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Bureau of Meteorology

Submission to the Inquiry into the 2022 Flood Event in Victoria

Victorian Upper House Parliamentary Inquiry

April 2023



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About the Bureau of Meteorology

The Bureau of Meteorology (the Bureau) welcomes the opportunity to make a submission to the Victorian Upper House Parliamentary Inquiry into the 2022 Flood Event in Victoria.

The Bureau is Australia's national weather, climate and water information agency. The Bureau operates under the Climate Change, Energy, the Environment and Water portfolio and reports to the Minister for the Environment and Water generally. The Bureau also provides weather, climate and water information to the Minister for Emergency Management. It operates under the authority of the *Meteorology Act 1955* (Cth) and the *Water Act 2007* (Cth), which together describe a range of functions that underpin delivery of information, advice, forecasts, warnings and associated services to meet Australia's needs.

Response to Terms of Reference

The Bureau's submission aims to address the following terms of reference (TOR) of the inquiry:

- TOR 1: Causes of and contributors to the Flood Event;
- TOR 2: Adequacy and effectiveness of early warning systems;
- TOR 6: Flood Event as a whole, including but not limited to, the catchments and floodplains of the: Avoca River, Barwon River, Broken River, Campaspe River, Goulburn River, Loddon River, Maribyrnong River, and Murray River;
- TOR 8: The implications for future planning decisions including:
 - a. How the Victorian planning framework can ensure climate mitigation is a consideration in future planning decisions.

Responses to Terms of Reference

TOR 1: Causes of and contributors to the Flood Event

Significant floods that impacted Victoria in 2022 were caused by a combination of climatic conditions that generally favour above average rainfall and high soil moisture, and specific weather systems that brought heavy rain.

Climate drivers

Several climate factors that enhance rainfall over southeast Australia coincided in 2022.

The Indian Ocean Dipole (IOD) is one of the key drivers of Australia's climate. A negative IOD, that typically increases the chance of above average winter–spring rainfall for much of Australia including the southeast, became evident at the end of August 2022 and continued through the spring months.

La Niña typically increases the chances of above average rainfall for northern and eastern Australia, including flood affected areas under consideration in this inquiry, during spring and summer. A third consecutive La Niña event occurred in the Pacific Ocean in the second half of 2022. While back-to-back La Niña events are not uncommon, 3 consecutive La Niña events are less common and had previously occurred only 3 times since 1900: 1954–57, 1973–76, and 1998–2001. La Niña conditions gradually strengthened and matured during October and November.

The Southern Annular Mode (SAM) was mostly positive during the spring months of 2022. A positive SAM in spring and summer increases the chance of above average rainfall for eastern Victoria.

Antecedent conditions

Above average rainfall across Victoria in the months prior to the spring 2022 severe flooding led to both high soil moisture and close-to-full water storages. When soil moisture is high, a large proportion of rain becomes runoff. When water storages are close-to-full, less runoff can be stored in them. Each condition results in more runoff moving downstream in rivers. By September and October 2022, when record rain fell, flood risk was significantly enhanced.

Prior to spring 2022, catchments across parts of Victoria were relatively wet following rainfall in previous months, particularly in the upper parts of the Murray and the Goulburn River catchments. After widespread rainfall during September and October, most catchments across the state had become saturated.

At the start of spring 2022, many public water storages across south-eastern Australia, including in the Murray–Darling Basin, were at or near-capacity after two years of above average rainfall (Figure 1).

- In the year from 1 September 2021 to 1 September 2022, overall storage volume of the Murray-Darling Basin increased from 82.7% to 94.8% of capacity.
- For the same period, in the Southern Basin, storage increased from 83.2% to 93.6% of capacity.

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- Storage in the Northern Basin increased from 80.7% to 100.3% of capacity.

Further significant rainfall in October across the southern parts of the Murray–Darling Basin and southern Victoria resulted in record flooding. Inflows subsequently filled most remaining space in many water storages in these regions.

