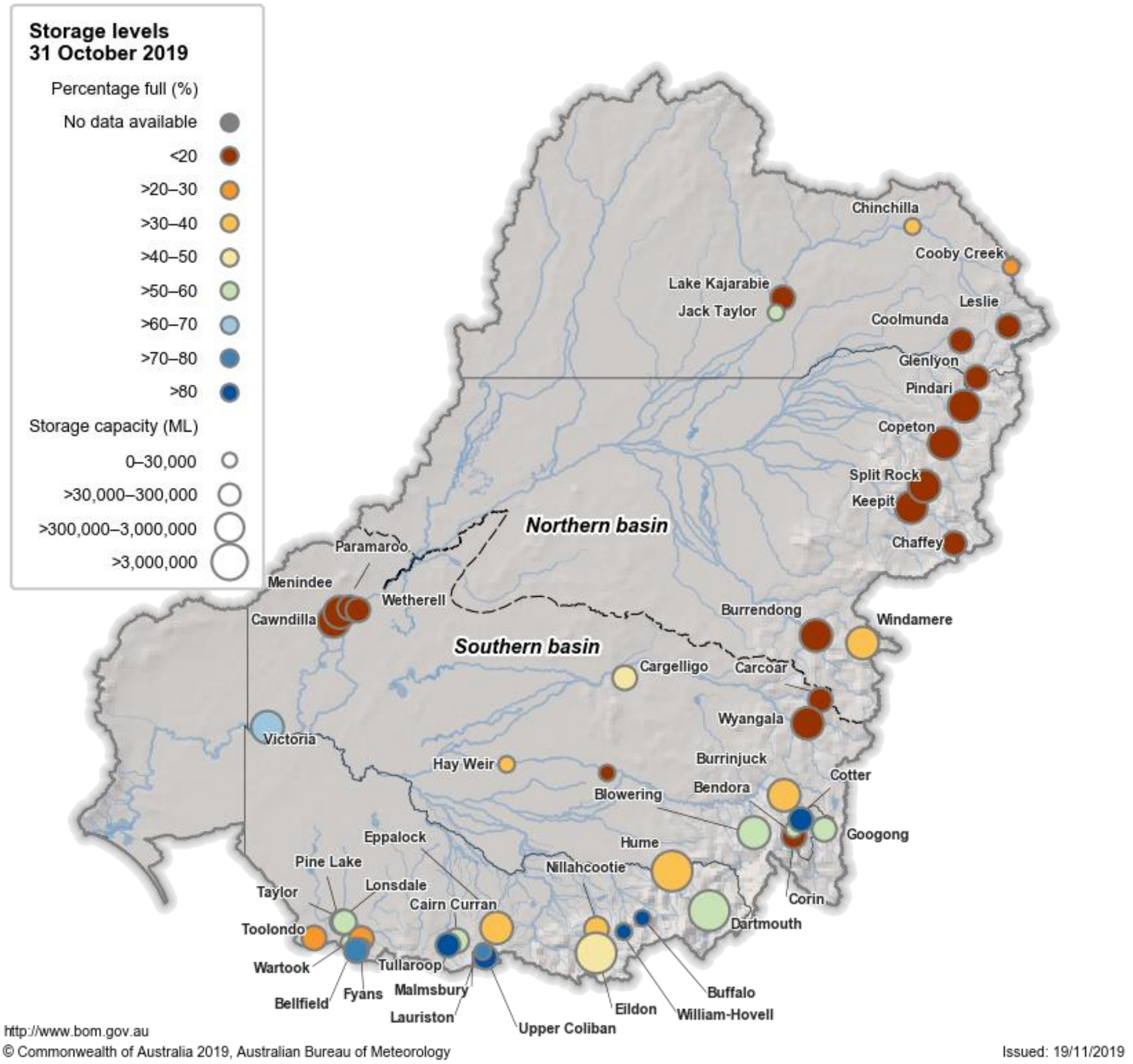


Figure 8. Root zone soil moisture deciles for the 34 months January 2017–October 2019 in the Murray–Darling Basin. From the AWRA-L version 6 model for the top 100 cm of the soil profile.

3.2. Major water storages

Storage volumes in the **n**orthern Murray–Darling Basin continue to decline**,** reaching a combined volume in mid-November of 6.7 per cent of capacity (Figure 9). This is 1.6 per cent lower than at any point during the Millennium Drought (2001–2009). Rainfall in the Northern Basin is generally summer-dominant and the last three summers have failed to deliver any significant inflows. If the Northern Basin experiences below average rainfall again during the 2019**–**20 summer, water storages still containing water will continue to decline through water releases and evaporation. Many towns in the region have raised their water restriction levels and are investigating alternative water sources, such as groundwater, to augment their water supply.

Storage volumes in the Southern Basin are much higher relative to the northern volumes and have not reached the lows seen in the Millennium Drought (Figure 9). Total storage volume was at 47 percent at the end of the winter filling season but has now started to drop. This follows the start of the southern irrigation season and reduced inflows to the major storages due to dry catchments and limited rain. The 2019 Southern Basin winter filling season marks the third season in a row that did not replenish water used during the summer draw down period (October–April). The current storage levels are 11 per cent lower than at the same time in 2018 and 40 per cent lower than November 2016.



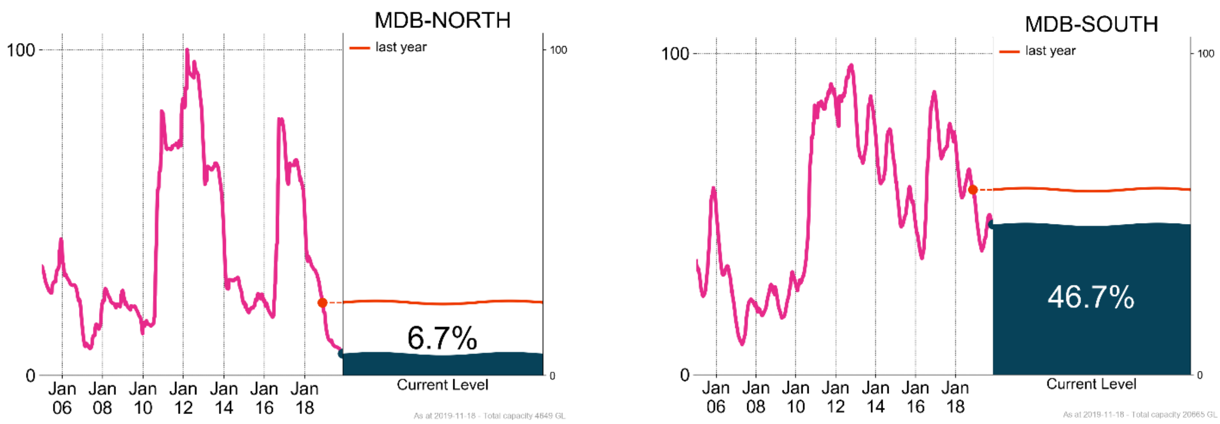


Figure 9. Total storage volumes in the northern and southern Murray–Darling Basin at 18 November 2019.

