The Bureau of Meteorology

Special Climate Statement 77

Persistent heavy rain and flooding in eastern Australia during spring 2022

21 September 2023

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Cover image: Murrumbidgee River at Uriarra Crossing, ACT, October 2022.

Photo by Mahadi Hasan

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Summary

- Spring (September to November) 2022 was the wettest on record (with rainfall analyses starting in 1900) for the Murray–Darling Basin (MDB), New South Wales and Victoria and the second-wettest for Australia overall.
- Spring rainfall was double the 1961–1990 average across the MDB, and more than 3 times above average for much of western New South Wales and north-west Victoria.
- The rainfall was widespread and prolonged, with all MDB, New South Wales and Victoria monthly rainfall totals for August, September, October and November 2022 in their respective 20 wettest on record since 1900.
- Many rainfall stations across south-eastern Australia had their highest total spring rainfall on record, including more than 200 stations with at least 100 years of observations.
- At the start of spring 2022 many of the MDB catchments had relatively wet soils, following the rainfall in previous months, and overall water storage in the MDB was at its highest level since October 2012, meaning there was limited air space in dams to support flood mitigation.
- Over 50% of streamflow sites in the MDB had their highest October or November streamflow on record, and many major storages released water during this period.
- From the start of October 2022 widespread major riverine flooding affected New South Wales, Victoria, Queensland and Tasmania, with waters in the MDB flowing downstream into South Australia by late December 2022.
- Around one-third of Bureau flood forecasting sites in New South Wales, Victoria and Tasmania reached major flooding level at least once during spring 2022.
- Some gauges exceeded their historical flood peaks during spring 2022, including on the Lachlan and Murrumbidgee rivers (New South Wales), the Campaspe River at Rochester (Victoria) and in the Tamar catchment (Tasmania).
- Many inland towns were impacted by flooding in several states, including New South Wales, Victoria and South Australia.
- Flooding in the second half of 2022 in the southern MDB was more significant, in terms of extent, severity and duration, than any other flooding in the region since 2009–10, using a consistent set of flood observations.
- Three major climate drivers likely contributed to the unusually wet conditions prior to and during spring 2022: an active La Niña phase of the El Niño–Southern Oscillation (ENSO), a negative Indian Ocean Dipole (IOD) event and a persistent positive phase of the Southern Annular Mode (SAM).
- The spring 2022 rainfall and flooding occurred against the background of global warming, which increases the likelihood of heavy rainfall events when other climate drivers combine to bring moist air over south-eastern Australia.

Introduction

The Bureau of Meteorology Special Climate Statements provide a detailed summary of significant weather and climate in Australia. They are produced on an occasional basis, when the weather or climate is unusual in the context of the climatology of the impacted region. Special Climate Statements serve as a historical record, informing the Australian public, Governments and the media by providing access to key data and information.

Spring 2022 saw the highest rainfall on record for the Murray–Darling Basin (MDB), New South Wales and Victoria, in the Bureau's rainfall analyses starting in 1900. Although there were few extreme daily rainfall totals, the spring 2022 total was more than double the 1961–1990 average for most of the MDB.

The rain fell on catchments that had received above average rainfall in the two years prior to spring 2022. Soils were already saturated, many water storages in the MDB and south-eastern Australia were at or near capacity, and streamflow at many locations was higher than average.

The antecedent conditions combined with the record rainfall resulted in extensive major flooding across the MDB, eventually flowing into South Australia. Victoria and Tasmania also experienced major flooding, particularly in October 2022. Comparison using a consistent set of flood observations showed that the spring 2022 floods in the southern MDB had a greater extent, severity and duration than the 2010–11 floods. However, at the national level 2010–11 remains the most significant flooding in recent decades.

This Special Climate Statement is in two sections. This document contains the analysis and results. A Supplementary Information document contains additional figures and tables.

1. Antecedent conditions

- Spring (September to November) 2022 was the wettest on record (with rainfall analyses starting in 1900) for the Murray–Darling Basin (MDB), New South Wales and Victoria (Figure 1a) and the second-wettest for Australia overall (Table 1).
- Total spring rainfall was double the 1961–1990 average across the MDB, and more than 3 times above average for much of western New South Wales and north-west Victoria (Figure 1b).
- Three major climate drivers likely contributed to the unusually wet conditions prior to and during spring 2022: an active La Niña phase of the El Niño–Southern Oscillation (ENSO), a negative Indian Ocean Dipole (IOD) event and a persistent positive phase of the Southern Annular Mode (SAM).
- The natural variability occurred against the background of global warming, with a global mean temperature for 2022 of 1.15 °C (with an uncertainty range of 1.02 to 1.28 °C) above a 1850–1900 pre-industrial baseline.
- Bureau long-range forecasts were highly accurate, in the months beforehand, in predicting an unusually wet spring.

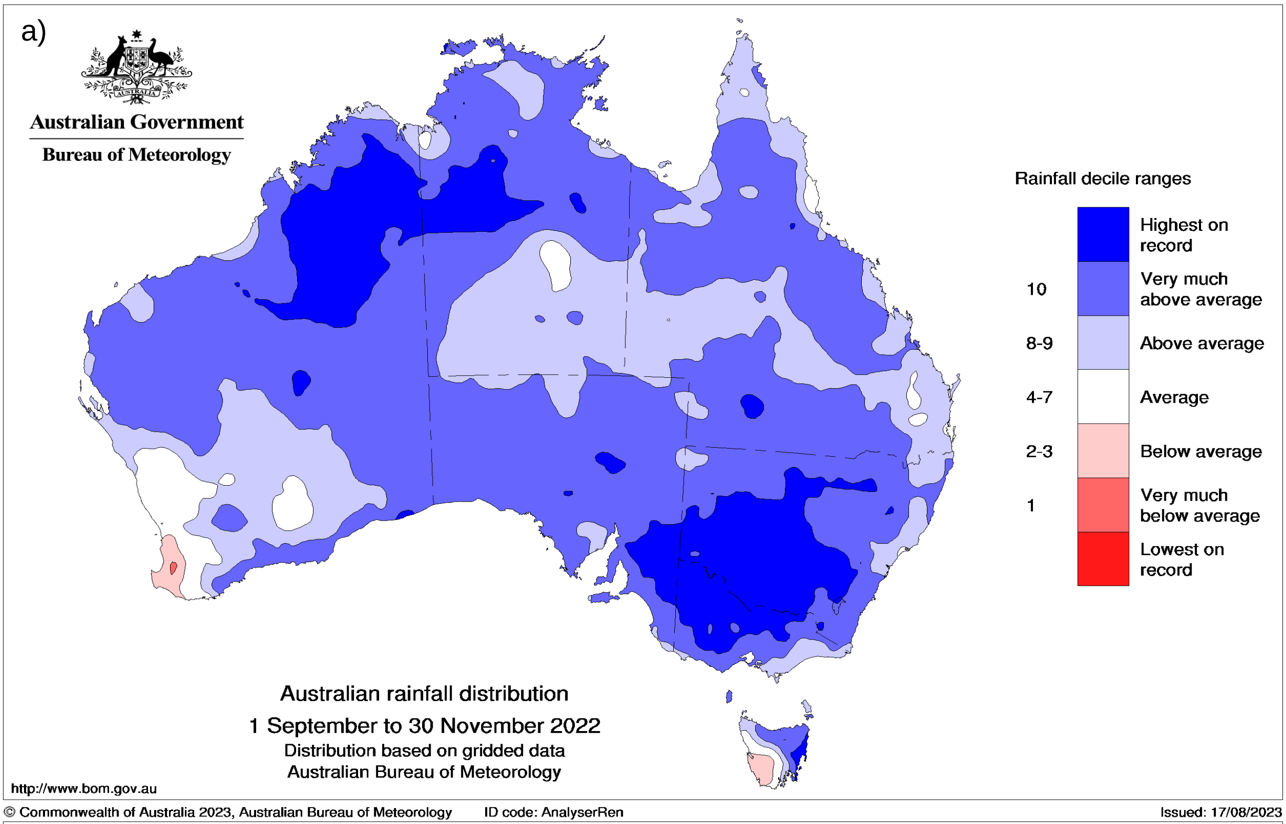
1.1. Climate drivers

La Niña in the Pacific Ocean

Australia's climate was likely influenced by 3 consecutive La Niña events in the Pacific Ocean over the 2020–22 period (Supplementary Information[1] (SI) Figure 1). While back-to-back La Niña events are not uncommon and have occurred in approximately half of all past events since 1900, 3 consecutive La Niña events had previously occurred only 3 times: 1954–57, 1973–76, and 1998–2001. All 3 previous triple La Niña periods, particularly 1973–76, were associated with widespread and prolonged flooding from extended periods of above average rainfall.

The peak of the 2021–22 La Niña occurred in January 2022, then declined slowly over autumn, although some atmospheric indicators continued to show a La Niña-like signal until the end of June. By the beginning of spring 2022, key atmospheric and oceanic ENSO indicators showed an established La Niña, with the Bureau of Meteorology's ENSO Outlook on 13 September declaring a third consecutive La Niña event underway. In the tropical Pacific Ocean, sea surface temperatures had been cooling since July and crossed the La Niña threshold (-0.8 °C in the NINO3.4 region) in September. Other atmospheric indicators including the Southern Oscillation Index, trade wind strength, and equatorial cloudiness were also displaying patterns typical of a La Niña event. La Niña conditions gradually strengthened and matured during October (Figure 2) and November, before easing in early 2023. The warmer oceans to the north of Australia, driven by the La Niña in the tropical Pacific, combined with increased cloudiness and rainfall likely contributed to the high rainfall over eastern Australia in spring 2022.

[1] Supplementary Information (SI) Figures and Tables



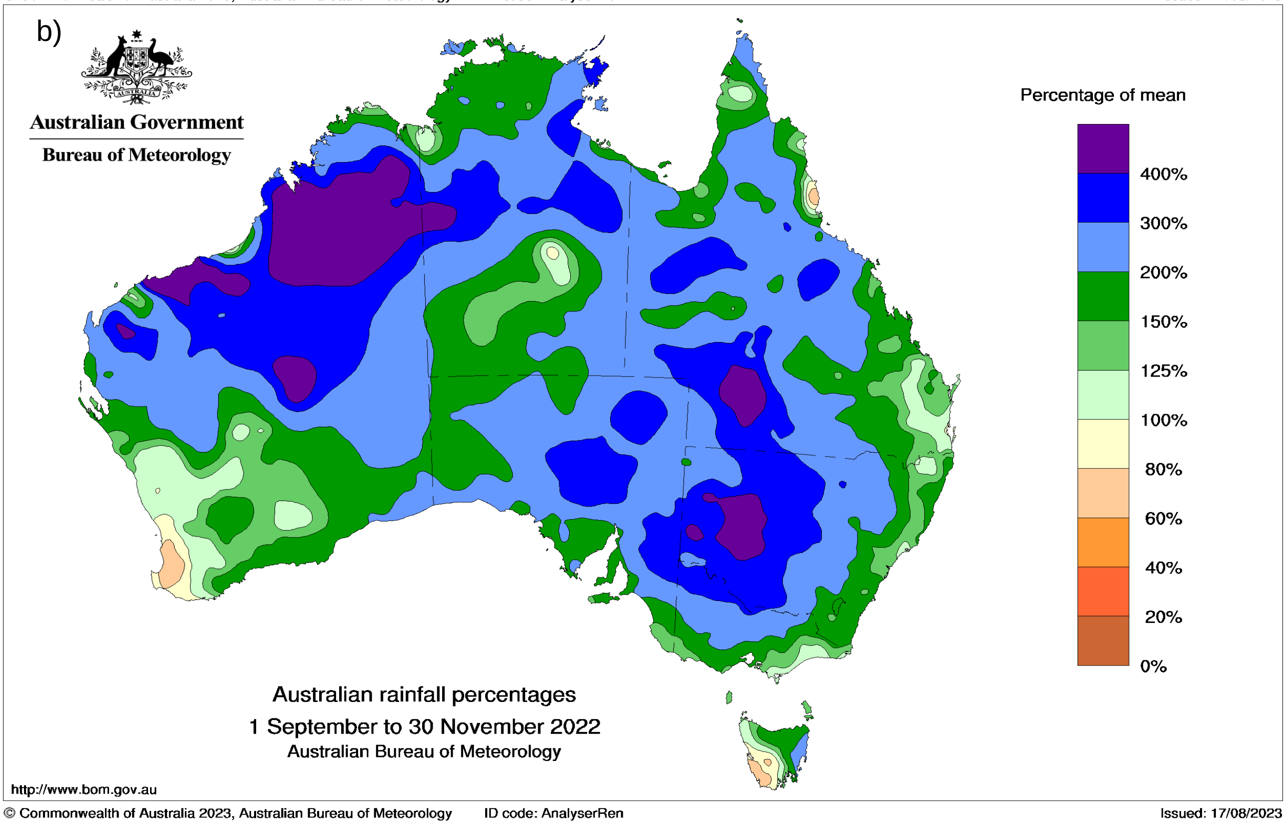


Figure 1: For spring (September to November) 2022 a) observed rainfall distribution, relative to all years since 1900, and b) total rainfall as a fraction of the 1961–1990 climatological average, multiplied by 100.

Negative Indian Ocean Dipole

Signs of negative IOD development began from late autumn 2022, with the IOD index first tipping over negative IOD thresholds (cooler than −0.4 °C) at the end of June (SI Figure 2). The negative IOD event remained very strong from July through to September. During a negative IOD event, warm waters in the tropical east Indian Ocean are a source of moist air. Weather systems are more likely to transport the moist tropical air to south-eastern Australia. In the August to November 2022 period, numerous slow-moving low-pressure systems and associated troughs and cold fronts moved across south-east Australia, bringing significant rainfall. The rainfall was likely enhanced by the presence of both the negative IOD and La Niña providing a source for the moist tropical air. The negative IOD event weakened over spring and dissipated in November as monsoon conditions developed over northern Australia.

Positive Southern Annular Mode

The SAM was mostly positive during spring 2022 (SI Figure 3). This resulted in the mid-latitude westerly jet stream being further south than usual. The consequent increased onshore flow likely contributed to the above average rainfall for eastern Tasmania, eastern Victoria, eastern New South Wales and south-eastern Queensland. The position of the westerly jet stream due to the persistent positive SAM in spring 2022 also likely contributed to the below average rainfall for western Tasmania (Figure 1a).