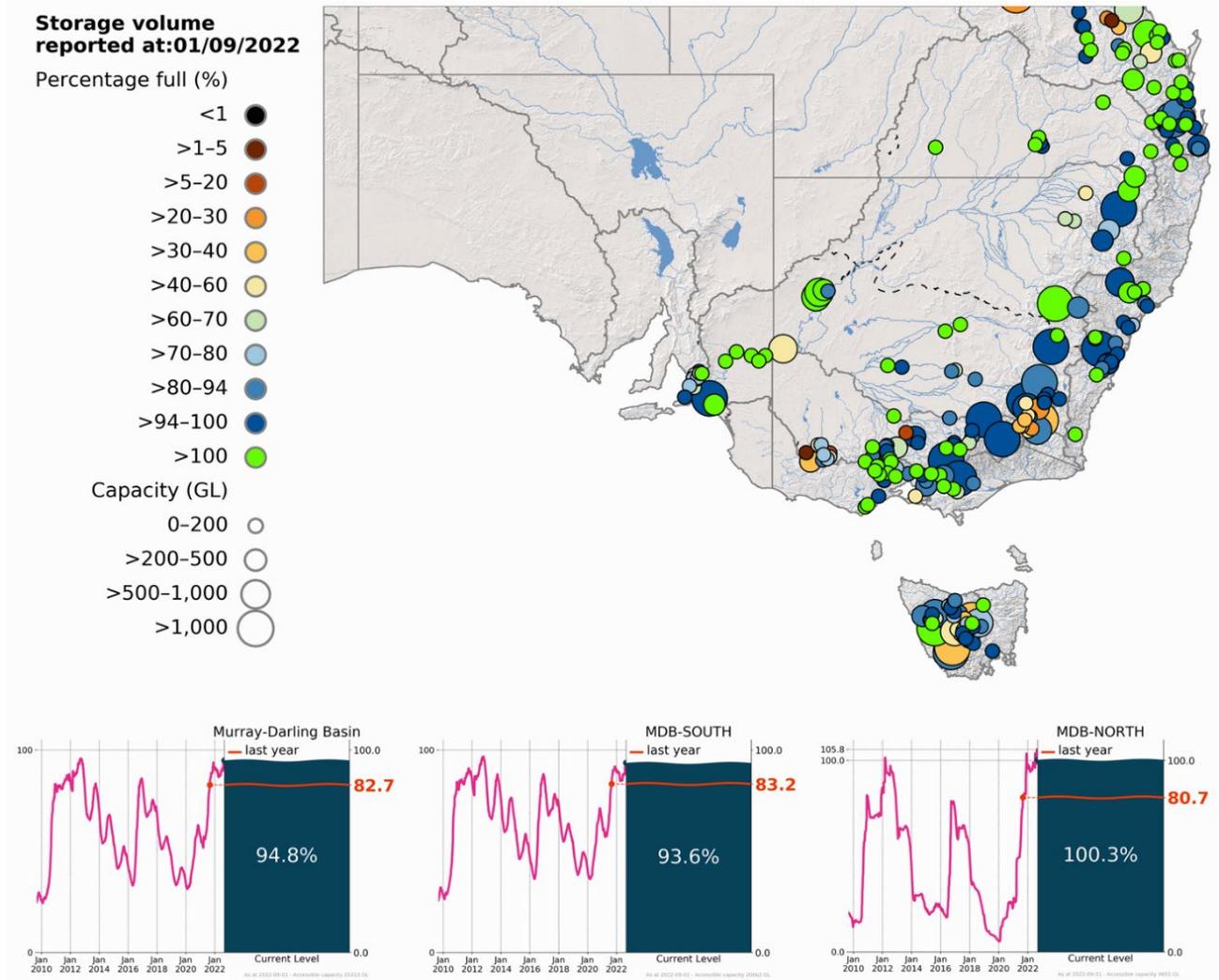


Figure 1: Storage conditions (Percentage full of accessible storages capacity) on 1 September 2022.

Heavy spring rainfall

Many sites in Victoria had either their highest total spring rainfall on record or their highest total spring rainfall in the last 20 years.

October 2022 was the wettest month on record for Victoria (Figure 2). The highest monthly totals were in Victoria's north-east, with Mount Buller being the state's wettest site with 490 mm recorded.