Runoff in the major storage catchments in the Gwydir (Lake Copeton), Namoi (Split Rock and Keepit Reservoir) and Macquarie (Lake Burrendong) valleys in particular have been well below average for the last two years (Figure 10). In the Namoi, the monthly average runoff to the major storages was only 30 per cent of the long-term average in 2018 and only 20 per cent in 2019. This equates to approximately 135 GL less water than average to supply to the Namoi river since the start of 2018. This reduced inflow has contributed to both Keepit and Split Rock now sitting at less than two per cent capacity.

Burrendong and Copeton storages are slightly fuller at 3.4 and 6.9 per cent capacity respectively but they too have had approximately 190 GL and 250 GL less than average water over the past two years. These storages, along with others in the region, play a crucial role in supplying water for communities, the environment, stock and domestic use and irrigated agriculture. Measures to secure water supplies are currently underway, including implementing water restrictions, pumping of water in storages that sits below the low level intake valve and installation of groundwater bores.

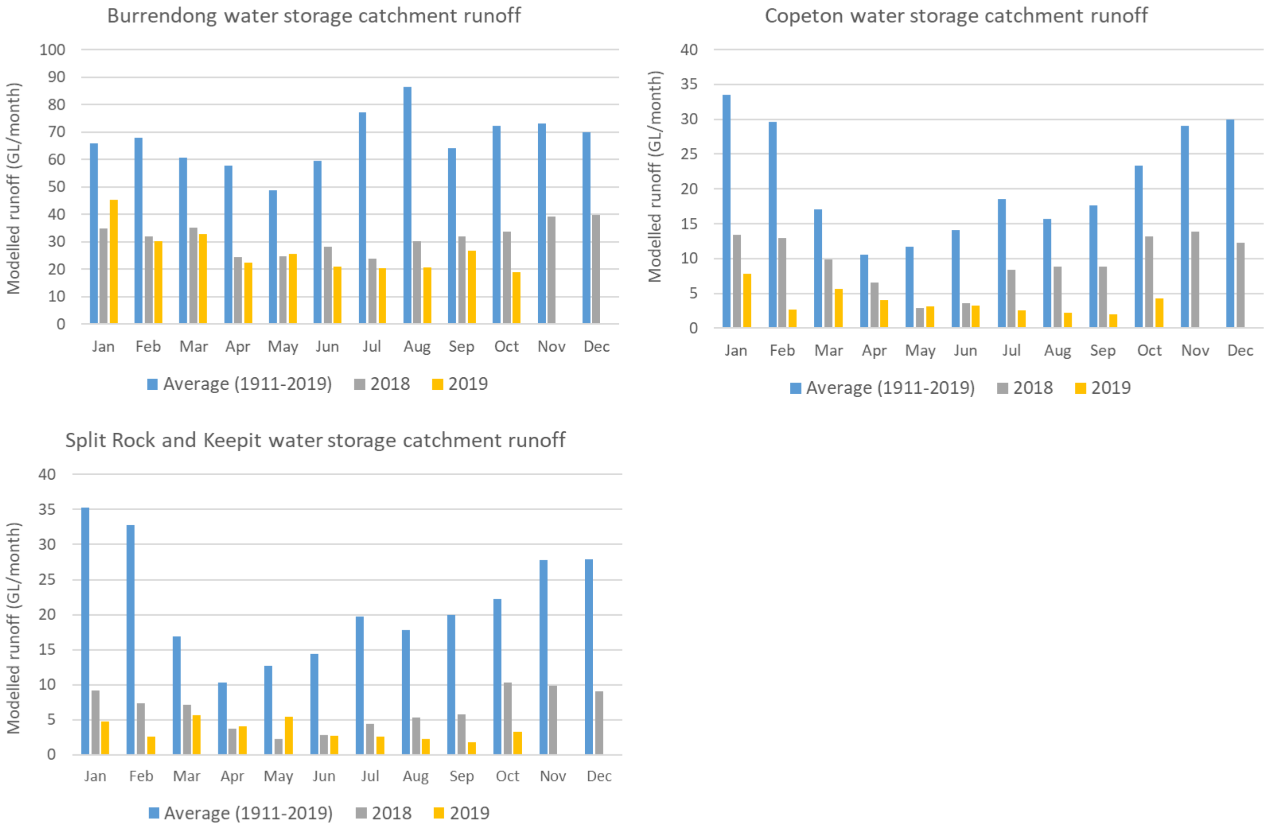


Figure 10. Modelled runoff in major northern Murray–Darling Basin storage catchments, from the AWRA-L version 6 model.

3.3. Streamflow

Streamflows have been average to lowest on record during October right across the Murray–Darling Basin (Figure 11). Very few of the Northern Basin rivers are flowing at all and while this is not that unusual for some of the northwestern rivers, the rivers in the northeast are seeing lowest on record flows for this time of year.There are some minor flows still running through some of the reaches downstream of the storages in the Namoi, Macquarie, Gwydir and Border Rivers, likely due to releases from the storages but none of this is making it to the lower sections of these rivers or into the Darling River. This is in stark contrast to the situation of the rivers during January 2017, when most in the north were running with above average flow (Figure 12).

The exceptionally dry conditions in the Northern Basin over the past 34 months have resulted in very limited natural inflows to these rivers, particularly at locations in the upper catchments of the Northern Basin tributaries. These upper reaches of the Northern Basin catchments, along the western side of the Great Dividing Range, are where the majority of inflows to the Darling River originate.

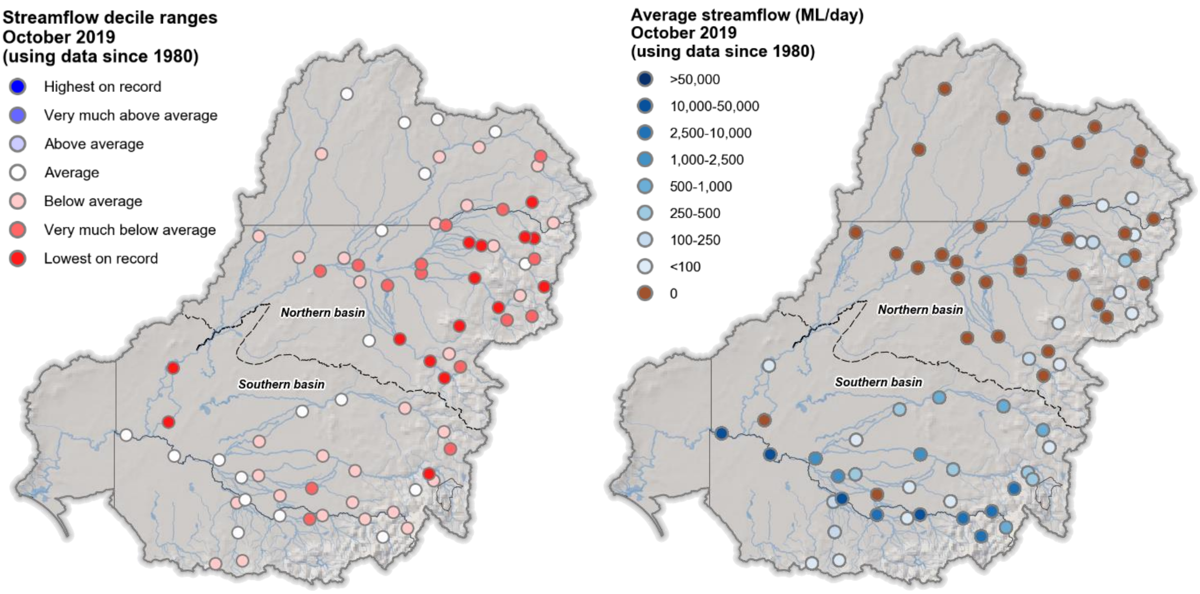


Figure 11. Streamflow at gauges during October. Deciles (left) and average daily flow (right).