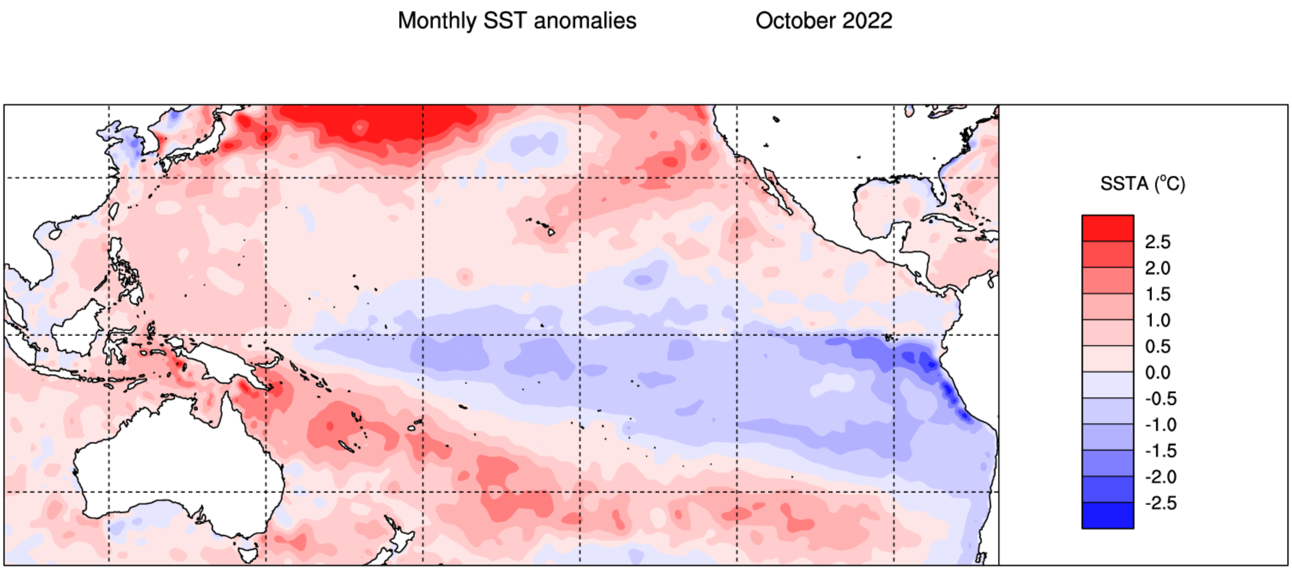


Figure 2: Monthly sea surface temperature anomalies (relative to the 1961–1990 average) for October 2022 using the Bureau dataset.

1.2. Global warming

Australia's climate is increasingly affected by global warming. The La Niña, negative IOD and positive phase SAM in spring 2022 occurred against this background. Australia's climate has warmed on average by 1.47 ± 0.24 °C between when national records began in 1910 and 2021, with most of the warming occurring since 1950. The ocean waters around Australia have also warmed significantly over the past century, rising by 1.05 °C since 1900, with 8 of the 10 warmest years on record occurring since 2010[2]. Globally, the years 2015 to 2022 were the 8 warmest on record, and the global mean temperature in 2022 was 1.15 °C (with an uncertainty range of 1.02 to 1.28 °C) above a 1850–1900 pre-industrial baseline[3].

As the climate warms, the atmosphere can hold more water vapour than cooler air can. This relationship alone can increase moisture capacity in the atmosphere by 7% per 1 °C of warming. Increased atmospheric moisture can also provide more energy for some processes that generate extreme rainfall events, which can further increase the intensity of heavy rainfall due to global warming.

When climate drivers favour bringing rain-bearing weather systems over Australia, the increased likelihood of heavy rainfall events due to global warming may offset the decrease in average rainfall due to changes in atmospheric circulation. For southern Australia[4] as a whole, 2022 was the second-wettest cool season (April to October) on record since 1900, behind only 1974. It was only the fourth year in the 21st century, after 2005, 2010, and 2016, that the southern Australia cool season rainfall was above the 1961–1990 average. In all 4 years, either or both a La Niña or negative Indian Ocean dipole was present.

1.3. Long-range forecasts

The Bureau of Meteorology's ACCESS-S long-range forecast for August to October 2022 predicted very likely (over 80% chance) above median rainfall across much of Australia (SI Figure 4a), with likely below median rainfall for south-west Western Australia and western Tasmania. Every forecast issued in May, June and July for the season of August to October was highly accurate, with each above/below median forecast having a weighted percent correct (WPC) skill above 90%, well beyond that expected by chance. Unusually wet conditions were also skilfully predicted by the Bureau's seasonal Forewarned is Forearmed (FWFA) outlooks (SI Figure 4b).

The spring 2022 long-range forecasts from the Bureau and international climate models indicated that La Niña might be short-lived and peak during spring, with a return to neutral conditions in early 2023. All models surveyed by the Bureau indicated that negative IOD conditions were likely to persist over spring 2022.

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[2] State of the Climate: http://www.bom.gov.au/state-of-the-climate/2022.
[3] WMO state of the global climate 2022: https://public.wmo.int/en/resources/library/state-of-global-climate-2022.
[4] Defined as south of 26°S, the South Australia – Northern Territory border.

2. Rainfall

- Spring (September to November) 2022 rainfall was characterised by a large number of slow-moving low pressure systems moved across south-eastern Australia, rather than individual extremes.
- When these systems combined with tropical air masses from the north, they produced extensive cloud, heavy rain and thunderstorms, which in some areas brought large hail, damaging winds and flash flooding.
- Indicative of the widespread rain, there were 13 days during October with MDB area-average rainfall exceeding 5 mm, equalling the monthly record set in January 1974.
- In contrast, no individual day in spring 2022 saw the MDB area-average rainfall exceed 20 mm, a threshold that had been reached 38 times previously since 1900.
- For the MDB, New South Wales and Victoria, all monthly rainfall totals for August, September, October and November 2022 were in their respective 20 wettest on record since 1900 (Table 2).
- The MDB, New South Wales and Victoria all had their wettest spring on record (since 1900), exceeding their previous records by around 40 mm, and for Australia as a whole it was the second-wettest spring on record, behind 2010.
- More than 200 stations with at least 100 years of data had their wettest spring on record.
- For the August to November 2022 period, it was the wettest on record (since 1900) for 20 of the 26 catchments in the MDB.

2.1. Major weather systems

September

Between 7 and 9 September, a low-pressure system moved across the Great Australian Bight and drew tropical moisture into a cold front, resulting in heavy rain and thunderstorms over South Australia and inland parts of eastern Australia.

On 15 and 16 September, significant rain fell over the inland side of the ranges of the New South Wales and Queensland border region, due to a complex series of cold fronts and troughs associated with a deep low-pressure system moving eastwards well south of the Great Australian Bight.

On 28 and 29 September, a low pressure system in the Tasman Sea and a strong high pressure system south of Tasmania produced showers across Victoria and south-east New South Wales.

October

On 12 October, a low pressure system south of the mainland linked up with tropical moisture, forming an extensive, slow-moving rain band over south-east Australia.

Between 19 and 22 October, troughs and a cut-off low crossing the continent produced thick middle- and upper-level cloud, bringing a moist airmass, widespread showers and embedded thunderstorms across much of Queensland.

Between 20 and 26 October, a low pressure system developing over New South Wales was overtaken by a strong cold front crossing further south, bringing thunderstorms and moderate to heavy rainfall to large areas. These storms continued to affect parts of Victoria and south-east South

Australia as a low pressure centre reformed on a remnant trough behind the front, with the low then becoming slow moving over Tasmania.

November

At the start of November, a cold front interacted with moist tropical air to bring widespread rain to inland New South Wales and eastern Queensland. Locally intense rainfall was embedded in this system, bringing flash flooding to parts of the South West Slopes District of New South Wales.

On 13 November, thunderstorms in a cloudband affected much of the Central West of New South Wales. Earlier, the same system brought thunderstorms to the north-west of South Australia on 11 November and a severe thunderstorm struck Alice Springs on 12 November. Strong winds, heavy rain and localised flash flooding also affected parts of Victoria on 13 November, including the Mornington Peninsula. This was the last significant large-scale spring rain event over inland eastern Australia, but in southern Victoria rainfall continued throughout the second half of November.

2.2. Major individual rain events

Given the significant flood impacts the number of long-term stations that set daily rainfall records for a given month was relatively modest (SI Table 1). Only a handful of locations had their wettest day on record for any month during spring 2022.

October

The most significant individual widespread rainfall occurred on 13 and 14 October (Figure 3), with heavy rain on and north of the ranges in Victoria and in the state's south-west, and in northern Tasmania. 14 October was the wettest October day on record for Tasmania overall. 188.8 mm fell at Mount Barrow, the fourth-highest station October daily total on record for Tasmania, and numerous other locations in the north exceeded 100 mm. 13 and 14 October were the fifth- and fourth-wettest October days on record for Victoria. Lima East (Charnwood), south of Benalla, had 123.2 mm on 13 October and 88.4 mm on 14 October for a 2-day total of 211.6 mm.

The rain was most significant in north-central Victoria. It was the wettest 2-day period on record (since 1900) for the Campaspe catchment and the second-wettest for the Loddon catchment (SI Table 2). Both catchments, along with the Goulburn, set two-day records for October. Extreme rainfalls at this timescale are relatively rare in the cool season; prior to this 2022 event, in each of the 3 catchments, 7 of the 8 highest 2-day totals had occurred between late November and April, when antecedent conditions are normally wetter. 23–24 September 1916 was the only previous instance of a comparable event during the cool season.

Further daily records were set across large areas between 19 and 25 October. This was initially the result of a broad area of rain which mostly affected inland areas of South Australia and southern Queensland. Later it was through scattered thunderstorm activity across south-eastern Australia.

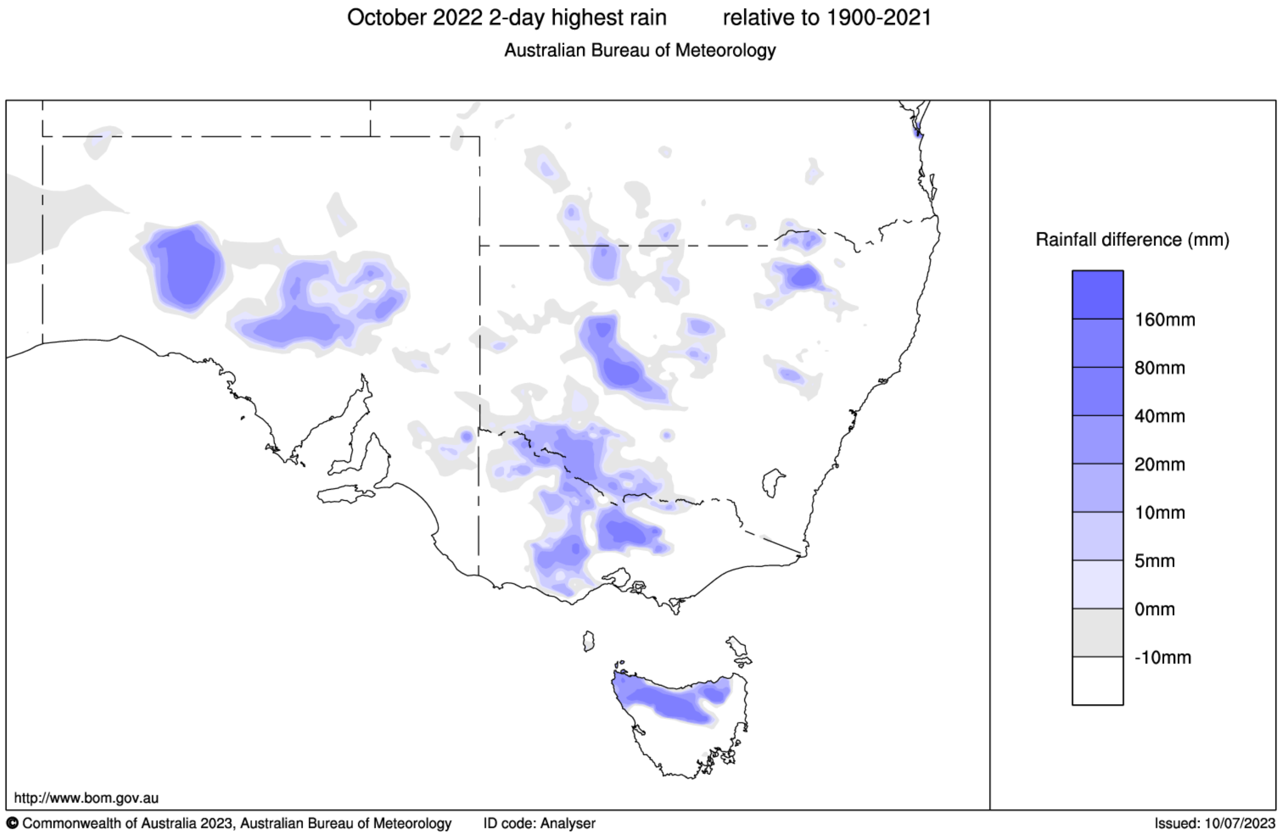

Figure 3: The highest 2-day rainfall in October 2022, relative to the record high 2-day rainfall totals in the 1900 to 2021 period. Purple shading indicates by how much the October 2022 highest 2-day rainfall total exceeded the previous October record.

November

There were 2 occasions of intense localised rainfall in New South Wales in the first half of November. While these affected a smaller area than the mid-October events in Victoria and Tasmania, both resulted in extreme flash flooding in the affected areas as well as exacerbating local riverine flooding.

The first occurred overnight on 31 October–1 November, particularly impacting parts of the South-West Slopes district of New South Wales. Whilst no Bureau gauge in the region exceeded 80 mm for the 24 hours ending at 9 am on 1 November, it is likely that localised heavier falls occurred. November daily records[5] were set at a number of sites in the Central and Southern Tablelands.

The second affected the Central West of New South Wales on 13 and 14 November. Forbes Airport AWS recorded 110.2 mm of rain in 6 hours on the afternoon and evening of 13 November. The Forbes Airport AWS daily total of 118.0 mm to 9 am 14 November (SI Figure 5) was a record for any month at Forbes, with observations starting in 1875. November daily rainfall records were also set at many other sites in the region (SI Table 1). Storms caused flash flooding across the Central West

[5] The Bureau defines daily rainfall as that recorded in the 24 hours *to* 9am local time. Accordingly, rain that fell *after* 9am on 31 October 2022 is included in the November 2022 rainfall statistics.

of New South Wales. Thunderstorms also affected parts of eastern South Australia and southern Victoria, with some November daily records set in both states.