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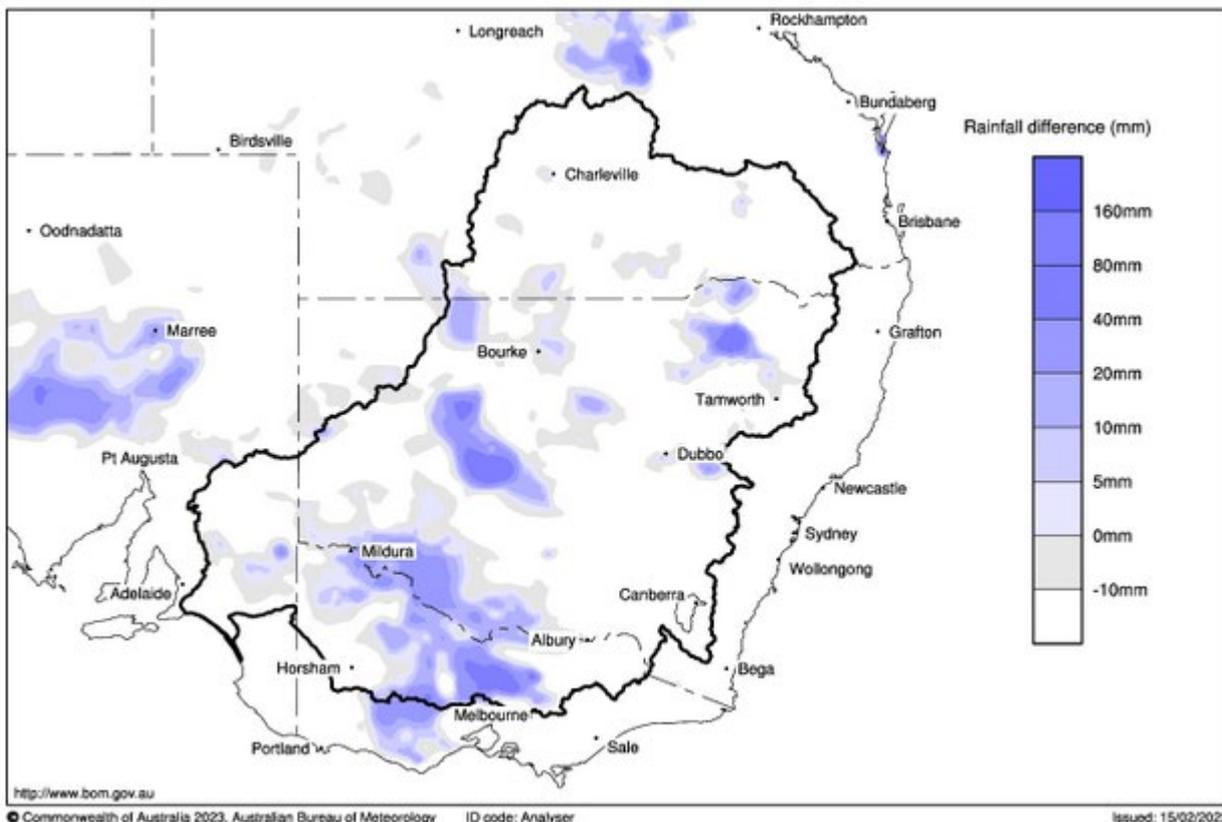


Figure 2: Map showing areas that had their highest 2-day rainfall totals for October on record (since 1900). Purple shading indicates by how much the previous highest 2-day rainfall was exceeded.

The most significant of the low-pressure systems that impacted Victoria crossed the state between 12 – 14 October 2022:

- Rain developed across most of Victoria on 12 October 2022 in a moist northerly airflow ahead of a low-pressure system.
- The heaviest falls were recorded in central parts of the state with widespread daily rainfall totals between 20 and 60 mm and isolated totals exceeding 100 mm.
- Many sites had their highest October daily rainfall on record during this period.
- The highest daily rainfall total recorded in Victoria in October was 123.2 mm at Lima East on 13 October 2022.
- Some locations recorded their wettest two consecutive days on record.

Another low-pressure system which had a significant impact on Victoria moved across south-eastern Australia from 12 – 14 November 2022.

- Showers and storms, tending to rain, produced locally heavy falls across the north-east of Victoria.
- Widespread daily totals of 35 – 70 mm were observed across the north-east to 9am on 13 November and 35 – 90 mm on 14 November 2022.

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TOR 2: Adequacy and effectiveness of early warning systems

In the months preceding the major floods, the Bureau actively communicated the risk of wetter than normal conditions for Victoria during the spring of 2022. This advice was based on the Bureau's long-range forecast for August to October 2022 which predicted above average rainfall across much of Australia. All forecasts for this period, issued twice weekly in May, June and July were highly accurate (forecast skill above 90%).

Briefings to emergency services and water stakeholders

On 2 September 2022, unusually wet conditions and the potential for widespread flooding were forecast and communicated in the Bureau at the High Risk Weather Season briefing. This was a briefing delivered to the National Emergency Management Agency (NEMA) and other jurisdictional emergency services including, but not limited to, Emergency Management Victoria (EMV), State Emergency Services (SES), Victoria Police, and the Department of Environment, Land, Water and Planning (DELWP). Pre-season briefings were delivered to emergency services stakeholders by Bureau staff to amplify the messaging.

Routine streamflow/inflow forecast briefings to the Murray Darling Basin Authority commenced in August 2022 to assist Hume Dam operation. Briefings were expanded to include rainfall information from September. Routine forecast streamflow inflow briefings were also delivered to Goulburn Murray Water to assist Lake Eildon operations from August.

In the immediate lead up to and during the floods the Bureau explicitly forecast and communicated risk to the Victorian emergency services, including the SES and EMV. This included daily briefings and products such as the Severe Weather Intelligence Briefing which was created for and shared with the Victorian emergency services three times a week.