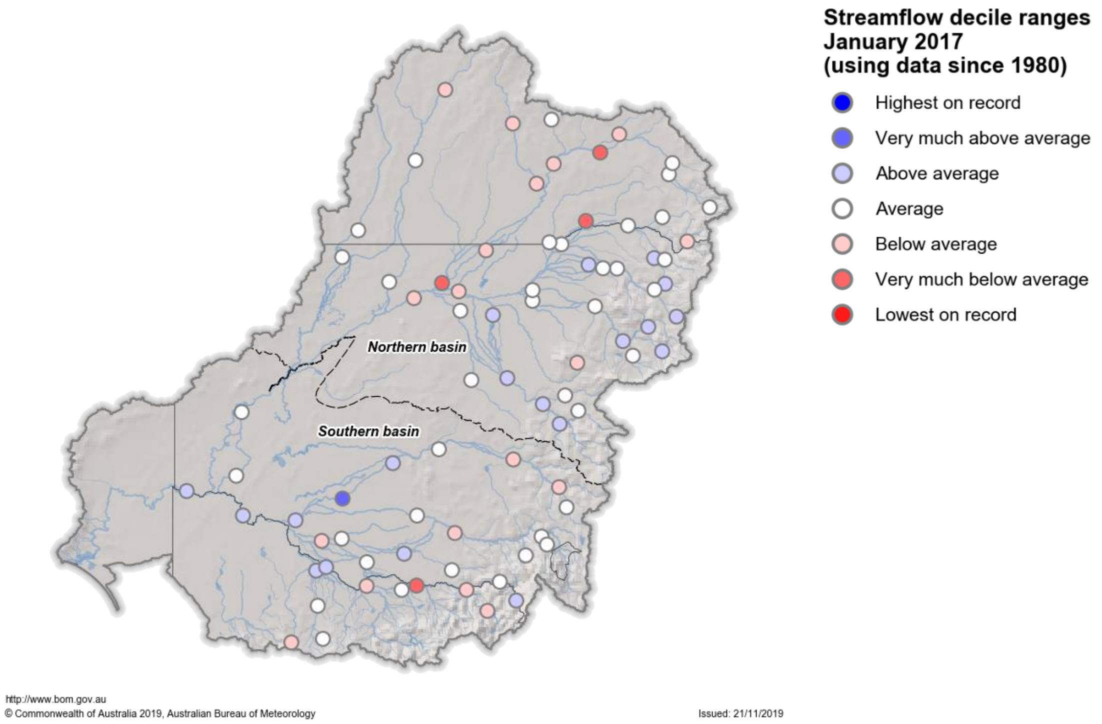


Figure 12. Streamflow deciles at key sites in the Murray–Darling Basin January 2017.

Due to the ongoing dry conditions across the Northern Basin, flows into the Darling River and downstream to Wilcannia have been very low (Figure 13). Since 2013, streamflow in the Darling has been average to below average, including periods of lowest on record, apart from a wetter than average 2016 winter-spring season. In a longer context, apart from three years between 2010 and 2012, the Darling River has not seen above average flow for more than a few months at a time, since March 2002.

While this low flow period has not yet lasted for as long as during the Millennium Drought, it has been noticeably more intense during the summer months. Conversely, throughout many of the summer months during the peak of the Millennium Drought, the Darling River received flows that were close to monthly averages or above average, while winter and autumn months were very dry.

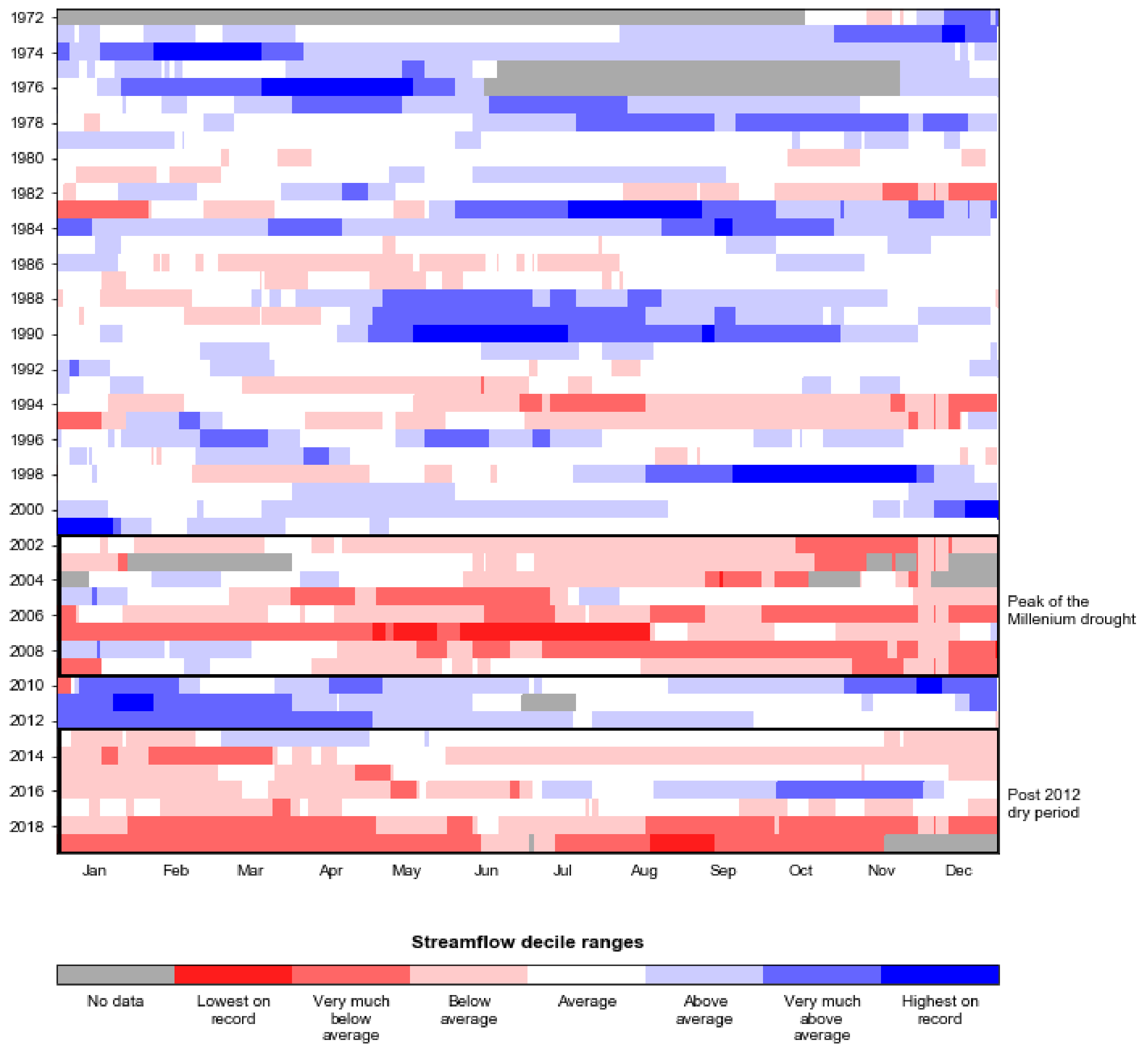


Figure 13. Daily streamflow deciles for Darling River inflows from 1972 to 2019 for upstream catchments as measured at Wilcannia. The red indicates periods of below average to lowest on record streamflow.