2.3. Monthly and longer timescales

Rainfall was very much above average (in the wettest 10% of all years since 1900) over most of mainland eastern Australia in August, September, October and November 2022 (Figure 4). Nationally, September was the fifth-wettest on record (compared to all years since 1900), October the second-wettest and November the tenth-wettest on record (Table 2).

August

August rainfall was very much above average over most of the Tablelands and Western Slopes districts of New South Wales, and parts of the Victorian ranges. August totals were highest on record in parts of the Central Tablelands District of New South Wales.

September

In September, very much above average rainfall fell over most of the MDB. Few station records were set, but many had their second-wettest September behind the extremely wet September 2016[6]. Overall, September was the third-wettest on record for New South Wales and the fourth-wettest for the MDB.

October

In October, rainfall was very much above average over almost the entire MDB and adjoining areas of Victoria and South Australia (Figure 4). Very much above average rainfall also extended to many parts of Queensland, especially inland areas south of the tropics, and northern and eastern Tasmania. It was the wettest October on record for most of the western half of New South Wales, northern and central Victoria, and much of inland South Australia.

Overall, it was the wettest October on record for New South Wales, Victoria, South Australia and the Murray–Darling Basin (Table 2). The Victorian October area-average total of 161.4 mm was the wettest month on record, for any month since 1900, exceeding the previous record of 152.8 mm set in October 1975. For the MDB, whose most extreme wet months normally occur during the warm season, October was the wettest month to occur outside of January to April.

It was also the wettest month on record for a number of catchments in the southern Murray–Darling Basin, including the Broken, Goulburn, Campaspe, Loddon, Murray Riverina, Benanee and Mallee catchments[7], as well as for the Lake Corangamite catchment in southern Victoria (SI Table 3). The Murray Riverina's October catchment average of 186.8 mm was more than 50 mm above the previous record. For a further 6 catchments within the MDB, it was the wettest October on record.

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[6] Special Climate Statement 58: Record September rains continue wet period in much of Australia. http://www.bom.gov.au/climate/current/statements/scs58.pdf.
[7] Maps of catchment regions are available at: http://www.bom.gov.au/hydro/wr/basins

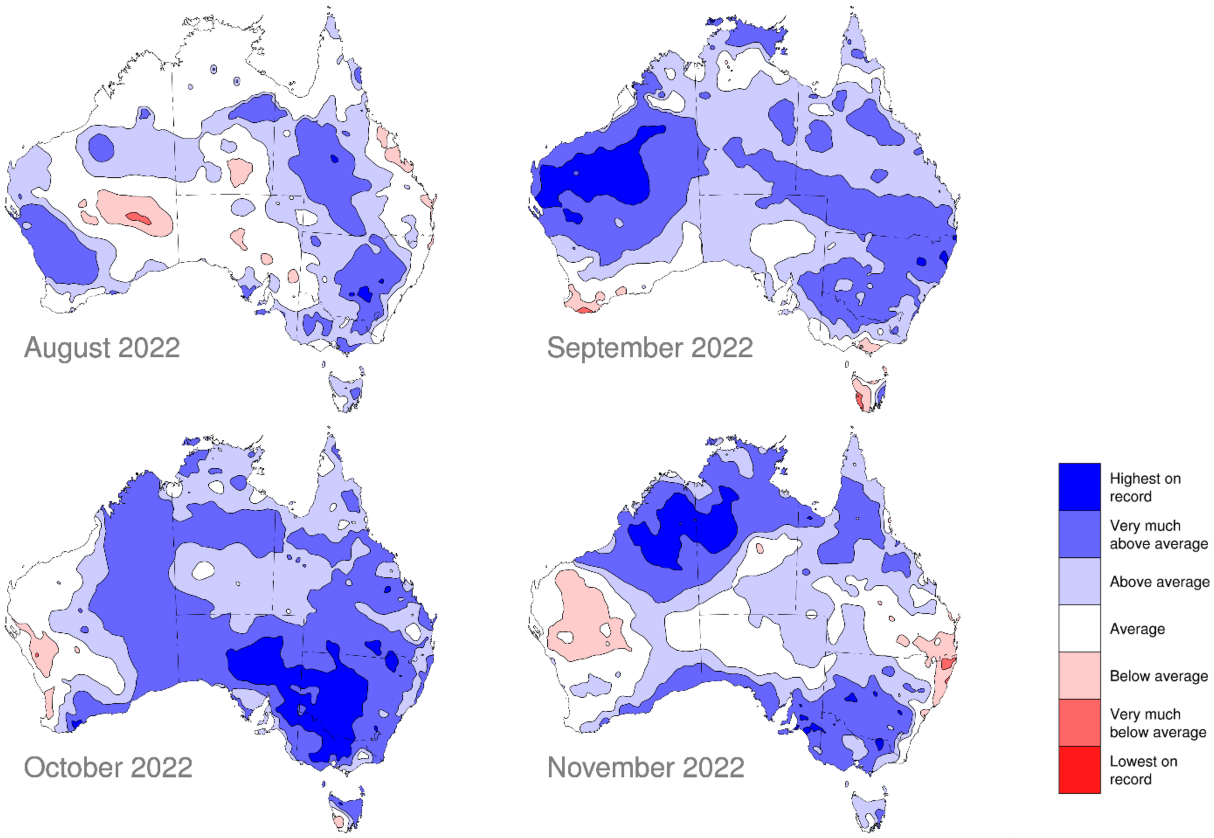

Figure 4: Monthly rainfall distribution, relative to all years since 1900, for August to November 2022.

November

Very high rainfall persisted into the first half of November 2022 in some areas, particularly on and inland of the southern ranges. It was the wettest November on record for Victoria's Mallee, whilst in the Australian Alps, the Kiewa catchment had its wettest November on record and the Upper Murray its second-wettest behind November 2021. Victoria had its fourth-wettest November on record overall.

Spring

Spring (September to November) 2022 rainfall totals in the MDB, southern Victoria and Tasmania were generally between 200 and 600 mm (Figure 5). Much of western Tasmania, mainland alpine regions and the New South Wales highlands received up to 800 mm of rainfall. More than 200 stations with at least 100 years of data had their wettest spring on record (SI Table 4).

Most areas of the MDB south of the Queensland border, and parts of eastern Tasmania had their wettest spring on record (Figure 1a). Remaining areas in mainland south-eastern Australia and northern and eastern Tasmania had very much above average rainfall (highest 10% of all years since 1900). Spring rainfall was only below average in western Tasmania. Over most of the MDB, rainfall for the 3-month period was at least double the long-term average, reaching 3 to 4 times the average in parts of western New South Wales (Figure 1b).

Overall, the MDB, New South Wales and Victoria all had their wettest springs on record since 1900 (Table 1) by around 40 mm, with Victoria breaking a record set in 1992 and New South Wales and the MDB breaking records set in 2010. For Victoria, it was also the wettest 3-month period on record for any time of the year. Nationally, it was the second-wettest spring on record, behind 2010.

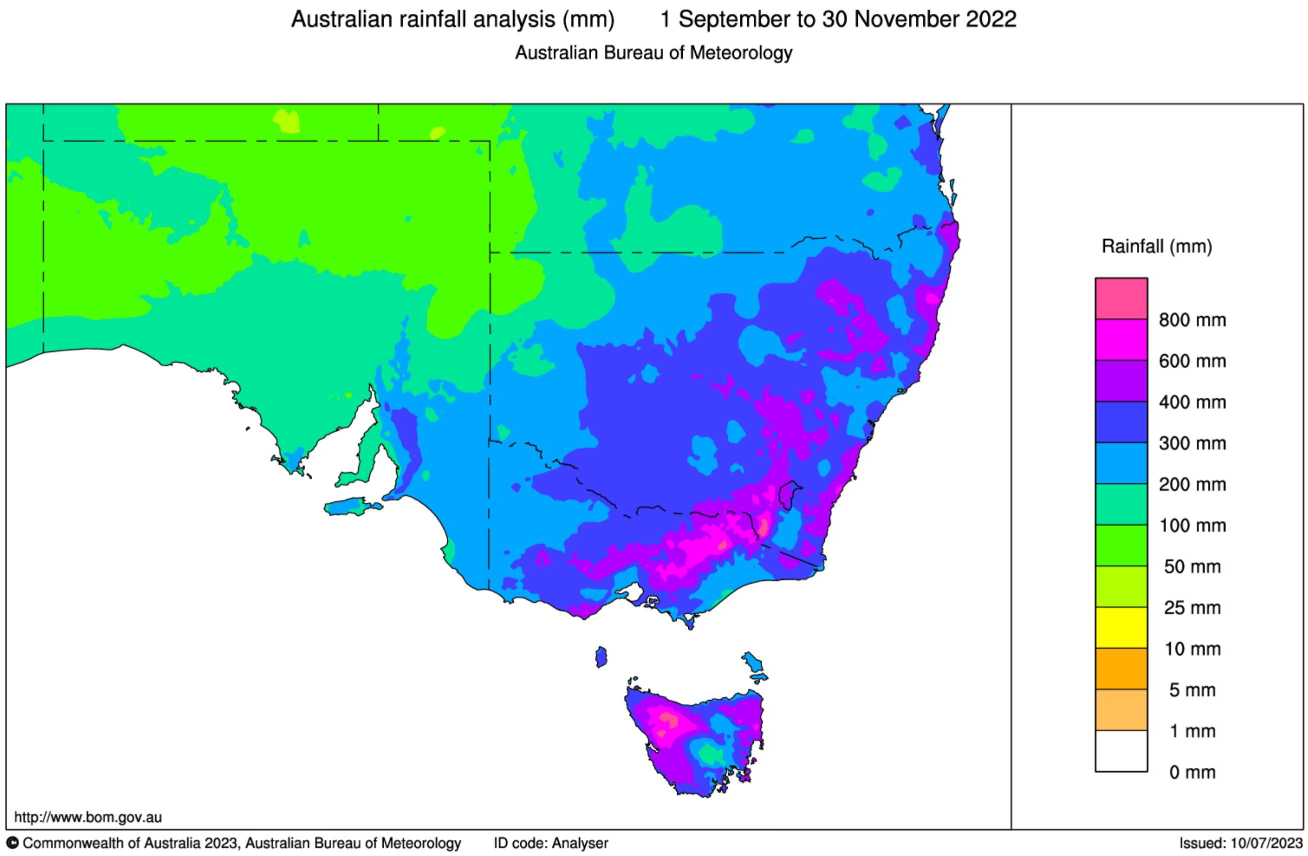

Figure 5: 2022 spring (September to November) total rainfall for south-eastern Australia.

August to November

August to November 2022 rainfall anomalies (SI Figure 6) were similar to spring, although the percentage anomalies are not as high in western New South Wales. It was the wettest August to November period on record by large margins for the MDB, New South Wales and Victoria, and the second-wettest on record for Australia (Table 1). In Victoria, it was the wettest four-month period for any time of year since 1900. The area-average rainfall of 364.4 mm (117% above the 1961–1990 average) for New South Wales was 58.3 mm above the previous record, set in 2010, whilst Victoria's area-average rainfall of 457.0 mm (78% above average) broke its 1992 record by 44.2 mm.

It was the wettest August to November record for 20 of the 26 catchments within the MDB (SI Table 3). Fourteen of these catchments had their wettest spring on record, and for 7 (mostly in the northern Basin), August to October 2022 was their wettest on record. The Lachlan catchment had its wettest 2-month, 3-month and 4-month periods on record for any time of the any year. The Murray Riverina had its wettest four-month period on record.

There were fewer multi-month records south of the Great Dividing Range in Victoria, although spring 2022 was the wettest on record for the Lake Corangamite and Hopkins catchments in south-west Victoria, and August to November was the wettest on record for the Bunyip, Hopkins and Glenelg catchments. October–November was the wettest on record for any time of year for the Barwon and Lake Corangamite catchments, and for the Yarra it was the third-wettest 2-month period on record, after October–November 1934 and April–May 1960.

Recent years

Many of the regions most affected by heavy rain in the second half of 2022 had also experienced very high rainfall in 2021, and severe drought in 2017–19. For New South Wales, 2020–22 was the wettest 3 calendar year period on record, immediately following 2017–19, the driest such period. 2022 was the second-wettest year on record for New South Wales, and 2021–22 the wettest 2-calendar year period. For the Lake George, Lachlan, Gwydir and Macquarie–Bogan catchments, January 2020 to December 2022 was the wettest 36-month period on record (SI Table 3). For Lake George and the Gwydir, this immediately followed the driest 36-month period on record from January 2017 to December 2019, whilst the Macquarie–Bogan's driest 36-month period was February 2017 to January 2020.

3. Hydrological conditions

- At the start of spring 2022 many of the MDB catchments had relatively wet soils, following the rainfall in previous months, and overall water storage in the MDB was at its highest level since October 2012.
- Rainfall in September and October saw modelled root-zone soil moisture (moisture in the top 100 cm of soil) exceed 80% capacity, the level at which catchments are considered saturated.
- The wet soils across south-eastern Australia were a significant contributor to the large inflows to water storages, and subsequent flooding.
- In October and November around 80% of streamflow sites in south-eastern Australia had very much above average (highest 10% of all years since 1975).
- Over 50% of streamflow sites in the MDB had their highest October or November streamflow on record.
- Major storages that were at capacity, and released water, in spring 2022 included the Wyangala Dam (Lachlan catchment), Lack Burrinjuck and Blowering (Murrumbidgee catchment), Dartmouth and Hume Dams (Murray catchment) and Lake Eildon (Goulburn catchment).

3.1. Soil moisture

September

At the start of spring 2022, catchments in the MDB had relatively wet soil following rainfall in previous months, particularly in the upper parts of the Macquarie, Lachlan, Murrumbidgee, Murray and Goulburn River catchments. After the widespread rainfall during September, the wet soil conditions extended westwards. Modelled root-zone soil moisture (moisture in the top 100 cm of soil) was above average (highest 30% of all years since 1911) for much of southern Queensland, north-eastern to inland areas of New South Wales and eastern Tasmania (SI Figure 7). Modelled root-zone soil moisture for September was above 70% capacity across much of south-eastern Australia (Figure 6). Once root zone soil moisture values exceed 80% (of available water holding capacity), catchments are considered "wet", or close to saturation. "Wet" catchments have very limited ability to store more water. Further rain that falls on "wet" catchments is likely to run overland to the river network.