Rainfall briefings to Melbourne Water were provided in the lead up to significant events impacting Melbourne catchments.

Flood watches and warnings were issued in advance of major flood levels being reached.

The Bureau clearly identified the potential for river rises in its communications with the emergency services and the community.

The above information was enhanced through specialist Bureau meteorologists, hydrologists and community engagement practitioners being embedded with the emergency services in the State Control Centre. During the months of October and November 2022, 63 shifts, including nights, were performed as a part of the embedded meteorologist role and a hydrologist was embedded on at least 20 occasions. The embedded hydrologist is a new capability implemented to uplift information and decision-making by emergency services relating to flood events.

Communication to the community

At a media conference held in August 2022 the Bureau, together with senior Victorian emergency services representatives, highlighted an increased risk of flooding in Victoria during the spring based on the Bureau's High Risk Weather Season Outlook.

Between 4 October to 7 December 2022, the Bureau:



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- participated in 14 press conferences with Victorian emergency services
- responded to 366 ad hoc media enquires in relation to the floods
- conducted 61 live television crosses
- reached more than 2.5 million people through its social media posts.

The Severe Weather long-range forecast 2022-23 video, released on 10 October 2022 to social media, specifically highlighted the wet landscape and increased risk of flooding and was viewed approximately 37,000 times.

Flood and severe weather warnings

The Bureau's flood and severe weather warning service provided highly valuable advice to Victorian emergency services and the community. To illustrate the adequacy and effectiveness of the warning services provided, the sequence of warnings for the two most noteworthy flood events that occurred in October and November 2022 is described below.

October major flood event

The Bureau updated forecasts and warnings as new information became available during what was, for many catchments, a rapidly evolving and dynamic riverine flood event.

The following timeline outlines the watches, warnings and products issued.

- 6 October 2022: The potential for widespread rain and locally heavy falls developing between 12 – 14 October 2022 in Victoria was included in a briefing to emergency services at the State Control Centre.
 - Subsequent daily briefings (1 – 5 scheduled mornings, 1 – 2 scheduled afternoons and a high volume of ad hoc including overnight) in the leadup to the event provided greater detail around expected rainfall totals and potential flood impacts as the event drew closer.
- 9 October 2022: the risk of heavy falls for the same period was included in the public weather forecast including on District, State, Precip and Metropolitan Area forecasts.
- 10 October 2022: a Flood Scenario Outlook product was produced and distributed to Victorian emergency services for initial planning purposes. This product included two credible alternative rainfall scenarios for the upcoming week. The initial Flood Scenario Outlook product indicated a risk of widespread minor to moderate flooding, with major flooding likely in some catchments.
- 11 October 2022: The first publicly available Flood Watch was issued, as heavy rainfall guidance became consistent across forecast models.
- 11 October 2022: A severe weather warning for heavy rainfall was issued for parts of western and central Victoria developing from 12 October.
- 12 October 2022: Subsequent Flood Watch was issued, highlighting that further widespread major flooding was likely over many northern Victorian catchments, and in south-west Victoria.
- 12 October 2022: A severe weather warning for heavy rainfall was extended to include remaining parts of central and north-eastern Victoria.

Rochester

- 10 October 2022: for Rochester, the flood scenarios product included a credible alternative scenario indicated that a major peak of 115.5 m Australian Height Datum (AHD), within 0.2 of the highest recorded flood peak, was possible. This information was used to brief emergency services and for initial emergency planning purposes.
- 11 October 2022 onwards: Major flooding was indicated for Rochester in most likely scenarios issued.
- 12 October 2022: Due to the clear alignment of heavy rainfall forecast guidance over the catchment, a major flood warning was issued for the Campaspe River at Rochester (6:53pm), two days before major flooding developed.
 - Between the initial major flood warning and the peak height of 115.7 m AHD occurring at Rochester, a total of 10 warnings were issued, keeping emergency services and the community informed as the situation developed.
- 13 October 2022: The first flood warning for Rochester that included a forecast above the record 2011 flood level, approximately 115 m AHD, was issued.
- 15 October 2022: A flood peak of 115.67 m AHD was observed.

Seymour

- 10 October 2022: for Seymour, the flood scenarios product included a credible alternative scenario indicated a moderate peak of 6.2 m was possible. This information was used to brief emergency services and for initial emergency planning purposes.
- 11 October 2022 onwards: Moderate flooding was indicated for Seymour in the higher possible scenario issued.
- 13 October 2022: Early in the morning (12:09am) a moderate flood warning was issued for the Goulburn River for Seymour. The forecast at Seymour was upgraded to major flooding approximately 12 hours later around midday (12:11pm) on the same day due to heavy rainfall around Seymour and its local tributaries.
 - Between the Initial Major Flood Warning and the peak height of 8.26 m occurring, 4 warnings were issued for Seymour.
- 14 October 2022: A flood peak of 8.26 m occurred early in the morning (2:45 am), well above the 1974 flood level of 7.64 m.