3.4. Groundwater

Groundwater levels across the Murray–Darling Basin have also declined in response to the prolonged dry period. Aquifer systems are being impacted by low rainfall and stream recharge and by increased pumping for consumptive use, especially given the scarcity of surface water supplies. Thus, less water is getting into aquifers and aquifer systems are under further stress due to increased extractions.

Figure 14 shows that in 2018–19, groundwater levels in many parts of the Basin had their lowest rate of recovery on record. The Southern Basin also had record low recoveries, suggesting that it may be influenced more strongly by groundwater extraction as the region has not experienced the same record low rainfall deficiencies as the north. However, several bores in the south also had above average recovery rates. These were mostly concentrated in the upper aquifers, which often have highly localised groundwater conditions given the heterogeneous nature of surficial sediments and are not indicative of regional conditions.

Hydrographs for two bores are presented in Figure 14 to highlight changes to aquifer systems across the basin over time. Groundwater levels in the Lower Namoi bore were mostly consistent until the late 1970s, after which the effects of groundwater extraction can be observed. Whilst groundwater levels recovered seasonally, there is a noticeable downward trend in groundwater levels over the long-term. Groundwater levels started to recover in 2010, but the downward trend has resumed since 2012 and groundwater levels are now lower than Millennium Drought levels for this bore.

A similar trend is observed in the Murrumbidgee alluvial bore, Groundwater extractions increased in the 1980s, but the rate of recharge was similar to the rate of extraction, so groundwater levels remained constant. Groundwater extraction increased during the 1990s and the decline in water levels was exacerbated during the Millennium Drought. Alluvial sediments, which form the upper-most aquifers, are usually strongly influenced by rainfall or streamflow recharge. This is likely why such strong recovery rates can be observed, particularly after the Millennium Drought ended. Like the bore in the Lower Namoi, the downward trend in water levels in this bore resumed in 2012 in response to continued rainfall deficiencies and groundwater extractions.

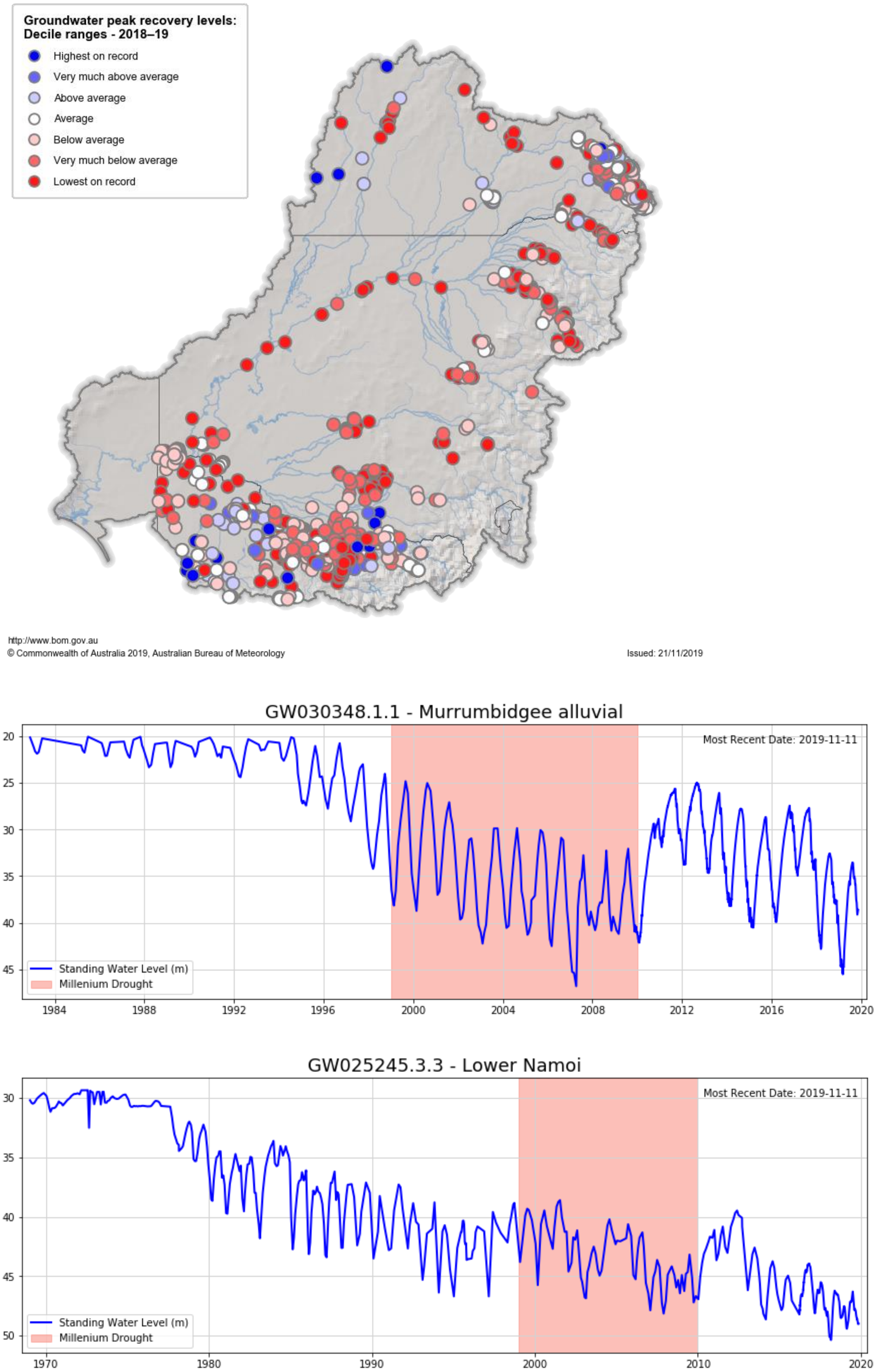


Figure 14. Groundwater recovery in the Murray–Darling Basin July 2018 to June 2019 with groundwater hydrographs in the Murrumbidgee alluvial and Lower Namoi.