October

During October, soil moisture further increased in inland parts of eastern Australia, especially in the MDB, in response to the record rainfall. The largest increases in soil moisture were seen in parts of the Macquarie, Lachlan, Darling and Goulburn catchments. Over the course of the month, modelled daily root zone soil moisture had increased significantly to above 80% (SI Figure 8).

November

Soil moisture increased and further extended to the central MDB region during November following further rainfall across south-eastern Australia. Soils over large areas of New South Wales, northern Victoria, central and south-eastern South Australia reached saturated conditions (Figure 6).

Spring

Overall, modelled root-zone soil moisture in spring 2022 was very much above average (highest 10% of all years since 1911) across most areas of southern Queensland, New South Wales, central and northern Victoria, central and eastern South Australia, and eastern Tasmania and highest on record for some areas (SI Figure 9). Soil moisture in the southern MDB was higher than in recent wet springs including 2010 (SI Figure 9).

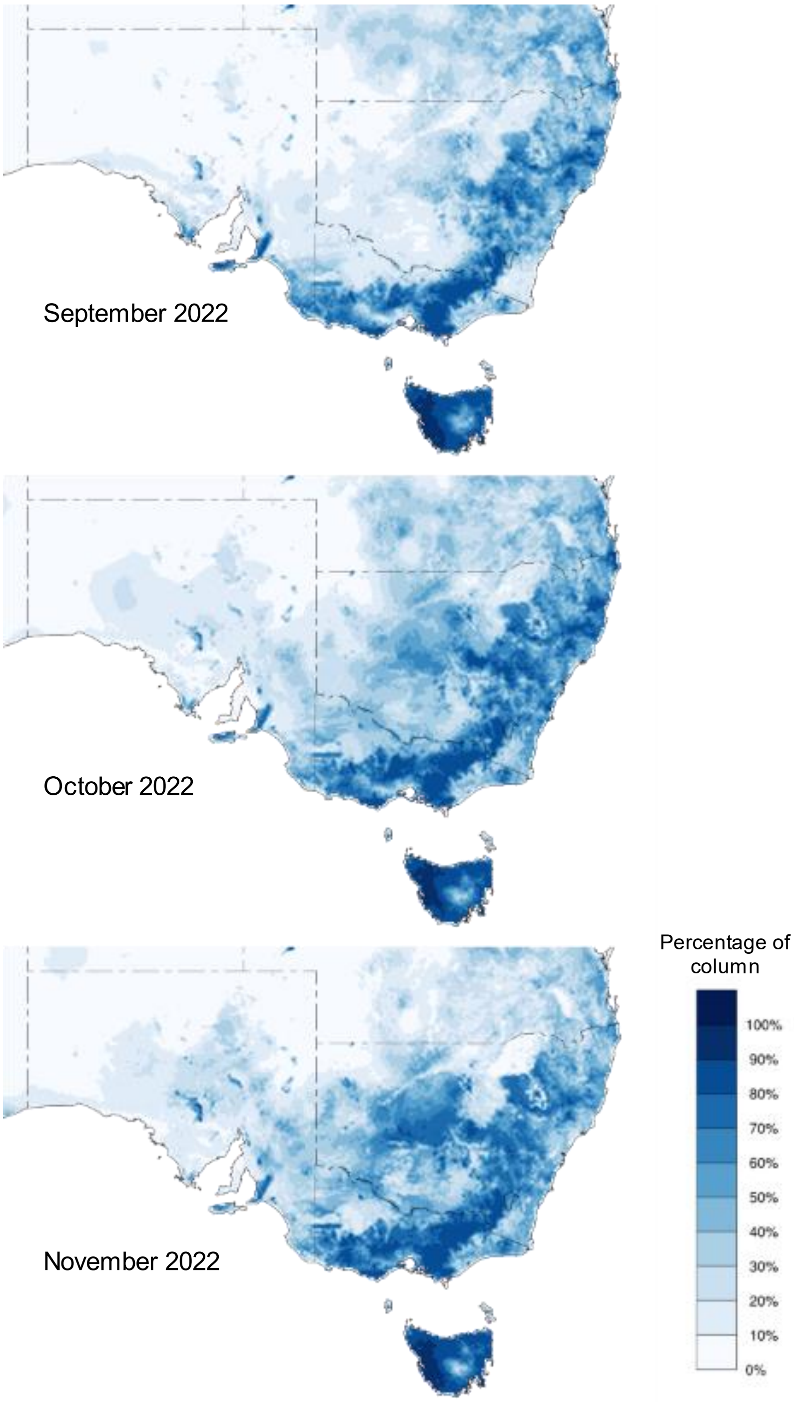

Figure 6: Modelled root-zone soil moisture (top 100 cm) percentage of capacity for September (top), October (middle) and November (bottom) 2022 from the Australian Water Resources Assessment Landscape model (AWRA-L).

3.2. Streamflow

In September, streamflow was generally above average (highest 30% relative to all years since 1975) across southern Queensland, north-eastern and inland areas of New South Wales and eastern Tasmania (Figure 7), consistent with the rainfall and wet soils. In the MDB, above average flows were observed in September at more than 95% of 336 sites and were highest on record at nearly 11% of sites (SI Table 5).

Following the record rainfall in October, above average or highest on record streamflow was observed around 80% of sites across south-eastern Australia in October and November. In the MDB, highest on record flows were recorded at over 50% of sites in October and November (SI Table 5).

High flows continued into December with above to very much above average streamflow observed at many sites, with 7% of sites having their highest December streamflow on record. Overall, the number of sites in the MDB with above average streamflow in spring 2022 was comparable to the peak of the 2010–11 floods in December 2010 (SI Figure 10, SI Table 6).

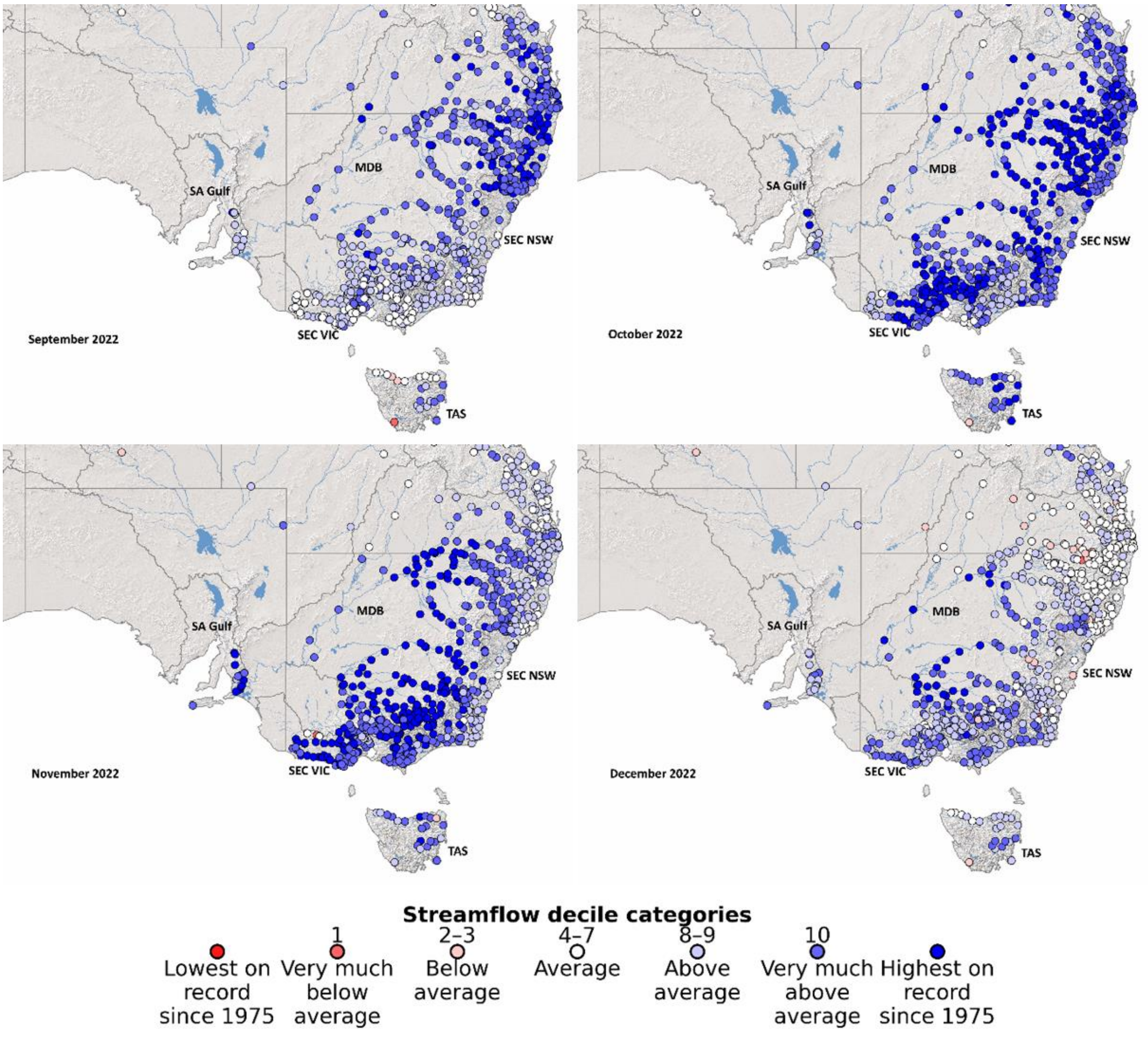

Figure 7: Monthly streamflow distribution, relative to all years since 1975, for September to December 2022.

3.3. Water storages

Most water storages in New South Wales and Victoria were not built for the purpose of mitigating floods. Rather, they are designed to, and operate to, maximise water security. When there is air space available in these dams, they can mitigate some flood impacts by capturing flood inflows and releasing that water over a longer period of time than would occur naturally, lowering the peak height in the river downstream. However, when storages are full, inflows must be passed through. Some dams, by the nature of their spillway design, attenuate the peak of floods even when full.

On 1 September 2022, total water storage in the MDB was at 95.1% of full capacity (26,948 GL), the highest since October 2012 (SI Figure 11). In the southern MDB, where most of the large storages are located, storages were at 94.1% of full capacity (22,219 GL), the highest since November 2012. The 3 largest storages in the MDB (Dartmouth, Hume and Eildon) were at 95% full (SI Figure 12). With storages in both the northern and southern MDB almost at capacity (Figure 8), their flood mitigation benefits were limited. The risk of flooding during spring 2022 was increased, especially in the southern MDB.

By the middle of September, rainfall across the border region of New South Wales and Queensland resulted in many storages in the northern MDB reaching capacity. Further significant rainfall in October across the southern MDB, southern Victoria and Tasmania contributed to inflows in these regions. Significant one-day filling was observed, including 5 major water storages of Lake Echo, Arthurs Lake, Keepit, Windamere and Lake Eppalock. Each of these storages can hold more than 300 GL of water. Each filled by over 20 GL (23.7 GL to 44.6 GL) on a single day in spring 2022, their highest daily fill volume on record.

Macquarie–Bogan and Castlereagh catchments

During spring 2022, Windamere Dam was at or above 100% capacity and could not be used to hold back the flooding in these catchments.

Lachlan catchment

Wyangala Dam in the Lachlan catchment released 50 to 100 GL/month from March to August 2022. The Lachlan catchment received record rainfall during spring (SI Table 3) and release volumes were increased to maintain safe operation of the dam. The total amount of water released[8] from Wyangala Dam between July and November 2022 was around 2,091 GL including October and November releases of 543 GL and 860 GL, respectively. By 2 November, Wyangala dam was 105.6% full. 230 GL was released on 14 November, well above the previous daily record release of 205 GL in 1990.

Murrumbidgee catchment

Lake Burrinjuck in the Murrumbidgee catchment released 609 GL in August 2022[9]. Over October and November Lake Burrinjuck and Blowering, two major storages in the Murrumbidgee catchment, respectively released in 1,230 GL and 994 GL.

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[8]WaterNSW: https://waterinsights.waternsw.com.au/11983-lachlan-regulated-river/storage#AMSRecent
[9] WaterNSW: https://waterinsights.waternsw.com.au/11982-murrumbidgee-regulated-river/storage#410131

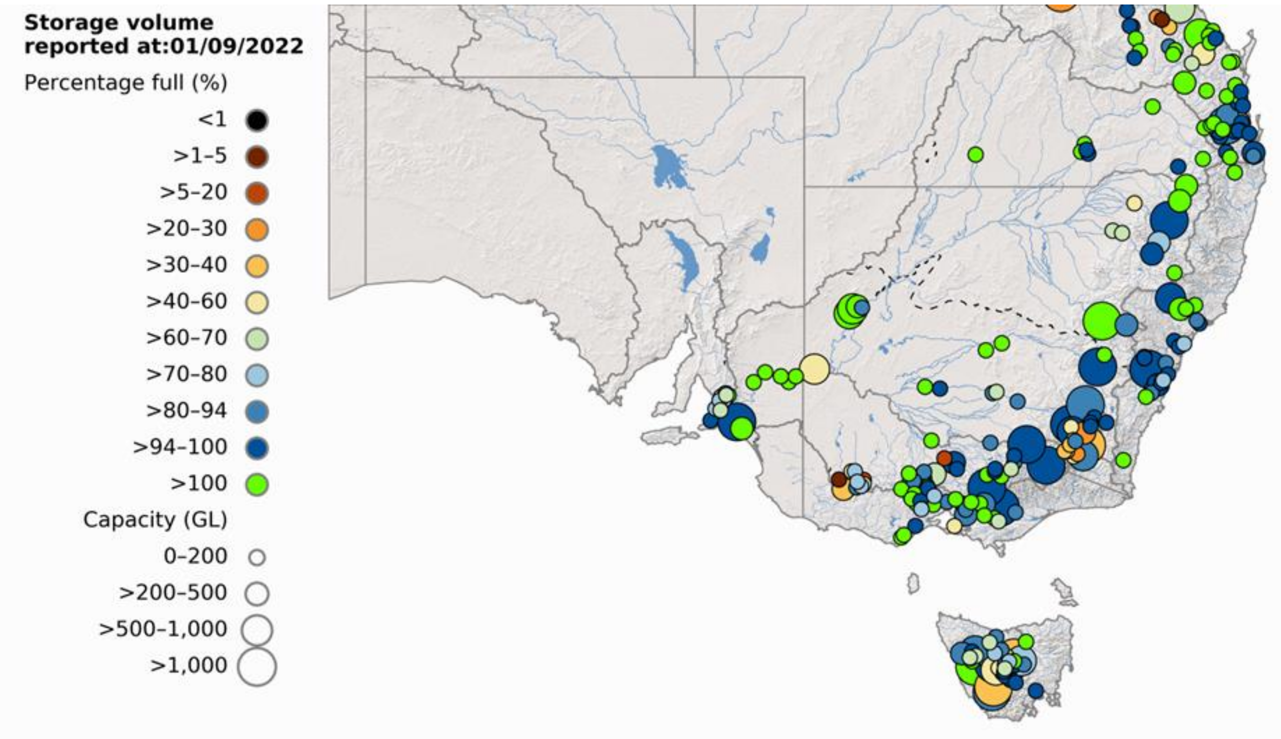

Figure 8: Water storage conditions (percentage full of total storage capacity) at 1 September 2022.