Shepparton

- 10 October 2022: for Shepparton, the flood scenarios product included a credible alternative scenario indicated a major peak of 11 m was possible. This information was used to brief emergency services and for initial emergency planning purposes.
- 11 October 2022: Major flooding was indicated for Shepparton in the higher possible scenario issued.
- 13 October 2022: A major flood forecast for Shepparton was included in the Goulburn River warning during the afternoon (2:53 pm).
- 16 October 2022: A peak of 12.06 m occurred at a level of 12.06 m, below the 1974 flood level (12.09 m).

Echuca

- 14 October 2022: the first major flood prediction was made for Murray River at Echuca Wharf (6:11 pm).
 - Between the initial major warning and the peak height occurring, 22 warnings were issued for Echuca and forecasts and warnings were updated as new information became available.
- 26 October 2022: A flood peak of 94.98 m AHD was observed.

November major flood event

The following timeline outlines the watches, warnings and products issued.

- 6 November 2022: The risk of rain, storms and moderate to heavy falls in north-eastern Victoria between 13 – 14 October 2022 was included in briefings to emergency services at the State Control Centre, including on the Severe Weather Intelligence Briefing product.
- 11 November 2022: The risk of heavy falls for the same period was included on the public weather forecast.
- 12 November 2022: A severe weather warning for heavy rainfall was issued for north-eastern Victoria.
- 12 November 2022: The Murray River to Tocumwal was included in a New South Wales Flood Watch and Flood Outlook Scenario Product which included the potential for moderate to major flooding.
- 13 November 2022: Spills from Hume Dam, combined with major flooding along the Kiewa River and localised heavy rainfall, resulted in major flooding developing at Albury. A major flood warning forecasting major flooding for Albury was issued in the morning (8:08am).
- 14 November 2022: In the afternoon (4:19pm), a major flood warning was issued forecasting major flooding at Yarrawonga and Tocumwal, as an expected moderate flood peak from the Ovens River would join with flows arriving from the Murray River. This created a second major flood peak moving downstream with the majority of flow diverted into the Edwards River system downstream of Tocumwal.
- 17 November 2022 (5:07pm): Another major food warning was issued for Echuca as upstream flows arrived from the Murray River through the Barmah Choke and combined with Goulburn River flows. The river level at Echuca remained above the moderate flood level until 1 December 2022, where it fell below the moderate flood level (93.9 m AHD).
- 5 December 2022: The flood level at Echuca fell below the minor flood level (93.5 m AHD).



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TOR 6: Flood Event as a whole, including but not limited to, the catchments and floodplains of the Avoca River, Barwon River, Broken River, Campaspe River, Goulburn River, Loddon River, Maribyrnong River, and Murray River

Summary of the spring flooding

Over the spring of 2022, major flooding occurred in the Broken, Campaspe, Goulburn, Kiewa, Loddon, Murray-Riverina, Ovens and Avon River catchments.

Outside of the Murray–Darling Basin, flooding occurred in many catchments including Avoca, Wimmera, East Gippsland, Snowy, Tambo, Mitchell, Thomson, Latrobe, South Gippsland, Bunyip, Yarra, Maribyrnong, Werribee, Barwon, Hopkins and Glenelg.

Out of 100 flood forecasting sites in various Victorian catchments, 80 reached or exceeded flood thresholds, with major floods at 29 sites, moderate floods at 21 and minor floods at 30 forecast locations.

Towns in Victoria that were severely impacted by major flooding included Shepparton and Seymour in the Goulburn catchment, Albury, Echuca and Mildura in the Murray River catchment, and Rochester in the Campaspe catchment.