3.5. Impact of early November rainfall on water resources

The rainfall in early November has led to some isolated increases in water resources but little has made it to the major storages of the Murray–Darling Basin. The recent rainfall has resulted in the Darling River at Bourke flowing across the weir for the first time since August 2018 (see Water Data Online). Flows were also recorded in the Warrego river at Fords Bridge and Dicks Dam. Significant losses are expected to occur from these minor flows as the dry riverbed wets, weir pools and waterholes fill**,** and the water evaporates.

The soils in the major storage catchments, particularly in the northern Murray–Darling, were extremely dry prior to this rain event, meaning that the rain that did fall soaked into the soil and produced very little runoff. These catchments will require significant follow-up rainfall in the coming weeks and months to start to replenish the water storages.

4. The current event compared to past droughts

The Murray–Darling Basin previously experienced major multi-year droughts in 1895–1903, 1938–1946, and 2001–2009. The general pattern in inland New South Wales and Queensland has been one of a relatively dry first half of the 20th Century, a relatively wet second half of the 20th Century (with especially wet decades in the 1950s and the 1970s), then a return since 2001 to drier conditions (except during the extremely wet 2010–11 and 2011–12 La Niña events). The more limited evidence available suggests that rainfall in the late 19th Century was comparable to that of the 1950–2000 wet period.

Compared to earlier droughts, the current drought has taken place against a backdrop of rising temperatures due to global warming. Since 1970, most of the region has been warming at a rate of between 0.2 °C and 0.4 °C per decade**,** with a total warming of more than 1 °C. For the Murray–Darling Basin, the last six years have had mean temperatures at least 1 °C above the 1961–1990 average, ranking amongst the ten warmest on record for the Basin (with 2018 being the warmest).

5. Influence of major climate drivers

The dry conditions of the last three years have occurred through a mix of broadscale climate drivers that influence Australia's climate. Notably, the dry conditions have occurred in the absence of an El Niño (the last significant El Niño ended in early 2016). Whilst long-term droughts have occurred in the interior of Australia in the absence of El Niño, this is rare in eastern Australia.

A major influence on the climate in winter and spring 2019 has been the presence of a very strong positive phase of the Indian Ocean Dipole (IOD). This is typically associated with dry conditions in many parts of Australia. Whilst the event is ongoing, data to date suggest that the 2019 event will be amongst the strongest positive IOD events on record, alongside those of 1997, 1994 and 1961.[3] Indian Ocean temperatures did not reach the criteria for an IOD event in 2017 or 2018, although sea surface temperatures off the northwest coast of Australia were relatively cool in winter and spring 2018**,** which likely suppressed rainfall**.**

In 2017, at the start of the 3-year period covered by this statement, a positive Southern Annular Mode (SAM) and strong subtropical ridge (STR) contributed to below average winter rainfall. Atmospheric pressure was higher than average across Australia between April and June 2017 under the influence of a persistently strong subtropical ridge (Figure 15). Many sites in southern Australia with long-term mean sea level pressure (MSLP) data observed record high mean 9am MSLP for June. The STR was not only stronger than average during this period, it was located further south than usual for this time of year. The more southerly position of the STR suppressed rain-bearing low pressure systems and cold fronts, pushing them further south of the continent than usual.

[3] IOD years have been assessed since 1960. A lack of reliable sea surface temperature data in key regions prevents a full assessment of IOD behaviour prior to 1960.

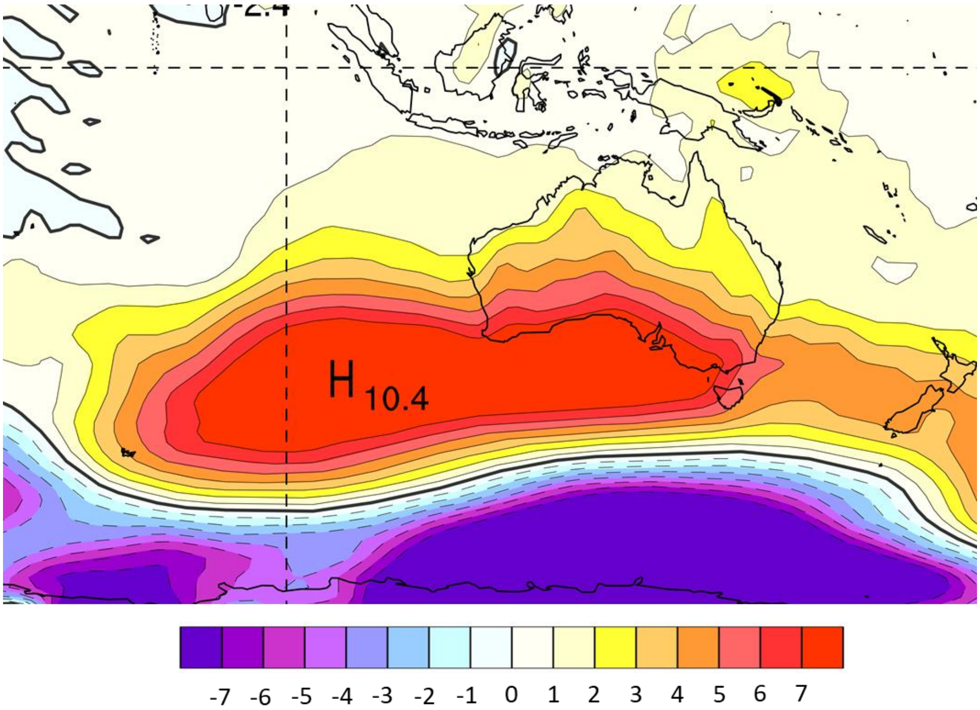


Figure 15. National Centers for Environmental Prediction (NCEP) Reanalysis MSLP anomalies (in hPa) over Australia in June 2017 (base period 1961–1990).

More recently, using National Centers for Environmental Prediction (NCEP) Reanalysis MSLP data, low pressure systems over southern Australia and the Tasman Sea during April to September 2019 were again much less common than average. The count of days with low pressure systems over southern Australia[4] for the period April–September was the lowest on record since at least 1950. Conversely, high pressure systems were more common than average across much of southern Australia.

There are downward trends in rainfall since the 1990s in southern parts of eastern Australia, particularly Victoria, and in the higher rainfall areas of the Murray–Darling Basin that are generally located in the highlands of the Great Dividing Range. These trends were described in the State of the Climate 2018 report and are concentrated in the April to October period, with little change during summer. A major influence on this drying has been the strengthening and extension of the subtropical high pressure ridge during winter, shifting rain-bearing weather systems south. It is difficult to confidently divide low rainfall between variations and trends, but the underlying drying trend will contribute to the likelihood and intensity of rainfall deficits.

[4] Cyclones with centres within two different sized boxes covering southern Australia were tested, one extending from 110°E to 160°E, and 27.5°E to 42.5°S, and another box extending from 110°E to 155°E, and 26°E to 44°S.