Murray catchment

Persistent rainfall during spring 2022 filled large Victorian storages that had been below full capacity for many years (SI Figure 11). When Dartmouth Dam (3,856 GL full supply level, the largest in the MDB) in the Murray catchment began spilling, it was only the fifth time since the storage was completed in 1979 and the first since November 1996.

Hume Dam was at 97.8% of capacity (3,038 GL) on 24 September, less than 1 metre below the spillway level. By the first week of November, Hume Dam had reached 99.6% capacity. Between 5 and 13 November, a significant amount of water was released, lowering it to 92.2% of capacity to accommodate further forecast rainfall and to ensure safe operation of the dam. By 18 December, Hume Dam had returned to 99.1% capacity.

Goulburn catchment

Lake Eildon in the upper Goulburn catchment had been near its full supply level (3,334 GL) since the beginning of spring 2022. *Goulburn-Murray Water (GMW)* started releasing water at 2 to 3 GL/day towards the end of August. Lake Eildon reached 100.4% capacity on 15 October, the first time it had exceeded its full supply level since 1996. From 15 to 25 October, about 106 GL of water was released and Lake Eildon was reduced to 97.4% capacity.

Thomson catchment

The Thomson Reservoir (1,123 GL full supply level) in West Gippsland, which accounts for more than half of Melbourne's water supply, reached full capacity for the first time since 1996.

4. Flooding

- From the start of October 2022 widespread major flooding affected New South Wales, Victoria, Queensland and Tasmania (Figure 9).
- Flood waters impacted both the upper and lower catchments of the MDB, and gradually flowed downstream, reaching South Australia by late December 2022 (Figure 10).
- In New South Wales, major flooding occurred along the Lachlan, Macquarie, Murrumbidgee, upper Murray and Barwon rivers.
- In spring 2022, of the 177 flood forecasting sites across all New South Wales catchments, 52 reached or exceeded their threshold for major flooding, 31 for moderate flooding and 32 for minor flooding.
- In Victoria, major flooding occurred on many catchments both within and outside of the MDB, including the Murray Riverina reach, Goulburn and Broken rivers, Campaspe, and the Maribyrnong and Werribee rivers catchments.
- In spring 2022, of the 100 flood forecasting sites across all Victorian catchments, 29 reached or exceeded their threshold for major flooding, 21 for moderate flooding and 30 for minor flooding.
- Heavy rainfall in the second week of October 2022 led to widespread flooding in Tasmanian catchments including the Forth, Mersey, Meander, Macquarie, South Esk, North Esk, Derwent and Huon.
- Of the 35 flood forecasting sites across all Tasmanian catchments, 10 reached or exceeded their threshold for major flooding, 9 for moderate flooding and 10 for minor flooding.
- Some gauges exceeded their historical flood peaks during spring 2022, including on the Lachlan and Murrumbidgee rivers (New South Wales), the Campaspe River at Rochester (Victoria) and in the Tamar catchment (Tasmania).
- Towns severely impacted by major flooding included: Cowra and Forbes (Lachlan catchment), Hay and Wagga Wagga (Murrumbidgee catchment), Menindee (Darling Catchment), Shepparton and Seymour (Goulburn catchment), Rochester (Campaspe catchment) Albury, Echuca, Moama, Barham and Mildura (Murray River catchment), and Renmark and Blanchetown (South Australia).
- Flooding in the second half of 2022 in the southern MDB was more significant, in terms of extent, severity and duration, than any other flooding in the region since 2009–10, using a consistent set of flood observations.
- Antecedent conditions and the timing of the rainfall likely also played a role in the severity of the flooding in the MDB, when compared to flooding in previous years.

4.1. Flooding extent and severity

Although most flooding occurred in mid-to-late spring 2022, the extent and severity varied over the period between August 2022 and January 2023. Figure 9 shows the spatial extent of the flooding across south-eastern Australia in spring 2022. The severity of the flooding can be measured by the peak flood height reached (minor, moderate or major flooding[10]) and by the duration of that peak. This is summarised in Figure 10 for all affected catchments from August to December 2022.

August

In the weeks prior to spring 2022, several catchments in New South Wales (including Condamine-Culgoa, Macquarie–Bogan, Namoi, Darling, Lachlan, Murray Riverina, Murrumbidgee), Victoria (Kiewa, Ovens and King) and Tasmania (Meander, Macquarie, South Esk, North Esk) flooded (Figure 10) as both winter rainfall and water storage releases contributed to high river levels.

September

Above average rainfall in September triggered flooding in the Macquarie and Namoi Rivers of the northern MDB, and in the Lachlan, Murrumbidgee and Murray Riverina catchments in the southern MDB. Flooding also occurred at the same time in parts of the Condamine catchment. With ongoing high rainfall and wet soil conditions, flooding in the Macquarie, Namoi, Lachlan and Condamine catchments reached major flood levels by mid-September. These catchments experienced the most prolonged flooding during this period (Figure 10).

October

Persistent rain continued to fall in the northern MDB during October causing renewed rises in water levels. Flooding spread to the Warrego, Paroo, Border Rivers, Gwydir and Darling catchments.

Record daily rainfall in downstream catchments of the MDB including Murray Riverina, Broken, Goulburn, Loddon, and Campaspe led to downstream channels filling with local runoff. This significantly slowed the drainage of flood peaks from upper catchments as upstream water could not drain into already-full channels. This resulted in flooding of small upland rivers and tributaries. By the middle of the month, most Victorian catchments in the MDB had experienced some level of flooding (Figure 10).

In Victoria outside of the MDB, flooding occurred in many catchments throughout October including East Gippsland, Snowy, Tambo, Mitchell, Avon, Thomson, Latrobe, South Gippsland, Bunyip, Yarra, Maribyrnong, Werribee, Barwon, Hopkins and Glenelg.

Mid-October rainfall resulted in widespread flooding in several Tasmanian catchments, including the Forth, Mersey, Meander, Macquarie, South Esk, North Esk, Derwent and Huon.

[10] For flood levels definitions, general flood information and service level specification see the Flood Knowledge Centre: http://www.bom.gov.au/australia/flood/knowledge-centre.

November onwards

Flood peaks in the MDB gradually moved downstream to the Darling and lower Murray rivers and reached the South Australian border on 23 December 2022.

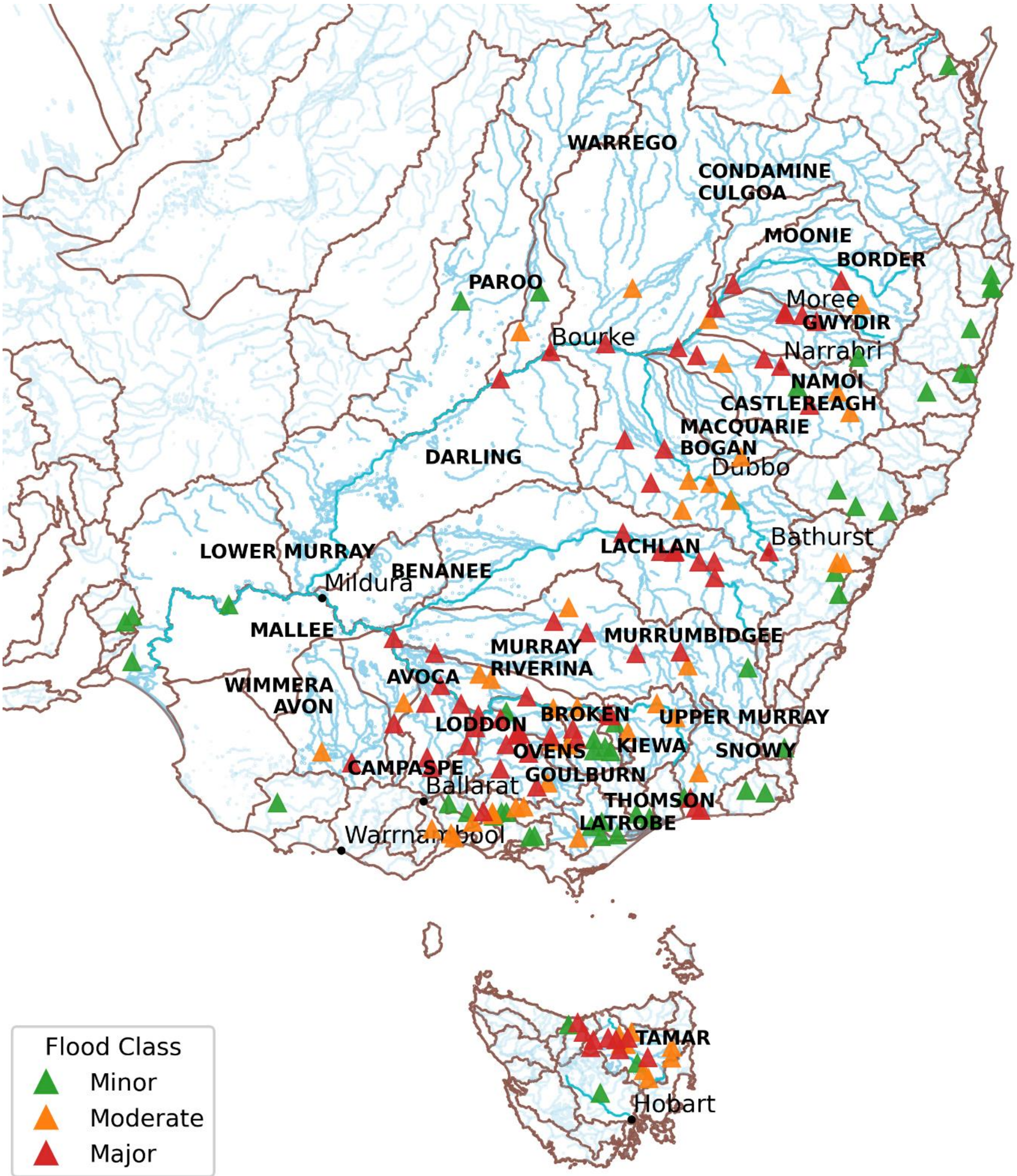

Figure 9: Flood peak classifications, by flood level, for spring 2022 over south-eastern Australia. Major rivers are shown in blue, and catchment boundaries by brown lines.

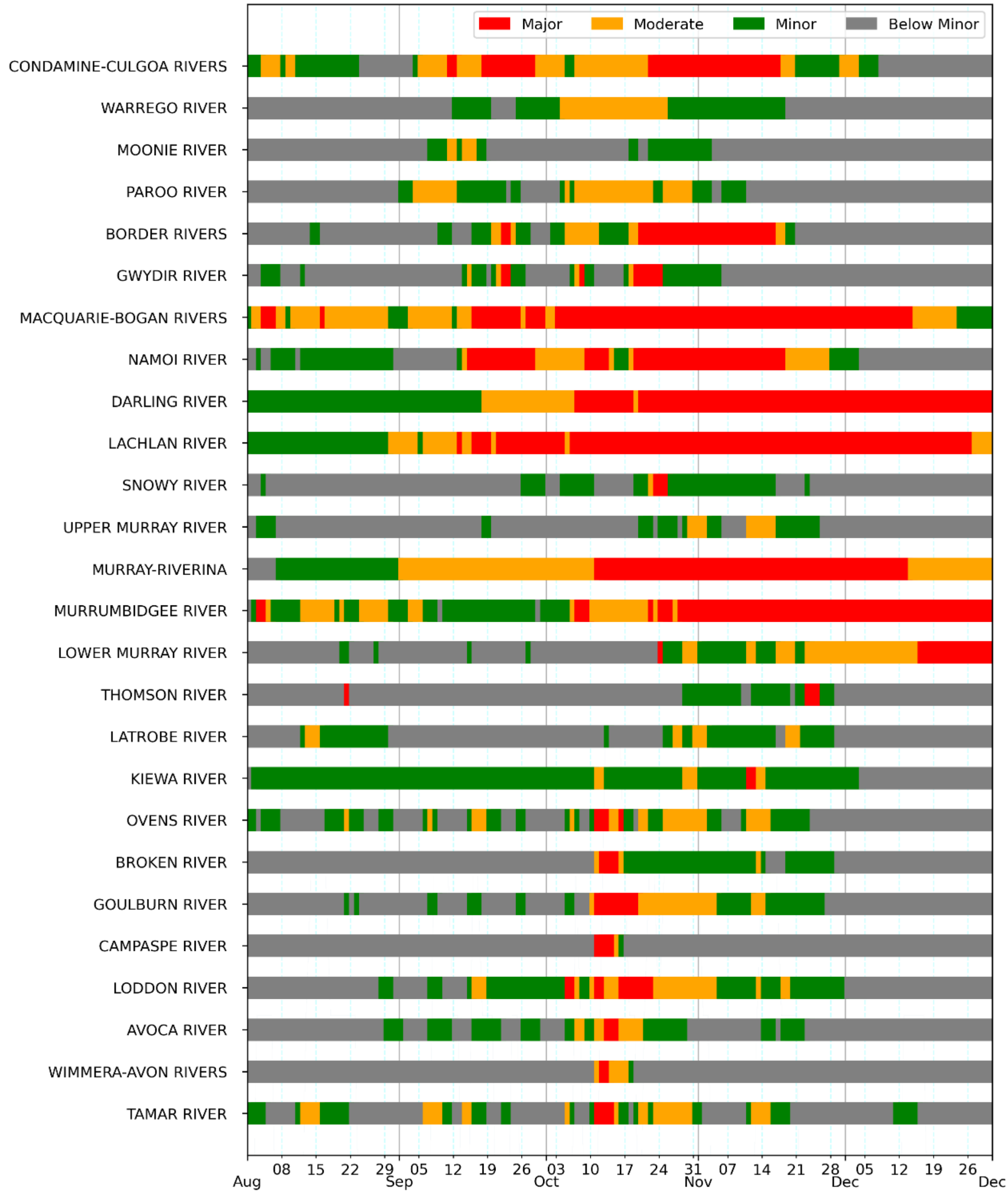

Figure 10: Timeline of the extent and severity of flood during August to December 2022 period. At least one site within the catchment is above the respective flood level shown. The Tamar River is the combined Tasmanian catchments of Meander, Macquarie, South Esk and North Esk Rivers.