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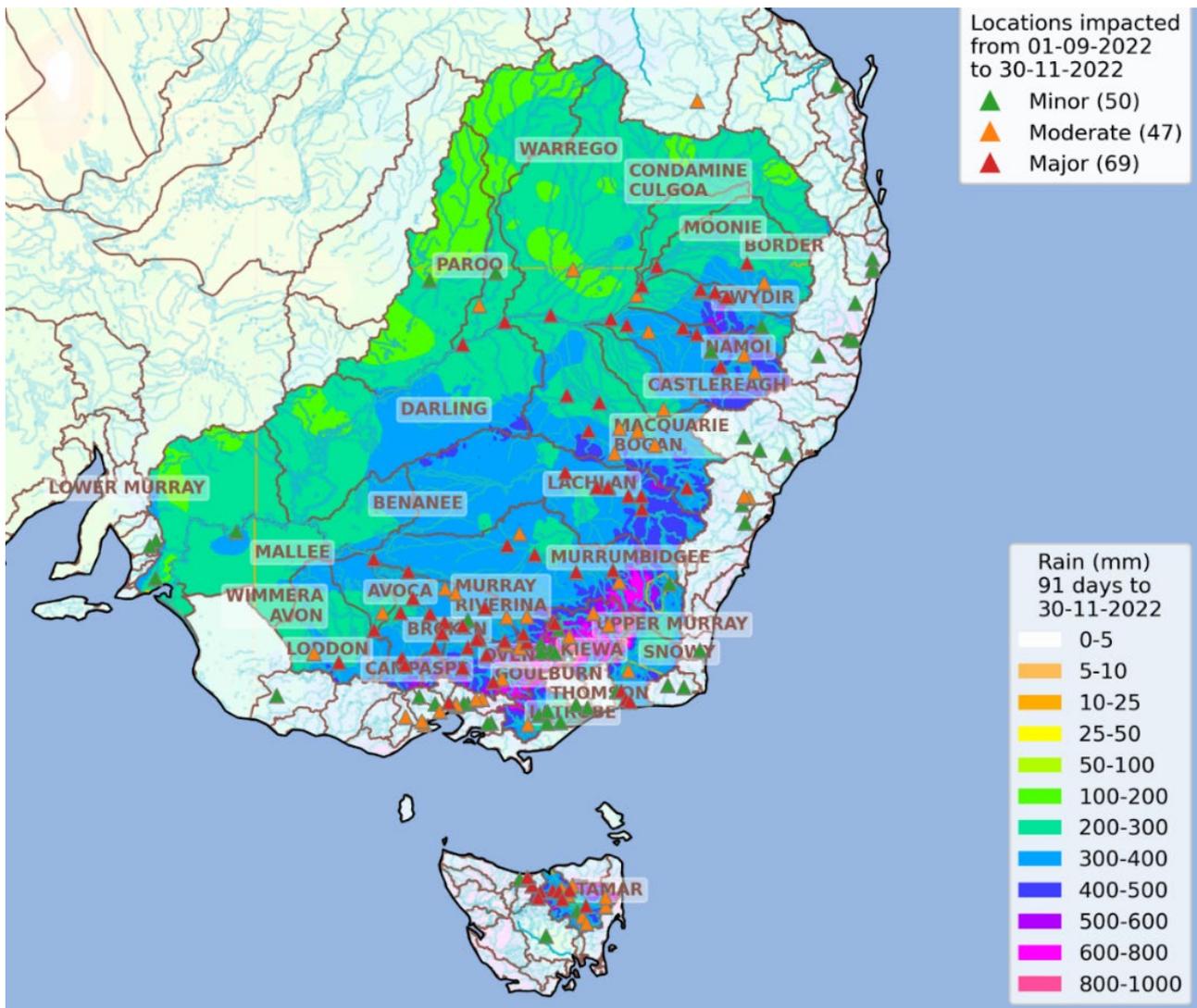


Figure 3: Spring 2022 rainfall totals and associated flood peaks in south-eastern Australia.

Summary of Bureau activities

- A total of 673 flood warnings were issued across eleven flood catchments (Avoca, Baron, Broken, Campaspe, Goulburn, Hopkins, Loddon, Murray, Ovens and King, Seven & Castle Creeks and Wimmera rivers) for the early October 2022 Flood event. Noting some of these warnings extended across months, in particular the Murray River into January.
- For the periods that warnings were active, the accuracy of the peak river height forecasts summarised across eleven catchments, was above 99%, with nine catchments having a forecast peak accuracy of above 99%.
- Warnings were issued prior to the stated next warning issue time on 88% of occasions.
- Target lead time summarised across eleven catchments, as specified in the service level agreements for each catchment, was achieved 84% of the time for the 80 forecast warning locations where major flooding was forecast.