Tables and figures

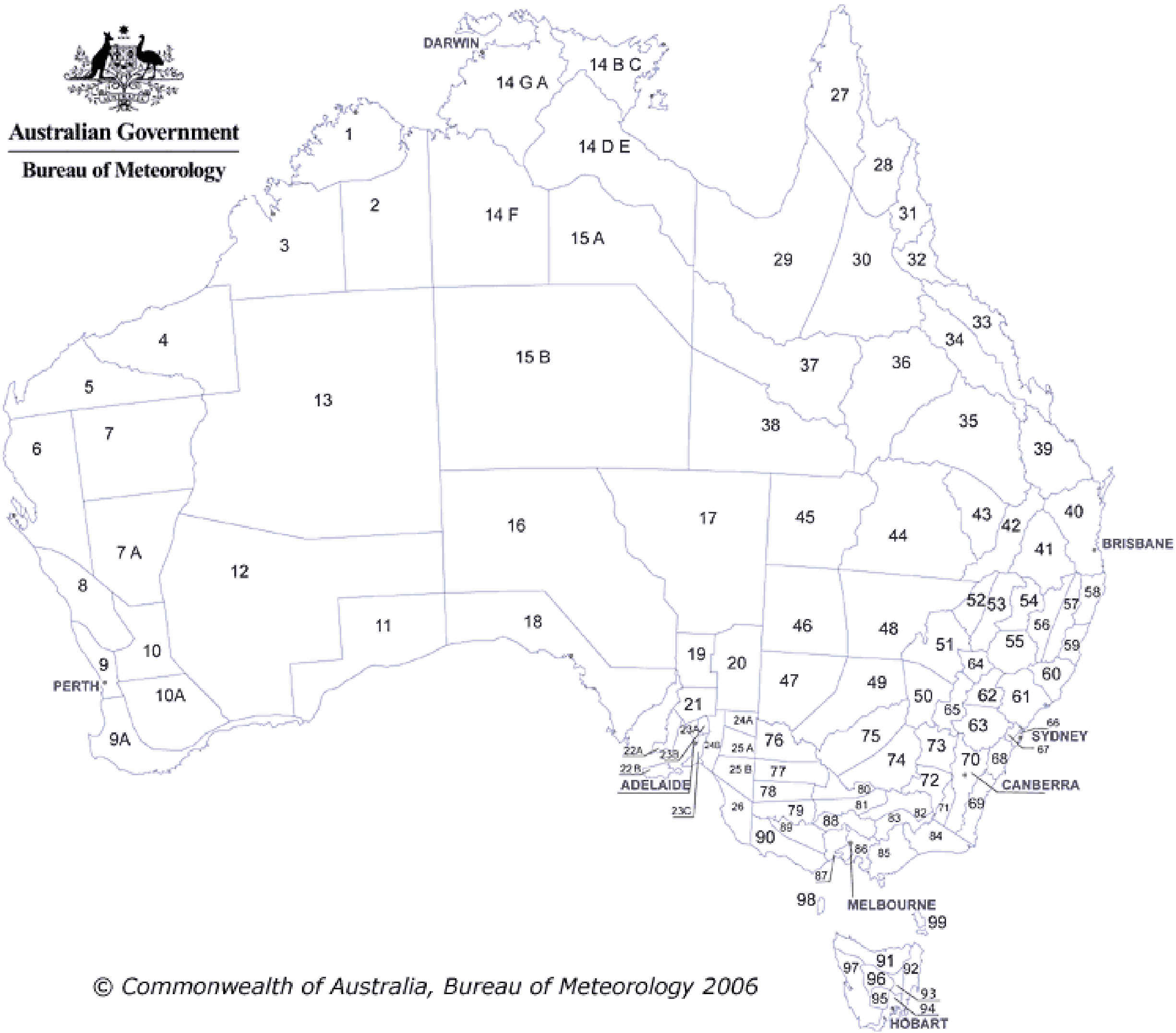


Figure 16. Map of Australia showing the rainfall districts.

1. Paroo
2. Warrego
3. Condamine-Culgoa
4. Moonie
5. Border Rivers
6. Gwydir
7. Namoi
8. Castlereagh
9. Macquarie-Bogan
10. Darling
11. Lachlan
12. Murrumbidgee
13. Lake George
14. Upper Murray
15. Kiewa
16. Ovens
17. Broken
18. Goulburn
19. Murray-Riverina
20. Campaspe
21. Loddon
22. Avoca
23. Benanee
24. Wimmera-Avon
25. Mallee
26. Lower Murray

Figure 17. Map of Murray–Darling Basin showing river catchments as defined on the Australian Landscape Water Balance.

Table 1. Average soil moisture in the Murray-Darling Basin for the past 34 months (January 2017 to October 2019) ranked against all the other 34-month periods for record breaking catchments. From AWRA–L v6 model with data spanning from January 1911 to October 2019. Catchment locations identified in Figure 17.

Catchment	Root-zone soil moisture (0–100cm) for 34 months (Jan 2017 to Oct 2019)
Border Rivers	Lowest on Record
Lachlan	Lowest on Record
Macquarie–Bogan	Lowest on Record
Namoi	Lowest on Record
Gwydir	Lowest on Record
Lake George	Lowest on Record
Moonie	Lowest on Record
Castlereagh	Lowest on Record
Murrumbidgee	Lowest on Record
Condamine–Culgoa	Lowest on Record

Table 2. Area-averaged rainfall totals for selected regions and periods from 6 to 34 months to October 2019. For the purposes of this table, the MDB North is those catchments that flow into the Darling River north of its junction with the Murray River, and the MDB South those catchments that flow into the Murray, excluding areas north of the river and downstream of its junction with the Darling.

Region	Period to Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Rank	Previous lowest (mm)	When previous lowest
Murray–Darling Basin	34	887	-36	1	947	1900-1902
	28	703	-38	2	680	1900-1902
	22	488	-45	1	528	1901-1902
	16	363	-43	2	347	1901-1902
	10	197	-51	2	156	1902
	6	103	-55	5	83	1982
Murray–Darling Basin North	34	854	-40	1	909	1900-1902
	28	650	-44	1	660	1900-1902
	22	463	-50	1	520	1901-1902
	16	328	-49	2	311	1901-1902
	10	168	-59	3	136	1902
	6	53	-74	1	66	1940
Murray–Darling Basin South	34	925	-30	3	889	1943-1945
	28	764	-31	3	702	1900-1902
	22	517	-39	1	524	2006-2007
	16	403	-37	6	355	1913-1914
	10	230	-41	9	178	1902
	6	160	-38	14	86	1914
New South Wales	34	1003	-36	1	1097	1900-1902
	28	761	-40	1	778	1900-1902
	22	550	-45	1	602	1901-1902
	16	400	-44	1	400	1901-1902
	10	217	-52	3	194	1902
	6	98	-60	4	91	1940

Table 3. Selected periods ending October 2019 of varying lengths from 3 months to 36 months for which the rainfall is lowest on record in river basins within the Murray-Darling Division. The rainfall percentage relative to the 1961–1990 mean is shown, together with the previous record and the period of that record (e.g. for the first entry, the previous lowest was the six months ending October 1940). An asterisk against the rainfall total signifies that the new record is more than 10% below the old record.