4.2. Flooding by catchment

Significant flood peaks at individual sites during the spring 2022 period, from 1 September to 30 November, and known historical flood peaks[11] are given in SI Table 7. River levels at observing sites are typically reported as height above their local datum. However, some sites report relative to the Australian Height Datum[12] (AHD). Quoted river height levels may be subject to further quality assurance processes by responsible agencies including the Bureau.

Namoi River

In the northern MDB, the most extensive and prolonged flooding occurred in the Namoi, Macquarie and Darling River catchments.

The Namoi River had multiple peaks reaching or exceeding major flood levels during spring. Major flooding occurred at most forecast locations (SI Figure 13) including Gunnedah (peak height 8.47 m on 23 October, major level 7.90 m), Narrabri (7.65 m on 16 October, major level 6.70 m), Glencoe Wee Waa (7.61 m on 26 October, major level 6.70 m) and Goangra (8.31 m on 1 November, major flood 7.80 m). Glencoe Wee Waa remained above major flood level for a total of 40 days during spring 2022 (SI Figure 14).

Macquarie–Bogan and Castlereagh rivers

Flooding in the Macquarie–Bogan River (SI Figure 15) started before spring with multiple flood peaks and continued until the end of the year. Bathurst experienced major flooding, when the Macquarie River peaked at 6.64 m on 14 November (major level 5.70 m) and the Bogan River at Gongolgon peaked at 1.41 m on 14 November (major level 1.30 m). Macquarie River at Warren Town peaked at 9.77 m on 14 October, and the water level at Warren Town remained above major flood level (9.00 m) for a total of 63 days (SI Figure 16).

Barwon–Darling rivers

Waters from the Macquarie–Bogan, Gwydir and Culgoa rivers flow through the Barwon–Darling river system. Major flooding occurred along the Barwon River at Mungindi (7.77 m on 3 November, major level 7.20 m), Walgett (13.37 m on 6 November, major level 12.50 m) and Brewarrina (10.21 m on 15 November, major level 9.50 m).

Flat topography of the lower Darling River catchment made movement of flood peaks slow. Major flooding in the Darling River started towards the end of November (SI Figure 17). Bourke Town, at the upstream end of the Darling River, reached a major flood peak at 13.95 m on 23 November (major flood level 12.70 m), very close to the historical record level of 14.18 m in 1976. Floodwater moved downstream, and major flooding occurred in Louth, Tilpa and Wilcannia in December. With the major flood peak arriving, the Menindee Lakes system (around 200 GL capacity) contributed to dissipating the flood. However, the significant inflows to the lake during the last week of December

[11] 2022 flood peaks referenced are sourced from the Bureau's peak height database. Historical flood peaks are sourced from a combination of the Bureau's peak height database, state Agency reports or published studies of historical floods.

[12] For more information on the Australian Height Datum, see https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/datums-projections/australian-height-datum-ahd.

lead to increased releases of water from the Lakes which caused major flooding at the Menindee town gauge, which peaked at 10.26 m on 6 January 2023 (major flood level 9.70 m), below the record flood level of 10.47 m in 1976.

Lachlan River

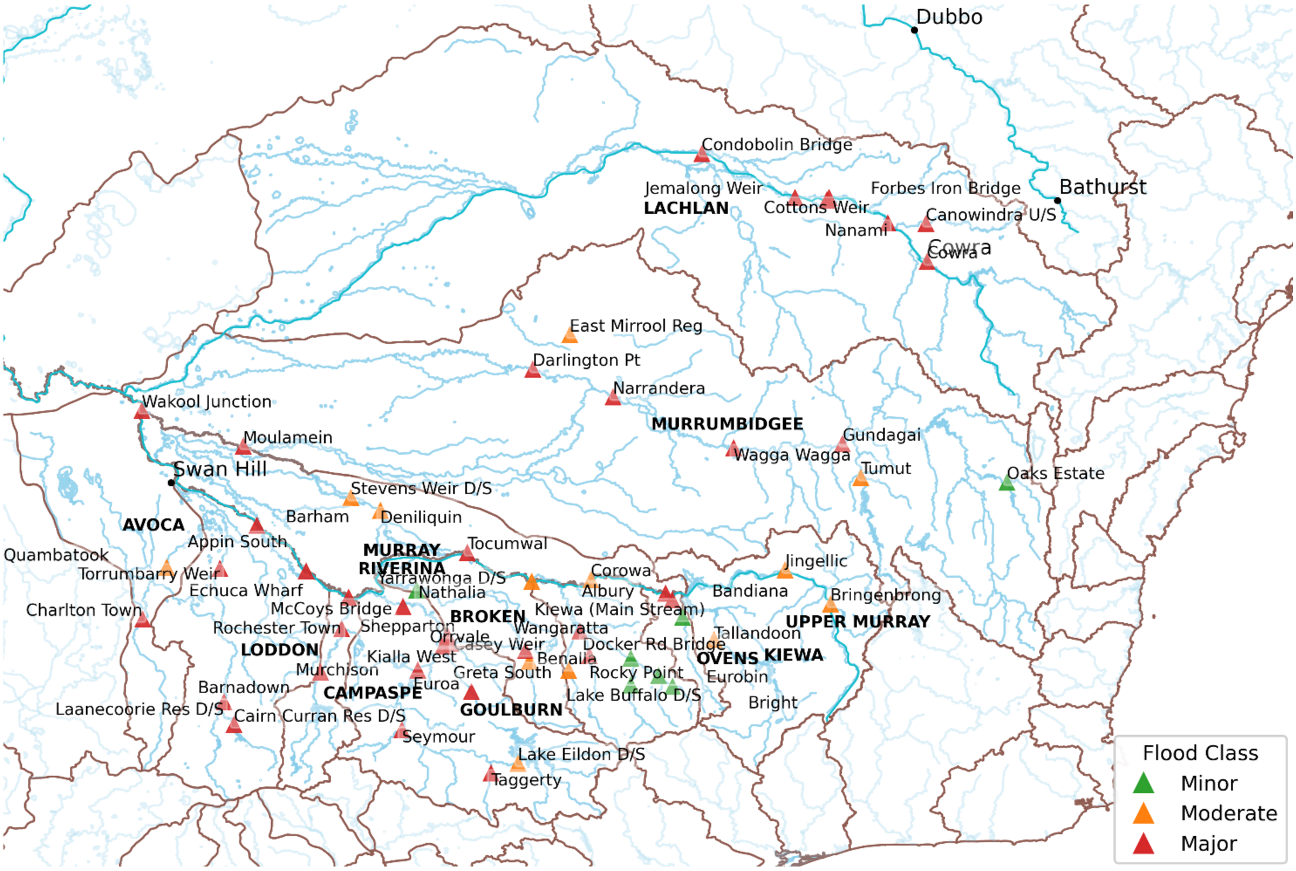

Figure 11: Flood peak classifications for gauges in the Lachlan, Murrumbidgee, Murray Riverina, Avoca, Loddon, Campaspe, Goulburn, Ovens, Kiewa and Upper Murray catchments during spring 2022. Catchment names are shown in bold, and their boundaries in brown.

The most extensive flooding occurred in the southern MDB, particularly of the Lachlan and Murray Rivers. Flooding of the Lachlan River started in the weeks prior to spring and by mid-September reached major levels at a number of locations, including Cowra, Canowindra, Nanami, Forbes Iron Bridge, Cottons Weir, Jemalong Weir, Condobolin Bridge, Euabalong and Hillston Weir (Figure 11).

The Lachlan River at Cowra flooded on and off during the October–November period. The highest peak was on 15 November at a level of 14.27 m (major flood level 13.40 m) which was below the record flood level of 15.93 m in 1870. The flooding of Canowindra and Nanami started at the beginning of September (SI Figure 18). The Lachlan River at Canowindra reached major level (4.50 m) in November; the highest peak observed was 5.78 m on 14 November, which was well above the previous record flood level of 4.83 m observed in 2010. The Lachlan River at Nanami reached major level (10.70 m) multiple times with the highest peak on 16 November (13.79 m).

Due to high streamflow from earlier months and widespread significant rainfall, the Lachlan River channel could not contain the water and prolonged major flooding occurred at downstream locations of the Lachlan catchment. The longest duration of flooding (at or above any flood thresholds) in the 2022 calendar year occurred at Hillston Weir with 144 days, 69 of which were above major flood level followed by Condobolin Bridge with 128 days, 43 of which were above major flood level. During spring prolonged major flooding occurred at Euabalong (58 days), Jemalong Weir (46 days), Condobolin Bridge (42 days; Figure 12), Hillston Weir (41 days; SI Figure 19), Cottons Weir (27 days; SI Figure19), Nanami (15 days; SI Figure 18) and Forbes Iron Bridge (12 days; SI Figure 18).

From mid-October to mid-November water levels at Forbes Iron Bridge and Cottons Weir peaked at or above the major flood level multiple times, with the highest peaks on 17 November at Forbes Iron Bridge at 10.69 m (major flood level 10.55 m) and Cotton Wier at 7.43 m (major flood level 6.6 m). In contrast, the Lachlan River at Jemalong Weir remained above the major flood level (7.70 m), with the highest peak of 8.43 m on 18 November. The highest peaks at Condobolin Bridge at 7.59 m on 20 November (major flood level 6.70 m) (Figure 12) and Euabalong at 7.82 m on 23 November (major flood level 6.80 m), both were above their previous record flood levels of 7.37 m and 7.52 m, respectively, in 1952. The Lachlan River at Hillston Weir had a highest peak of 3.30 m on 30 November, (major flood level 3.00 m) similar to the 1990 record flood level (SI Figure 19).

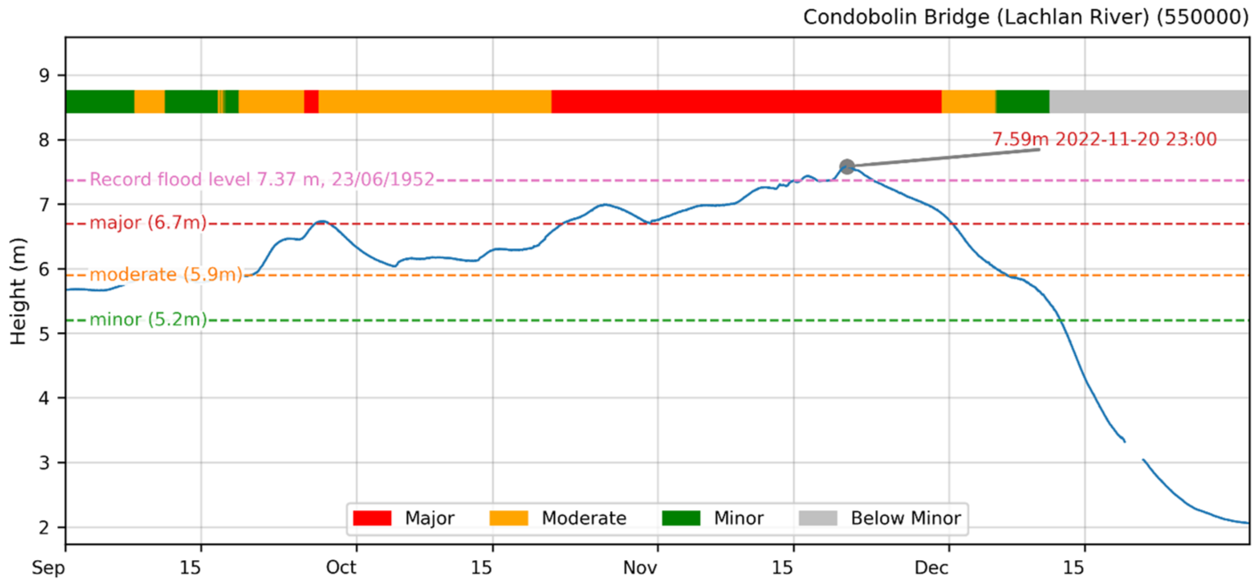

Figure 12: Observed water levels of the Lachlan River at Condobolin Bridge.

Murrumbidgee River

Flooding in the Murrumbidgee River started in early October and reached major flood levels at most locations downstream to Tumut by late-November (Figure 11). The highest peaks above major flood level were reached at Gundagai (9.76 m on 2 November, major flood level 8.50 m) (SI Figure 20), Wagga Wagga (9.72 m on 4 November, major flood level 9.60 m), Narrandera (8.49 m on 7 November, major flood level 8.20 m), Darlington Point (7.60 m on 10 November, major flood level

7.30 m), Hay Town (9.11 m on 16 November, major flood level 8.00 m) and Balranald Weir D/S[13] (7.39 m on 30 November, major flood level 7.10 m) (SI Figure 20). In Hay Town, the flood peak crossed the 1974 record level of 9.02 m (SI Figure 20). The peak flood level at Narrandera was below the 1974 record level of 8.99 m. The water level at the Hay Town gauge remained above major flood level for 22 days, and at Balranald Weir D/S for 12 days during spring.

Murray River

Flooding in the Upper Murray River was not as significant as the flooding downstream of Hume Dam. Moderate flooding occurred at Jingellic in the Upper Murray, peaking at 7.04 m on 2 November (major flood level 7.50 m) and at Tallandoon on the Mitta Mitta River, peaking at 5.26 m on 15 November (major flood level 5.60 m).

Flooding of the Murray Riverina reach started in mid-August and rose to major levels in early October. The Murray Riverina catchment received record October rainfall, (186.8 mm, 380% above the 1961–1990 average, SI Table 3). Of 13 forecast gauges on the Murray Riverina reach, 8 locations had major flooding, from upstream to downstream: Kiewa, Albury, Tocumwal, Echuca Wharf, Torrumbarry, Barham, below Wakool Junction and Boundary Bend. The Edward River at Moulamein and Stevens Weir also reached major flood levels (SI Figure 21).

Following rainfall events on 31 October to 2 November and 12 to 15 November, flows from the Upper Murray, Mitta Mitta, Kiewa, Ovens and King, Broken, Edward, Goulburn, Campaspe and Loddon Rivers joined the Murray River flows. The Murrumbidgee River joins the Murray River downstream of Wakool Junction. The Darling River meets the Murray River upstream of Wentworth Lock 10. Elevated water levels at many places along the river, along with releases from Hume Dam, contributed to the slow progression of flood peaks along the Murray River.