Catchment	# Flood Warnings	Initial warning	Final warning	Verification from	Verification to	Lead-Time Achieved	Timeliness Achieved	Peak Accuracy
Avoca River	55	6-Oct	3-Nov	16-Sep	16-Nov	63%	90.32%	100%
Barwon and Moorabool Rivers	15	13-Oct	19-Oct	16-Sep	16-Oct	60%	92.31%	100%
Broken River	23	13-Oct	19-Oct	16-Sep	16-Oct	100%	92.59%	100%
Campaspe River	60	12-Oct	8-Dec	16-Sep	16-Dec	100%	91.8%	100%
Goulburn River	88	13-Oct	29-Nov	16-Sep	16-Dec	75%	82.29%	100%
Hopkins River and Mt Emu Creek	12	13-Oct	17-Oct	16-Sep	16-Oct	0%	77.78%	100%
Loddon River	129	9-Sept	3-Dec	16-Aug	16-Dec	100%	88.72%	100%
Murray River	147	5-Aug	21-Jan	16-Aug	16-Dec	79%	86.3%	99.12%
Ovens and King River	54	12-Oct	8-Nov	16-Sep	16-Nov	88.89%	83.54%	94.44%
Seven and Castle Creeks	68	12-Oct	21-Nov	16-Sep	16-Dec	85.71%	90.28%	94.44%
Wimmera River	22	13-Oct	22-Oct	16-Sep	16-Oct	100%	90.48%	100%

Table 1: Key Performance Indicators for key Victoria catchments issued over the 2022-2023 spring summer.

a. Avoca River

- A severe weather warning issued on 11 October at 4:57 pm included the potential for heavy rain over the Avoca River catchment.
- 57.1 mm was recorded at St Arnaud to 9am on 13 October.
- 79.6 mm was recorded at Avoca to 9am on 14 October.
- A major flood warning was issued for Charlton Town on 13 October at 8:00 pm. A peak height of 7.87 m (major flooding) was observed at 2:45 am on 17 October.
- A major flood warning was issued for Quambatook on 17 October at 7:40 pm. A peak height of 2.36 m (major flooding) was observed at 3:45 pm on 21 October.

b. Barwon River

- A severe weather warning issued on 11 October at 4:57 pm included the potential for heavy rain over the Barwon River catchment.
- 29 mm was recorded at Inverleigh to 9 am in the 24 hours to 13 October.
- 49.4 mm was recorded at Mount Mercer in the 24 hours to 9 am on 14 October.
- A moderate flood warning was issued for Shelford Highway Bridge on 13 October at 9:35 pm. A major flood warning was issued for Shelford Highway Bridge on 14 October at 3:20 am. A peak height of 7.82 m (moderate flooding) was observed at 7:45 am on 14 October.

c. Broken River

- A severe weather warning issued on 12 October at 10:48 am included the potential for heavy rain over the Broken River catchment.
- 128 mm was recorded at Strathbogie North in the 24 hours to 9 am on 13 October.
- 94 mm was recorded at Strathbogie North in the 24 hours to 9 am 14 October.
- A major flood warning was issued for Benalla on 14 October at 1:31 am. A peak height of 4.49 m (major flooding) was observed at 10:14 am on 14 October.
- A major flood warning was issued for Caseys Weir on 14 October at 1:31 am. A peak height of 3:52 m (major flooding) was observed at 9:45 pm on 14 October.
- A major flood warning was issued for Orrvale on 14 October at 1:31 am. A peak height of 8.34 m (major flooding) was observed at 8:45 am on 17 October.

d. Campaspe River

- A severe weather warning issued on 11 October at 4:57 pm included the potential for heavy rain over the Campaspe River catchment.
- 83.6 mm was recorded at Kyneton in the 24 hours to 9 am on 13 October.
- 51.4 mm was recorded at Heathcote in the 24 hours to 9 am 14 October.
- A Major Flood Warning was issued for Barnadown on 12 October at 6:53 pm. A peak height of 8:66 m (major flooding) was observed at 8:45 am on 14 October.
- A major flood warning was issued for Rochester on 12 October at 6:53 pm. A peak height of 115.7 m AHD (major flooding) was observed at 12:08 am on 15 October.

e. Goulburn River

- A severe weather warning issued on 11 October at 4:57 pm included the potential for heavy rain over the Goulburn River catchment.
- 97.4 mm was recorded at Too Rour in the 24 hours to 9 am on 13 October.
- 91.4 mm was recorded at Too Rour in the 24 hours to 9 am 14 October.
- A major flood warning was issued for Taggerty on 13 October at 9:38 am. A peak height of 3.27 m was (major flooding) was observed at 2:45 am on 14 October.
- A major flood warning was issued for Seymour on 13 October at 12:11 pm. A peak height of 8:26 m (major flooding) was observed at 2:45 am on 14 October.
- A major flood warning was issued for Shepparton on 13 October at 2:53 pm. A peak height of 12.06 m (major flooding) was observed at 9:08 pm on 16 October.
- A major flood warning was issued for Murchison on 13 October at 11:25 pm. A peak height of 12.05 m (major flooding) was observed at 9:45 pm on 15 October.
- A major flood warning was issued for McCoys Bridge on 15 October at 2:55 am. A peak height of 10.59 m (major flooding) was observed at 10:30 pm on 18 October.

f. Loddon River

- A severe weather warning issued on 11 October at 4:57 pm included the potential for heavy rain over the Loddon River catchment.
- 78.4 mm was recorded at Sandhurst Reservoir in the 24 hours to 9 am on 13 October.



