Menindee Lakes Flood Operations Review 2021-2023

November 2023

Contents

Executive Summary

The Menindee Lakes are an important water resource for the Lower Darling region in southwestern NSW. Originally a series of natural lakes, later modified into artificial water storages, the Lakes sit at the bottom of a vast catchment area the size of France, stretching 574,000 km^2 from southern Queensland through to southern New South Wales.

Following a severe drought, extensive rainfall in the northern basin saw the lakes refill in 2021. Further rainfall throughout 2022 in the Northern Basin resulted in extensive inflows into the Menindee Lakes System, equating to more than six times the storage capacity.

The volume of water received was significant and it was also sustained, with three distinct flood peaks taking place over a year. During this period, there was a minor or greater flooding alert in place in Menindee for 9 months (May 2022 to February 2023).

The floods had a devastating impact on the Menindee community, particularly on those who rely heavily on the river and First Nations communities, given their deep connection to the river and country.

WaterNSW has conducted this review to better understand the flooding event, seek community feedback and identify opportunities to improve its operations, so lessons can be learned and incorporated into the next flooding event.

As the operator of the state's dams, including the Menindee Lakes, WaterNSW worked to manage the Lakes throughout this period under the obligations in its legislative operating objectives. These follow a hierarchy - the preservation of dam safety, conservation of the water resource and provision of downstream flood mitigation, where possible. During these operations, WaterNSW considered a range of risks and risk factors prior to each decision. As described in section 4 of the report, this was a constantly changing situation throughout 2022 as successive flood peaks travelled from the Northern Basin, through the Barwon-Darling, to the Menindee Lakes system. WaterNSW managed the Menindee Lakes throughout 2022 and consulted with the State Emergency Service (NSW SES), Bureau of Meteorology (BOM) and other stakeholders to inform its flood operation decisions.

Flood operations at the Menindee Lakes occurred over three distinct time periods:

- May to August 2022, when flows at the Menindee Town gauge exceeded the Minor flood level.
- September to November 2022, when flows at Menindee Town gauge exceeded the Moderate flood level.

- December 2022 to February 2023, during which flows at the Menindee Town gauge exceeded the Major flood level from 30 December 2022. This impacted a number of residences adjacent to the river in the Menindee township.

This review should be considered alongside other recently completed or ongoing inquiries that have investigated similar topics, events and themes. This includes the 2022 NSW Flood Inquiry which made a series of findings and recommendations relating to improvements in the way NSW prepares for, responds to, and recovers from flooding events, as well as the Office of the NSW Chief Scientist & Engineer (OCSE) review of the February-March 2023 fish deaths in the Darling-Baaka River, Menindee.

While covering separate (but related) events, this review has specifically been designed to not duplicate any of the other inquiries.

The purpose of this review was to understand:

- Whether WaterNSW systems, policies and procedures enabled WaterNSW to properly execute its functions over the course of the event.
- Whether WaterNSW actions helped to provide flood mitigation benefits for the local area.
- The quality and availability of inflow data and modelling, in particular, the inflows from unregulated tributaries.
- The effectiveness of WaterNSW's engagement and communications with other agencies involved in the emergency response; and
- To identify opportunities to further enhance communications with the local community before and during the event.

This report includes a compilation of facts relating to the management of the Menindee Lakes System, and assessment of WaterNSW's performance, and feedback from other agencies, stakeholders and community members. Notably, on 28 and 29 June 2023, WaterNSW spent two days on ground in Menindee speaking with the community in preparation for this report. Feedback was also received from WaterNSW Customer Advisory Group representative members.

The report makes five findings and three recommendations. A key finding is that the management of floodwaters through the Menindee Lakes throughout the flooding events

provided significant flood mitigation benefits, contributing to a reduction in the peak instantaneous flood magnitude of 29.2%.

The report also identifies opportunities for improvement. In particular, upgrades to the river gauging network are needed to improve WaterNSW's ability to measure river flows and forecast floods, while efforts must be taken to improve engagement with the local community.

The findings and recommendations in this report have all been accepted by WaterNSW. In compiling the report, it has been reviewed and critiqued by a suitably qualified independent expert and approved by the WaterNSW Board.