Region	Period ending Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Previous lowest (mm)	When previous lowest
Border Rivers	6	57*	-78	75	1940
	9	135*	-69	170	1902
	12	250	-62	259	1901-1902
	15	376	-53	414	1901-1902
	18	412*	-55	487	1918-1919
	21	549	-50	550	1917-1919
	24	697*	-48	833	1900-1902
	27	823	-44	912	1900-1902
	30	891*	-44	1085	1900-1902
	33	1132	-36	1206	1917-1920
	36	1290*	-35	1488	1939-1942
Moonie	3	13*	-88	19	1991
	6	43*	-80	66	1940
	18	367*	-52	420	1901-1902
	24	642	-42	666	1900-1902
	30	808	-39	873	1900-1902
	33	991	-33	999	1943-1946
	36	1095	-34	1175	1943-1946
Gwydir	3	21*	-84	31	1991
	6	63*	-77	86	1994
	9	117*	-74	180	1965
	12	244*	-64	284	1964-1965
	15	361*	-55	435	1901-1902
	18	392*	-59	510	1918-1919
	21	514	-54	558	1917-1919
	24	666*	-51	876	1900-1902
	27	788*	-47	920	1900-1902
	30	894*	-45	1110	1900-1902
	33	1081*	-40	1230	1917-1920
	36	1244*	-39	1425	1964-1967
Namoi	3	20*	-86	33	1928
	9	169	-61	182	1946
	15	420	-48	448	1945-1946
	18	442*	-53	519	1918-1919
	21	527	-52	566	1917-1919

Region	Period ending Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Previous lowest (mm)	When previous lowest
	24	677*	-49	823	1964-1966
	27	772*	-47	901	1900-1902
	30	859*	-47	1123	1900-1902
	33	1012*	-43	1225	1943-1946
	36	1154*	-42	1417	1964-1967
Castlereagh	3	17*	-85	19	1928
	18	396	-52	413	1918-1919
	24	610	-47	671	1900-1902
	27	695	-45	709	1900-1902
	30	737*	-47	872	1900-1902
	33	860*	-44	1003	1899-1902
	36	963*	-44	1115	1964-1967
Macquarie-Bogan	9	140	-63	154	1902
	30	750*	-44	834	1900-1902
	33	870*	-40	974	1917-1920
	36	983*	-40	1092	1964-1967
Condamine-Culgoa	6	45*	-76	60	1946
	18	342*	-52	388	1901-1902
	21	481	-44	489	1917-1919
	24	583	-44	596	1900-1902
	30	720	-42	768	1900-1902
	33	853	-38	869	1899-1902
	36	965	-39	1063	1943-1946
Warrego	36	844	-41	920	1943-1946
Paroo	36	473	-50	480	1926-1929
Darling	3	5*	-93	13	2006
	21	236	-55	245	1900-1902
	33	433	-48	435	1899-1902
Lower Murray	21	260	-49	288	1942-1944
	30	450	-39	459	1943-1945

Table 4. Record low district average rainfalls in New South Wales for various periods since January 2017. An asterisk against the rainfall total signifies that the new record is more than 10% below the old record.

Region	Period to Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Previous lowest (mm)	When previous lowest
Far Northwest (NSW)	3	2*	-96	4	2006
	21	126*	-69	155	2016-2018
	24	162*	-66	189	1900-1902
	27	200	-62	210	1900-1902
	30	224	-62	245	1900-1902
	33	248*	-62	297	1926-1929
Lower Darling (NSW)	3	8*	-89	13	1914
	21	203	-57	212	1942-1944
Upper Darling (NSW)	3	5*	-92	9	1957
	6	36	-76	37	1940
	21	259	-57	281	1900-1902
	36	557*	-49	620	1943-1946
Southwest Plains (NSW)	3	10*	-88	15	2007
	33	568	-40	568	1899-1902
Central Western Plains South (NSW)	3	18*	-83	21	1982
	9	132	-60	134	2018
	21	389*	-52	435	1917-1919
	24	527	-45	530	1900-1902
	30	663	-44	735	1900-1902
	33	778	-39	863	1943-1946
	36	888	-38	944	1979-1982
Central Western Plains North (NSW)	3	8*	-91	16	1931
	6	41*	-80	58	1982
	9	94	-71	103	1902
	18	299	-56	300	1928-1929
	21	337	-58	352	1917-1919
	24	470	-51	472	1900-1902
	30	592	-49	630	1900-1902
	33	695	-45	748	1899-1902
	36	784	-45	852	1964-1967
Northwest Plains West (NSW)	3	6*	-94	15	1928
	9	96*	-72	107	1902
	15	252	-59	252	1901-1902
	18	266*	-64	362	1901-1902

Region	Period to Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Previous lowest (mm)	When previous lowest
	21	365*	-58	426	1917-1919
	24	480*	-55	539	1900-1902
	27	555	-52	580	1900-1902
	30	607*	-52	732	1900-1902
	33	712*	-49	828	1899-1902
	36	801*	-50	1005	1943-1946
Northwest Plains East (NSW)	3	13*	-89	25	1928
	6	61	-76	62	1994
	9	131*	-68	154	1902
	15	344	-54	358	1901-1902
	18	365*	-58	472	1918-1919
	21	473	-54	514	1917-1919
	24	611*	-51	719	1900-1902
	27	719	-47	760	1900-1902
	30	790*	-47	932	1900-1902
	33	931*	-44	1098	1899-1902
	36	1050*	-44	1260	1964-1967
Northwest Slopes North (NSW)	3	25*	-84	31	1991
	6	64*	-78	88	1940
	9	136*	-72	194	1965
	12	273*	-63	307	1964-1965
	15	403*	-55	466	1918-1919
	18	440*	-57	522	1918-1919
	21	559	-54	576	1917-1919
	24	713*	-51	975	1964-1966
	27	851*	-47	1040	1900-1902
	30	963*	-45	1235	1918-1920
	33	1202	-38	1289	1917-1920
	36	1396*	-37	1598	1964-1967
Northwest Slopes South (NSW)	3	26*	-83	41	1928
	18	509*	-50	566	1939-1940
	21	597	-49	620	1917-1919
	24	761*	-47	884	1964-1966
	27	862*	-45	1019	1900-1902
	30	963*	-44	1205	1938-1940
	33	1140*	-40	1290	1937-1940
	36	1307*	-39	1516	1937-1940

Region	Period to Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Previous lowest (mm)	When previous lowest
Northern Tablelands West (NSW)	3	45*	-75	54	1991
	6	90*	-74	113	1940
	9	180*	-68	287	1918
	12	366*	-58	463	1964-1965
	15	530*	-49	649	1939-1940
	18	590*	-51	704	1918-1919
	21	745	-47	808	1917-1919
	24	971*	-44	1214	1938-1940
	27	1123*	-41	1356	1900-1902
	30	1250*	-39	1528	1918-1920
	33	1592	-30	1633	1917-1920
	36	1852	-28	1986	1938-1941
Northern Tablelands East (NSW)	18	813	-43	819	1901-1902
	21	1090	-39	1131	1917-1919
	24	1404	-35	1413	1900-1902
	30	1710	-32	1710	2001-2003
Upper North Coast (NSW)	21	1509	-38	1591	1914-1916
	24	1854	-35	1871	1914-1916
Manning (NSW)	9	406	-54	430	1991
	12	614	-50	636	1939-1940
Hunter (NSW)	30	1439	-35	1446	1939-1941
Central Tablelands North (NSW)	30	1069	-37	1141	1938-1940
Central Tablelands South (NSW)	30	1374	-34	1420	2002-2004
Central Western Slopes North (NSW)	6	71	-74	77	1994
	24	754	-42	788	1900-1902
	30	889*	-44	1026	1900-1902
	33	1037*	-40	1162	1937-1940
	36	1155*	-41	1315	1964-1967
Central Western Slopes South (NSW)	21	568	-46	582	2005-2007
	24	745	-39	785	2005-2007
	27	850	-38	887	1900-1902
	30	896*	-41	1066	2002-2004
	33	1068	-36	1132	1943-1946
	36	1210	-34	1248	1979-1982
Illawarra (NSW)	27	1453	-42	1482	1939-1941