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- 41 mm was recorded at Sandhurst Reservoir in the 24 hours to 9 am 14 October.
- A major flood warning was issued for Laanecoorie Res D/S on 13 October at 3:53 pm. A peak height of 8.40 m (major flooding) was observed at 9:45 am on 14 October.
- A major flood warning was issued for Appin South on 15 October at 4:40 pm. A peak height of 3.47 m (major flooding) was observed at 11:45 pm on 20 October.
- A major flood warning was issued for Kerang on 15 October at 4:40 pm. A peak height of 77.97 m AHD (major flooding) was observed at 11:00 am on 22 October.

g. Maribyrnong River

- A severe weather warning issued on 12 October at 10:48 am included the potential for heavy rain over the Maribyrnong River catchment.
- 42 mm was recorded at Romsey to 9am in the 24 hours to 13 October.
- 58.2 mm was recorded at Romsey to 9am in the 24 hours to 14 October.
- Flood forecasts and predictions for the Maribyrnong River are produced by Melbourne Water.

h. Murray River

- A severe weather warning issued on 12 October at 10:48 am included the potential for heavy rain over the Upper Murray River.
- 51.4 mm was recorded at Snowy Creek in the 24 hours to 9am 14 October.
- A major flood warning was issued for Torrumbarry on 14 October at 6:11 pm. A peak height of 7.84m (major flooding) was observed at 10:30pm on 22 October.
- A major flood warning was issued for Echuca Wharf on 14 October at 6:11 pm. A peak height of 94.98m AHD (major flooding) was observed at 11:45 pm on 26 October.
- A moderate flood warning was issued for Swan Hill on 15 October at 4:00 pm. A peak height of 4.60 m (moderate flooding) was recorded at 12:00 am on 15 November.
- A major flood warning was issued for Mildura Weir Hg on 2 November at 5:41 pm. A peak height of 38.53 m AHD (major flooding) was observed at 9:00 am on 15 December.
- A major flood warning was issued for Below Wakool Junction on 1 November at 1:22 pm. A peak height of 11.73 m (major flooding) was observed at 1:00 pm on 13 November.
- A major flood warning was issued for Boundary Bend on 2 November at 5:41 pm. A peak height of 9.15 m (major flooding) was observed at 4:30 pm on 6 December.
- A major flood warning was issued for Wentworth Lock 10 on 2 November at 5:41 pm. A peak height of 9.38 m (major flooding) was observed at 11:00 am on 16 December.
- A major flood warning was issued for Euston on 8 November at 4:41 pm. A peak height of 10.26 m (moderate flooding) was observed at 3:00 pm on 9 December.
- A severe weather warning issued on 12 November at 10:46 am included the potential for heavy rain over the Upper Murray River.
- 67.8 mm was recorded at Tallandoon in the 24 hours to 9 am 13 November.
- 73.8 mm was recorded at Burrowye Station in the 24 hours to 9 am 14 November.
- A major flood warning was issued for Albury on 13 November at 8:08 am. A peak height of 5.52 m (major flooding) was observed at 12:00 am on 14 November.



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- A major flood warning was issued for D/S Yarrowonga on 14 November at 4:19 pm. A peak height of 7.79 m (major flooding) was observed at 6:45 am on 16 November.
- A major flood warning was issued for Tocumwal on 14 November at 4:19 pm. A peak height of 7.40 m (major flooding) was observed at 4:45 pm on 17 November.

TOR 8: The implications for future planning decisions including:

a. How the Victorian planning framework can ensure climate mitigation is a consideration in future planning decisions

As per the 2022 State of the Climate¹, there has been a decrease of around 10 per cent in April to October rainfall since the late 1990s across south-east of Australia. This period is when peak streamflow occurs in most catchments in the region, as cool season rainfall is generally more effective than warm-season rainfall in generating runoff. The decreasing trend is due to a combination of natural variability on decadal timescales and changes in large-scale circulation caused by an increase in greenhouse gas emissions.

Even in regions where the average rainfall is expected to decrease or stay the same such as Victoria, it is anticipated that there will be an increase in intense in short-duration heavy rainfall events. Short-duration extreme rainfall events (such as for hourly rainfall totals) are often associated with flash flooding, which brings increased risk to communities. This will lead to a complex mix of effects on streamflow, and associated flood and erosion risks, including increased risk of small-scale flash flooding.

¹ 2022 State of the Climate <http://www.bom.gov.au/state-of-the-climate/future-climate.shtml>