Findings and Recommendations

Findings

Finding 1 – WaterNSW' systems, policies and procedures are appropriate

WaterNSW operates within a highly regulated environment and takes its obligations to operate and maintain water infrastructure seriously. Its personnel have strong engineering and scientific qualifications and experience. During the Darling River flood events WaterNSW had in place robust systems, policies and procedures to work within its regulatory environment and fulfil its system operations, dam safety, asset management and incident management responsibilities. Further details can be found in *section 6.1* of the report.

Finding 2 – WaterNSW' actions provided a flood mitigation benefit to the community

WaterNSW managed the lakes throughout these events within the operating rules and asset limitations of the system. Acknowledging that some members of the community were impacted by the floods, the actions taken by WaterNSW were found to have provided a flood mitigation benefit to the community. Estimated inflows to the lakes system peaked at 106,000 ML/d whereas peak releases were contained to 75,000 ML/d reducing the magnitude of the peak instantaneous flood discharge by 29.2%. This was achieved by the creation of airspace in the storages in the lead-up to the flood peak, combined with surcharging of the storages consistent with the operating procedures. The Menindee Town gauge was forecast by the

Bureau of Meteorology to peak at 10.7 m whereas it actually peaked 44 cm lower at 10.26 m[1]. According to data provided to WaterNSW by the NSW State Emergency Service (SES)[2], the number of dwellings that experienced over-floor flooding at the peak of the event was 27 while a further 30 dwellings had access cut-off and were isolated. In addition, the yards of 19 dwellings were inundated. Had the peak been 10.7m as forecast by the BoM, some 0.44m higher than the actual flood peak, data from the NSW SES estimates that the number of dwellings likely to have been impacted by over-floor flooding would have been around 55 while some 60 would have had access cut-off and become isolated. The actions of WaterNSW flood operations over the late December 2022 to early January 2023 period therefore contributed to a flood mitigation benefit for a significant number of dwellings. Further details are provided in *section* 6.2 of the report.

Finding 3 – The river gauging network is not currently designed for Menindee Lakes flood operations

The number and location of river gauges created challenges for WaterNSW's flood planning and operations. The gauging network is not currently designed for Menindee Lakes flood operations and contributed to high levels of uncertainty in the modelling of inflows to the lakes system. The current gauges do not account for water losses and gains to the system between Wilcannia, above Menindee, and Wentworth, below Menindee, from ungauged tributaries, flood runners, distributary creeks and floodplain lakes, among other factors. Historical reports and analyses indicated that during past floods inflows to Lake Wetherell have peaked at around 60% of the combined flows in the Main Channel at Wilcannia and the Talyawalka gauge at the Barrier Highway. During the 2002/23 Darling River floods the combined gauges (as expressed by station 425002 – Darling @ Wilcannia Total) peaked at 104,925 ML/d whereas

[1] Noting that the 'Provision and requirements for flood warning in NSW' (November 2019) specifies a target peak accuracy of 70% of BOM forecasts being within +/- 0.3m at the Menindee town gauge. Note also that there is no rating curve at the Menindee gauge, so it is difficult to equate the reduction in peak flood discharge with a difference in gauge height.

[2] Email communication from NSW SES Chief Inspector and Coordinator Emergency Planning – Southern Zone and Western Zone, 6 September 2023.

the inflows to Lake Wetherell peaked at 106,000 ML/d, far exceeding the previous expected ratio of 60% of the Wilcannia total flow peak. With better gauge information and improved modelling of flow routing between Wilcannia and Menindee, post-event scenario analysis suggests that peak releases may have been restricted to 66,100 ML/d (cf 75,000 ML/d) and more lead time could have been provided to the response agencies. Further details are provided in *section 6.3* of the report.

Finding 4 – WaterNSW' engagement and communication with other agencies was appropriate and consistent with the requirements of the Menindee Lakes operations procedures

WaterNSW and its partner agencies in water management, flood management and emergency management have well established methods of engagement and communication that have operated for some time throughout multiple floods and other events across NSW. WaterNSW' interactions with these agencies, including the State Emergency Service, the Bureau of Meteorology, the Department of Planning and Environment (Water), the Murray Darling Basin Authority and the Local Emergency Management Committee during the Menindee and Lower Darling floods was appropriate and consistent with the requirements of the Menindee Lakes operations procedures. Further details are provided in *section 6.4*.