Region	Period to Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Previous lowest (mm)	When previous lowest
	30	1562	-43	1567	1939-1941
Riverina West (NSW)	21	345	-49	358	1900-1902

Table 5. Record low district average rainfalls for States other than New South Wales for selected periods since January 2017. An asterisk against the rainfall total signifies that the new record is more than 10% below the old record.

Region	Period to Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Previous lowest (mm)	When previous lowest
Queensland					
Upper Carpentaria (Qld)	3	2	-95	2	1977
East Darling Downs (Qld)	6	64*	-75	101	1940
	18	473	-49	492	1918-1919
	24	768*	-43	917	1900-1902
	27	888*	-40	1005	1900-1902
	30	953*	-41	1118	1992-1994
	33	1209	-32	1218	1917-1920
	36	1359*	-33	1525	1992-1995
West Darling Downs (Qld)	6	57*	-74	69	1902
	18	408	-50	426	1918-1919
	30	911	-35	928	1900-1902
	36	1218	-31	1342	1990-1993
Maranoa (Qld)	18	386	-50	409	1901-1902
	30	851	-36	852	1900-1902
Warrego (Qld)	36	711	-45	749	1943-1946
Victoria					
East Gippsland (Victoria)	21	1116	-31	1121	1978-1980
	33	1852	-27	1954	1985-1988
	36	1995*	-28	2229	2001-2004
West Gippsland (Victoria)	21	1212	-26	1235	1936-1938
	36	2174	-22	2210	2005-2008
Western Australia					
North Coast (WA)	30	726	-31	732	2000-2002
	33	793	-29	799	2005-2008
South Coast (WA)	24	1288	-20	1302	2013-2015
	30	1854	-17	1858	1985-1987
South Central (WA)	24	598	-26	609	2008-2010
Northeast (WA)	9	38*	-76	50	1936
South Australia					
Northwest (SA)	9	28*	-80	40	1902
Upper North (SA)	21	242	-56	254	1927-1929
	30	385	-52	397	1927-1929

Region	Period to Oct 2019 (months)	Total (mm)	Percentage above/below average (%)	Previous lowest (mm)	When previous lowest
Northeast (SA)	21	143*	-63	176	1942-1944
Lower North (SA)	30	698	-34	735	1927-1929
Upper and Lower Murray Valley (SA)	21	335	-42	353	1942-1944
	27	489	-34	507	1943-1945
	30	545	-34	561	1943-1945
Murray Mallee and Upper Southeast (SA)	21	503	-29	517	1943-1945

Table 6. State, national and regional rainfall for the 10 months January to October 2019. Values that are lowest on record are shown in bold.

Region	Total (mm)	Percent above/below average (%)	Rank
Australia	250	-34	2
Western Australia	154	-47	3
Northern Territory	232	-45	5
South Australia	**71**	**-63**	**1**
Queensland	468	-6	54
New South Wales/ACT	217	-52	3
Victoria	413	-26	13
Tasmania	1079	-9	32
Murray-Darling Basin	197	-51	2
Southwest Western Australia	437	-29	5

Table 7. Record low rainfalls for selected locations with 50 years or more of data (sometimes combining multiple sites) for the period from January to September 2019. Values which are more than 30% below the previous record are shown in bold.

Location	State	Total (mm)	Previous record (mm)
Forrest	**WA**	**29.6**	**49.8 (1957)**
Warburton	**WA**	**19.2**	**33.9 (1961)**
Wave Hill	NT	122.2	148.7 (1992)
Tennant Creek	NT	30.6	32.0 (1883)
Hermannsburg	NT	19.3	27.2 (1924)
Yulara	**NT**	**20.0**	**37.0 (2007)**
Oodnadatta	**SA**	**12.4**	**21.8 (2018)**
Marree	**SA**	**9.4**	**14.6 (2002)**
Cook	SA	27.8	31.0 (1928)
Lady Elliot Island	**QLD**	**300.2**	**493.0 (2001)**
Toogoolawah	QLD	253.0	273.0 (1977)
Bell Store	QLD	166.4	179.6 (2005)
Dalveen	QLD	199.1	230.3 (1902)
Glenelg	**QLD**	**104.0**	**178.4 (1902)**
Pratten	**QLD**	**116.5**	**171.6 (1902)**
Stanthorpe	**QLD**	**138.3**	**204.2 (1902)**
Texas	QLD	107.2	147.2 (1965)
Wallangarra	QLD	158.6	176.3 (1902)
Yangan	**QLD**	**143.2**	**214.3 (1922)**
Leslie Dam	QLD	159.4	169.2 (1957)
Warwick	QLD	168.0	178.9 (1902)
Yuleba	QLD	92.4	107.1 (1902)
St. George	QLD	86.6	103.5 (1902)
Lake Victoria	NSW	57.0	64.0 (1929)
Croppa Creek	NSW	120.6	140.2 (1965)
Pallamallawa	NSW	135.6	152.2 (2002)
Moree	NSW	83.0	110.1 (1902)
Warialda	NSW	154.4	171.5 (1965)
Deepwater	**NSW**	**182.4**	**264.1 (1940)**
Glen Innes Ag Res	NSW	229.5	291.3 (1965)
Old Koreelah	**NSW**	**209.8**	**317.2 (1966)**
Uralla (Salisbury Court)	**NSW**	**167.6**	**253.2 (2018)**
Emmaville	NSW	170.8	213.8 (1905)
Tenterfield	**NSW**	**144.6**	**223.2 (1888)**
Armidale	NSW	194.2	244.1 (1965)
Guyra	**NSW**	**211.8**	**333.8 (1965)**
Drake	NSW	243.9	246.1 (1902)
Krambach	NSW	332.6	372.4 (1994)
Wingham	NSW	311.0	312.4 (1994)
Port Macquarie	NSW	420.6	554.0 (1991)
Taree	NSW	339.4	379.2 (1902)

References and further information

Data used in this statement is current as of 22 November 2019 and is subject to the Bureau's routine quality control processes. Maximum temperature observations prior to 1910 have not been used unless it is known that they were measured using standard equipment comparable to post-1910 standards.

Further information is available from:

www.bom.gov.au/climate

www.bom.gov.au/water/

Australia's changing climate:

www.bom.gov.au/state-of-the-climate/

Monthly Drought Statement:

www.bom.gov.au/climate/drought/