The Murray River at Albury exceeded the major flood level (5.50 m) and peaked at 5.52 m on 14 November. The river at Tocumwal exceeded the major level (7.30 m) and peaked at 7.40 m on 17 November. The Edward River at Deniliquin had moderate flooding (7.20 m) from 22 October that continued for 48 days with a peak of 9.19 m on 21 November. Downstream of Deniliquin, the Edward River at Moulamein had a record major flood peak of 6.24 m on 30 November (above the 1956 record flood level and major flood level of 6.10 m).

The Murray River at Torrumbarry exceeded the major level (7.80 m) and peaked at 7.83 m on 18 November. It remained above major level for 46 days. The water level at Barham reached the major flood level (6.10 m), and peaked at 6.21 m on 25 October, similar to the 1939 record level of 6.23 m (SI Figure 21). Along the Murray, Barham experienced the longest major flooding of 49 days. The Murray River at Boundary Bend exceeded major level (9.00 m), peaking at 9.14 m on 6 December and remained above the major level (9.00 m) from 13 November to 14 December. At Mildura Weir, the Murray River exceeded the major level (38.50 m AHD – Australian Height Datum), peaking at 38.52 m AHD on 15 December. At Wentworth, the river exceeded the major level (33.88 m AHD) on 28 November and peaked at 34.16 m AHD on December 16. The water level at Wentworth remained at or above major flood level for 35 days until 1 January 2023.

[13] In 'Balranald Weir D/S', the official station name used by the Bureau, the 'D/S' refers to downstream.

Goulburn and Broken rivers

Major flooding of the Goulburn River occurred at several locations including Seymour, Murchison, Shepparton and McCoys Bridge (Figure 13). The Goulburn River and Broken River catchments received highest on record catchment average rainfall in October (Goulburn River 239 mm, 212% above the 1961–1990 average, Broken River 199 mm, 253% above average, SI Table 3)

The record October rainfall, combined with water releases upstream at Lake Eildon, resulted in the Goulburn River at Seymour exceeding the major flood level (7.00 m) and reaching 8.26 m on 14 October (SI Figure 22). This was above both the May 1974 and May 1975 flood levels (7.64 m and 7.03 m respectively). The Shepparton flood level peaked at 12.06 m on 17 October (SI Figure 22), well above the major flood level (11.00 m) and similar to the May 1974 flood level (12.09 m). The Goulburn River at Murchison exceeded the major flood level (10.70 m), peaking at 12.02 m on 15 October.

The Murray River is constrained by the *Barmah Choke*[14] upstream of the confluence with the Goulburn River. During the time of Goulburn River flooding, water flowing down the Murray River backed up at the junction of the Goulburn and Murray rivers at Barmah. The water level of the flooded Goulburn was sufficiently elevated for Goulburn River flood water to flow along the Murray channel in an upstream direction.

In the Broken River catchment, major flooding occurred at Orrville (8.33 m on 17 October, major flood level 7.99 m) and Caseys Weir (3.58 m on 15 October, major flood level 3.00 m).

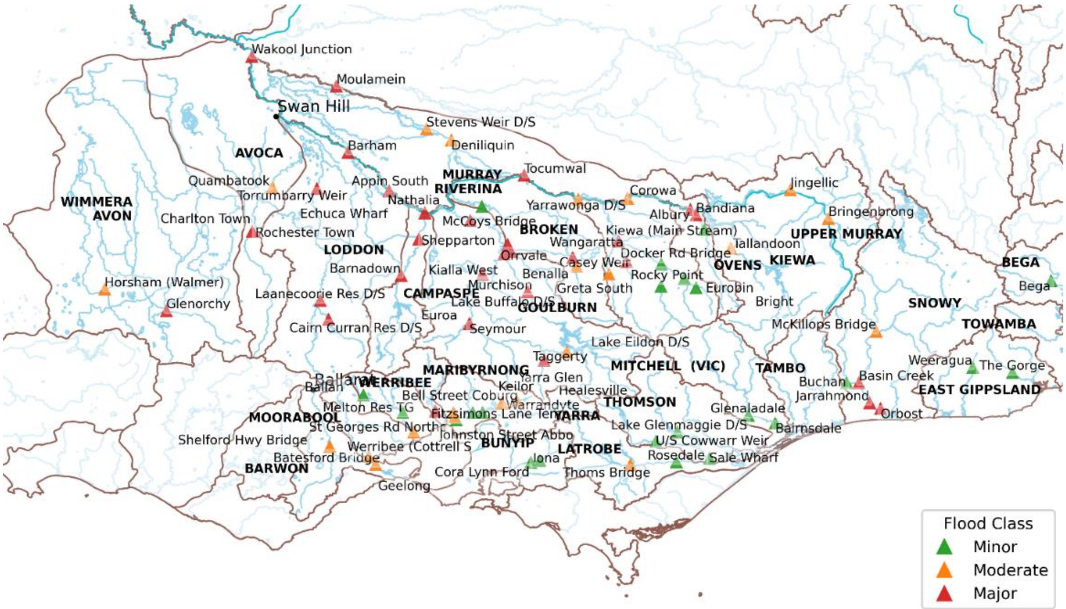

Figure 13: Flood peak classifications for gauges in Victorian catchments during spring 2022. Catchment names are shown in bold.

[14] See https://www.environment.nsw.gov.au/topics/water/water-for-the-environment/murray-and-lower-darling/barmah-choke

Ovens and King rivers

The Ovens River at Wangaratta peaked at 12.77 m on 15 October (major flood level 12.70 m). This was the most significant of the river's several peaks during spring.

Campaspe River

Record catchment average rainfall in October (215 mm, 259% above the 1961–1990 average, SI Table 3) resulted in widespread major flooding at several locations including Lake Eppalock, Barnadown and Rochester in the Campaspe River catchment. The Campaspe River at Rochester peaked at 115.65 m AHD on 15 October (major flood level 114.5 m AHD), higher than the previous record flood of 115.40 m AHD in January 2011 (SI Figure 23).

Loddon River

Major flooding occurred at several locations including at D/S Cairn Curran, Laanecoorie and Appin South in the Loddon River catchment around mid-October in response to record rainfall (185.9 mm, 291% above the 1961–1990 average, SI Table 3) during the month. The water level at D/S Laanecoorie reached 8.38 m on 14 October (major flood level 5.50 m) (SI Figure 24).

Avoca River

Major flooding along the Avoca River impacted the town of Charlton. On 15 October the Avoca River at Charlton reached major flood level (7.50 m) and peaked at 7.86 m on 17 October.

Wimmera River

The Wimmera River at Glenorchy peaked at 5.00 m on 15 October (major flood level 4.80 m), above the September 2010 flood level of 4.92 m and slightly below January 2011 flood level (5.03 m).

Snowy River

Significant rainfall occurred in the Snowy River catchment between 21 and 25 October, which caused major flooding at several locations along the Snowy River. The river at D/S Basin Creek (peaked at 7.96 m on 26 October, major flood level 6.60 m), Jarrahmond (peaked at 8.70 m on 26 October, major level 7.40 m) and Orbost (peaked at 7.69 m on 27 October, major level 7.00 m) reached above the major flood level.

Maribyrnong and Werribee rivers

On 14 October, major flooding occurred along the Maribyrnong River in north-west Melbourne. The water level at Keilor exceeded the major level (6.10 m) and peaked at 8.60 m (SI Figure 25). At Maribyrnong, the river exceeded the major level (2.90 m) and peaked at 4.22 m, slightly above the 1974 flood level (4.20 m) but below the 1906 highest record flood (4.50 m). At Ballan, the Werribee River exceeded the major level (3.00 m) and peaked 3.44 m on 14 October. Several other places along the Werribee River recorded minor to moderate flood levels.

Tasmania

Many rainfall stations across northern Tasmania set daily rainfall records for October during the 24 hours to 9 am on either 13 or 14 October. The 4 days of rainfall between 10 and 14 October totalled 398.6 mm at Great Lake East, 320.4 mm at Lake Mackenzie, 312.2 mm at Fisher River above Lake Mackenzie, 273.4 mm at Mount Barrow (South Barrow), 262 mm at Loongana (Serendipity), 231.2 mm at Targa (Mountain Views), 226.2 mm at Lake Gwendy and 222 mm at Strathbogie North. This rainfall resulted in widespread flooding in several catchments, including the Forth, Mersey, Meander, Macquarie, South Esk, North Esk, Derwent and Huon (Figure 14).

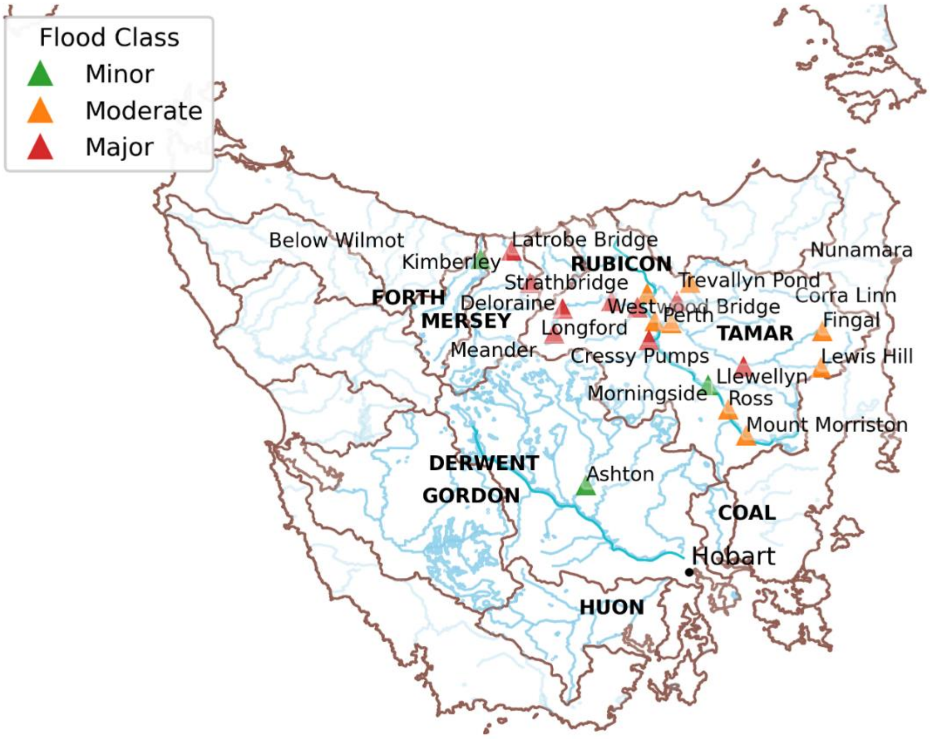

Figure 14: Flood peak classifications for gauges in Tasmanian catchments during spring 2022. Catchment names are shown in bold.

The Meander River reached major flood level at Meander, Deloraine Railway Bridge, Strathbridge, and Westwood Bridge). At Deloraine Railway Bridge the river peaked above the 1929 record flood level of 4.15 m and reached 4.44 m (major flood level 3.00 m) on 14 October. The Meander River at Strathbridge peaked above the 1998 record flood level of 8.66 m and reached 9.45 m (major flood level 7.00 m) on 15 October (SI Figure 26). At Westwood Bridge the Meander River peaked at 8.52 m (major flood level 7.00 m) on 16 October.

The Macquarie River at Cressy Pumps peaked above the 2016 record flood level of 5.41 m and reached 5.73 m (major flood level 5.00 m) on 14 October (SI Figure 26). On the same day, the North Esk River at Corra Linn peaked at 6.27 m (major flood level 4.90 m) and the South Esk River at Llewellyn peaked at 8.60 m (major flood level 8.50 m) (SI Figure 27). Also on 14 October, the Mersey River peaked at Kimberley at 4.67 m (major flood level (4.00 m) (SI Figure 26) and at Latrobe Bridge at 4.50 m (major flood level 4.00 m).

South Australian reaches of the Murray–Darling River

River Murray flooding in South Australia is measured in terms of volume rather than water level. Flow rates of the River Murray at the South Australian border of 100 to 130 GL/day are defined as minor flooding, 130 to 200 GL/day as moderate and any flows above 200 GL/day as major flooding[15].

Darling River flood peaks that had moved slowly through the Menindee Lakes reached the South Australian border on 23 December 2022. Major flooding occurred at Renmark, Loxton, Blanchetown, Overland Corner and Murray Bridge over the following month.

The water level at Renmark (Lock 5) peaked at 18.54 m AHD on 25 December, which was above the major level (18.40 m AHD) and peaked at 15.33 m AHD at Loxton on 28 December, which was also above the location's major level (15.10 m AHD). Flow peaked at Blanchetown (Lock 1) on 6 January, Mannum on 7 January and Murray Bridge on 9 January 2023, and then passed into the Lower Lakes. Floodwaters reached the Murray Mouth, where it scoured the channel, increasing the width and depth of the Mouth.

The River Murray in South Australia has only flooded 4 times in the past 100 years: 1931, 1956, 1973 and 1974. The 1956 flood, which peaked at 341 GL/day, was the biggest South Australian River Murray flood on record. Compared with previous flood flow records, 2022 was the third-highest on record for the River Murray in South Australia. Peak flow at the border in December 2022 was estimated to be approximately 190 GL/day (similar to the event in 1931 when flow was 210 GL/day).

4.3. Comparison with historical floods

Heavy rainfall is the primary cause of flood. However, each flood event is different from others in terms of severity, extent, duration and impacts. This makes a quantitative comparison between any two flood events difficult. However, from disaster reduction perspective it is important to know how the recent flooding compares with other historical floods. For a quantitative comparison, consistent daily flood data is the primary requirement. Such data is only available nationally since 2009. While there have been many floods recorded in the MDB, the comparison here is restricted to floods that have occurred since 2009.

Using the 12-month July to June period, which covers the Australia's warm season, there are 6 years since 2009–10 when Australia had widespread areas of rainfall above the 1961–1990 average. They are: 2010–11, 2011–12; 2016–17; 2020–21, 2021–22 and 2022–23[16] (Figure 15). In all 6 years, there was extensive flooding nationally, especially in eastern Australia.

[15] River Murray Inundation Mapping - Home (waterconnect.sa.gov.au).
[16] For Australia overall, 2009–10 was around 6% above the 1961–1990 average, and 2013–14 just over 0.5% above average.

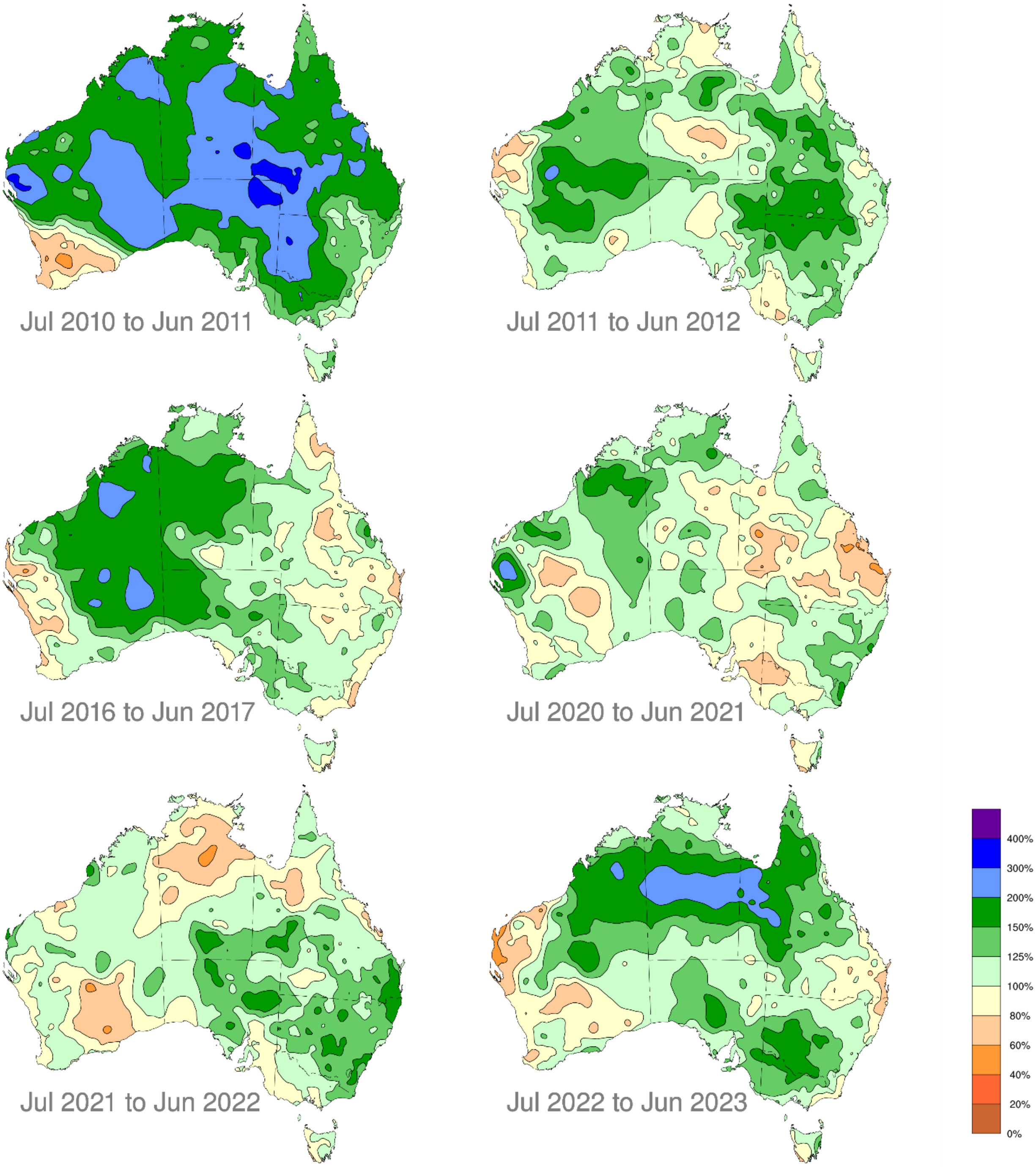

Figure 15: July to June total rainfall, as a fraction of the 1961–1990 climatological average, for 2010–11, 2011–12, 2016–17, 2020–21, 2021–22 and 2022–23. Fractions are shown as multiplied by 100.

Extent

Of the years since 2009–10, the floods during the second half of 2022 were more extensive than the flooding in 2011–12 and 2016–17 nationally, but slightly less extensive than the floods in 2010–11 (Figure 16a). This outcome is from the comparison of 453 flood forecast sites along 107 rivers in Australia, based on the count of sites with major flooding. However, for the southern MDB, the flooding in the second half of 2022 was more severe. For the southern MDB, comparison of historic flood peaks of 98 flood forecast sites selected across 16 river regions shows that the extent of major flooding during July to December 2022 was almost double than that of 2010–11 (Figure 16b).

Severity and duration

The severity and duration of the spring 2022 floods is measured by the number of days individual gauges were above flood thresholds, when compared with previous years. Figure 17 shows this for 10 selected gauges. The durations of flooding along the Lachlan, Macquarie–Bogan, Namoi, Murray, Murrumbidgee and Barwon–Darling rivers were significantly longer than that during the 2010–11, 2011–12, 2016–17, and 2021–22 floods.

During the flooding in July to December 2022, the Lachlan River at Euabalong remained at or above major flood level for a total of 61 days, 46 days at Jemalong Weir and 43 days at Condobolin Bridge. The count of days at or above the major flood level exceeded previous records for: the Namoi River at Glencoe Wee Waa (42 days), Murrumbidgee River at Balranald Weir D/S (43 days), Macquarie River at Warren Town (65 days) and Barwon River at Walgett (22 days). Gauges which were above major level for longer than any time in recent decades included the Murray River at Barham (62) and the Darling River at Bourke (51 days), Louth (66 days) and Tilpa (86 days).

Temporal and spatial distribution

The temporal and spatial distribution of rainfall can modulate the flooding pattern. The MDB had its third-wettest July to June period on record during 2010–11 (780.0 mm), with December 2010 the wettest month during that period with 116.5 mm. Higher rainfall totals were recorded in the northern MDB that led to flooding, which gradually moved south during the period of October 2010 to May 2011. In contrast, 2022–23 rainfall was more concentrated spatially in the southern MDB and during spring. October 2022 was the wettest month during this period, with the MDB recording an area-averaged total of 142.9 mm (Table 2), almost 30% of its annual mean rainfall. The large amount of rainfall in a short period sharply raised the river levels and triggered flooding.

Antecedent conditions

Antecedent conditions played a significant role in changing the intensity, duration and spatial extent of the spring 2022 flooding in the MDB. 2022–23 was the third consecutive July to June period with above average rainfall. Before the flooding started in spring 2022, the landscape was relatively wet, most of the water storages were at or near capacity, and streamflow in the MDB was high from the rainfall in previous years.

In 2020–21, and to an extent in 2021–22, the drier antecedent conditions influenced the flooding in the opposite way. During the 3-year period from July 2017 to June 2020, rainfall totals in the MDB were below average, the soils were dry, and the river and water storage levels were low. The landscape and storages had a larger capacity to accommodate the rain and streamflow.

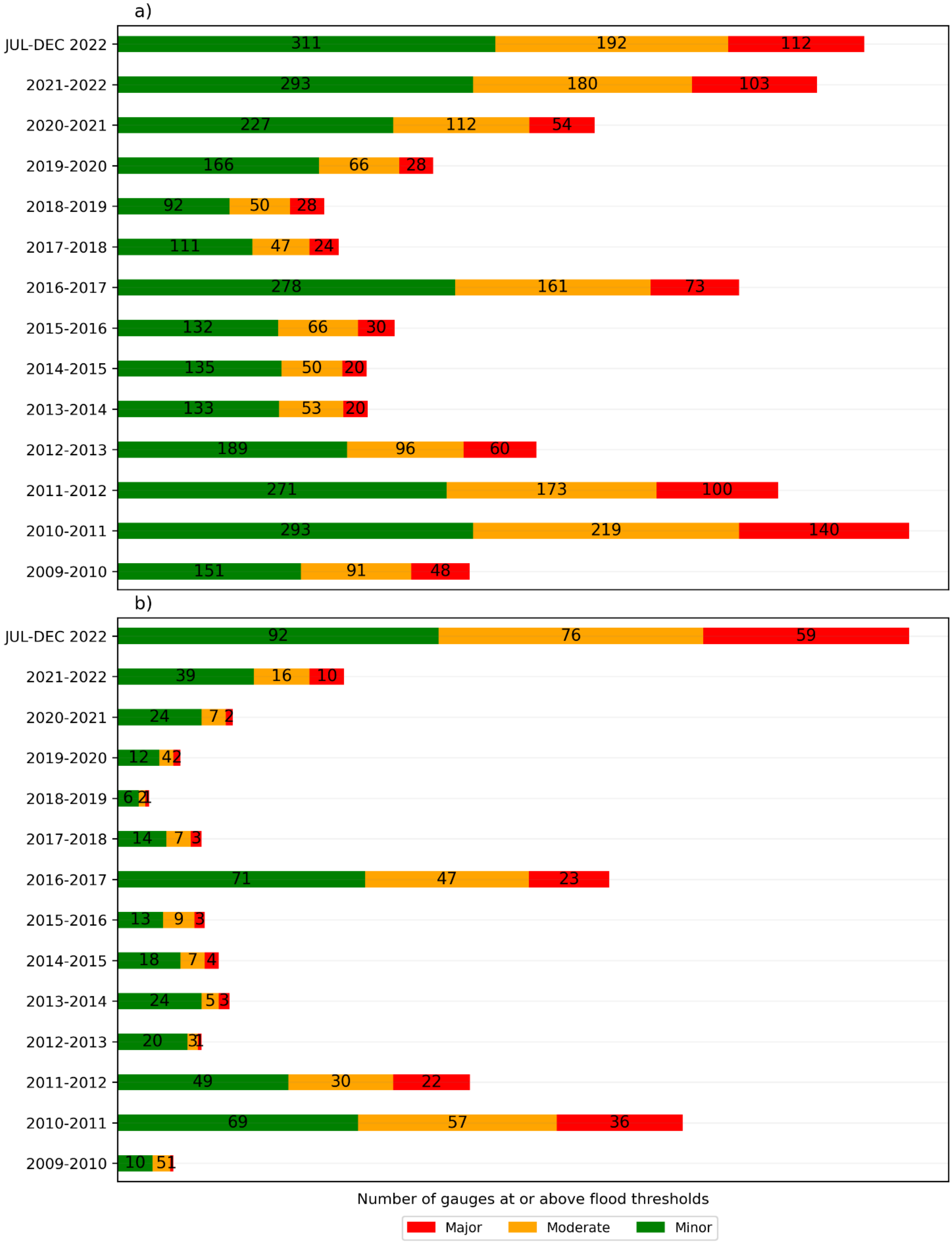

Figure 16: For each July to June year since 2009–10 and July to December 2022, the number of gauges above flood thresholds in a) Australia (453 gauges in 107 rivers) and b) the southern MDB (98 gauges in 16 rivers).

Figure 17: Number of days above flood thresholds during July to June 2010–11, 2011–12 and 2016–17, 2020-21, 2021-22 and June to December 2022 for a) Jemalong Weir D/S (Lachlan River) b) Condobolin Bridge (Lachlan River) c) Hillston Weir (Lachlan River) d) Bourke Town (Darling River) e) Louth (Darling River) f) Warren Town (Macquarie River) g) Hay Town Gauge (Murrumbidgee River) h) Barham (Murray River) i) Wentworth Lock 10 (Murray River) j) Tilpa (Darling River).

Tables

Table 1. Area-averaged rainfall for the August to November 2022 and September to November (spring) 2022 periods: rank from 1 (highest) to 123 (lowest), total, and percentage above or below the 1961–1990 climatological average.

Region	August to November			September to November (spring)		
	Rank	Total (mm)	Difference from 1961–1990 average (%)	Rank	Total (mm)	Difference from 1961–1990 average (%)
Australia	2	183.4	+102	2	158.2	+119
Qld	7	196.1	+101	6	175.6	+109
NSW	1	364.4	+117	1	305.3	+138
Vic	1	457.0	+78	1	355.8	+97
Tas	17	625.4	+24	24	428.6	+21
SA	6	136.8	+98	4	119.8	+134
WA	1	115.1	+112	2	93.8	+137
NT	5	149.7	+113	3	147.3	+121
MDB	1	356.9	+127	1	296.3	+152

Table 2. Monthly area-averaged rainfall for August to November 2022: rank from 1 (highest) to 123 (lowest), total, and percentage above or below the 1961–1990 climatological average.

Region	August			September			October			November		
	Rank	Total (mm)	Diff. (%)	Rank	Total (mm)	Diff. (%)	Rank	Total (mm)	Diff. (%)	Rank	Total (mm)	Diff. (%)
Australia	18	25.2	+36	5	34.7	+110	2	62.5	+169	9	61.0	+88
Qld	22	20.5	+49	10	37.5	+198	8	68.9	+168	22	69.2	+52
NSW	9	59.1	+50	3	82.5	+134	1	148.0	+208	13	74.8	+67
Vic	13	101.0	+34	18	90.0	+40	1	161.4	+150	4	104.5	+101
Tas	18	196.8	+33	92	102.2	−24	16	189.4	+60	17	137.0	+36
SA	52	17.0	−5	23	26.1	+48	1	65.8	+262	20	27.9	+83
WA	22	21.3	+44	3	24.9	+142	5	27.2	+136	4	41.8	+134
NT	38	2.4	−32	12	13.6	+95	11	42.1	+124	5	91.6	+123
MDB	7	60.7	+54	4	81.2	+136	1	142.9	+231	14	72.1	+79

References and further information

This Statement covers information available as of 3 July 2023.

National gridded rainfall analyses, and regional and catchment averages based on them, are for the period since 1900 and national gridded temperature analyses are for the period since 1910. Climatological averages use a 1961−1990 base period unless otherwise stated.

Links to further information

- Climate information:
  - http://www.bom.gov.au/climate/
- Australian Rainfall Analyses:
  - http://www.bom.gov.au/climate/maps/rainfall/
- Australian Water Outlook:
  - https://awo.bom.gov.au/
- Climate Data Services:
  - http://www.bom.gov.au/climate/data-services/
- Water Data Services:
  - https://portal.wsapi.cloud.bom.gov.au/arcgis/apps/sites/#/australian-water-data-service
- Rainfall and River Conditions:
  - http://www.bom.gov.au/australia/flood/
- Water Information:
  - http://www.bom.gov.au/water/
- Annual Climate Statement 2022:
  - http://www.bom.gov.au/climate/current/annual/aus/2022/
- Australia's Changing Climate:
  - http://www.bom.gov.au/state-of-the-climate/2022