Finding 5 – There are opportunities to improve communications and engagement with the local community

While multiple agencies made efforts to provide timely and important information, there remains confusion about roles and responsibilities in this complex environment. This contributes to poor understanding of where relevant information can be found during floods. There is a tension between economic and environmental benefits of overbank flows downstream of the Menindee Lakes, and the social consequences associated with impacts of flooding on houses in Menindee township. A sentiment expressed by many locals who provided feedback to this review process, is that locals would appreciate being listened to by agencies in a more coordinated manner, with a desire to have their local knowledge, experience and

connections to the river system incorporated into water system operations. Further details are provided in *section 6.5*.

Recommendations

In response to these findings, a series of recommendations have been developed. In the interest of continuing to improve its performance and ability to manage dam flood operations, WaterNSW will now implement the following:

Recommendation 1 - Review the River Gauging Network

It is recommended that a thorough review of the number and location of river gauges be undertaken by WaterNSW and partner agencies, with a view to identifying the need for any new and/or modified river gauges that will account for system losses and gains between Wilcannia and Wentworth. The proposed network should be compatible with models owned by WaterNSW and other agencies including the Bureau of Meteorology. The review should consider and evaluate any new or emerging technologies that could be incorporated into the network to improve accuracy, reliability and/or safety during floods. Potential funding sources should also be identified.

Recommendation 2 - Develop a formalised communication and engagement protocol with other agencies to improve communication with the community

While each government agency has its own means of communicating and engaging, it is recommended that WaterNSW develop a more formalised approach to its communications to community, during flood operations, coordinated with other agencies. This protocol should be developed in consultation with the local community and reflect feedback from stakeholders, and this review. Flood operations in this region can take place over many months. While NSW SES leads communications during an emergency, including evacuations, there are other opportunities outside this for WaterNSW to communicate more clearly and keep community up to date. During an incident or emergency, individuals and communities need access to timely and relevant information that is tailored to their needs and delivered in the most efficient and appropriate manner. The protocol should clearly outline roles and responsibilities, and information flow paths, so community is clear on where to access essential

information. WaterNSW and other agencies should also explore opportunities to increase community involvement.

Recommendation 3 – Continue to deliver improvements to the CARM decision support system

The Computed Aided River Management (CARM) decision support system has been established over the past five years and there is an ongoing work program to enhance the underlying modelling to improve forecasting capability and better understand catchment and river behaviour. For Menindee Lakes flood operations, it is recommended to focus on:

- Improved forecasting of river flows upstream of Wilcannia
- Improved understanding of flow behaviour between Wilcannia and the Menindee lakes, and downstream of the lakes.
- More detailed tools, models and analysis for flood operations.

1. Introduction

The Menindee Lakes Scheme was constructed between 1949 and 1968 at the site of a chain of large natural lakes on the western side of the Darling-Baaka River in the vicinity of Menindee Township, approximately 200 km upstream of the junction with the Murray River at Wentworth. The upstream catchment is vast, comprising of southern Queensland and much of northern New South Wales, west of the Great Divide.

Following a severe drought, extensive rainfall in the northern basin saw the lakes refill in 2021. Further rainfall throughout 2022 resulted in extensive inflows into the Menindee Lakes System. In managing the vast volume of water inflows, WaterNSW worked to manage the lakes throughout these events in accordance with the operating rules and considering the asset limitations of the system.

However, despite the efforts of multiple agencies involved, it is acknowledged that flooding of some residences occurred in the early part of 2023. WaterNSW is committed to reviewing, seeking feedback on and continuously improving its operations. This report includes an analysis of the management of the Menindee Lakes System as well as feedback from other agencies, stakeholders and community members.

1.1 Report Objectives

WaterNSW is committed to reviewing, seeking feedback on and continuously improving its operations. This report aimed:

- To determine whether WaterNSW systems, policies and procedures enabled WaterNSW to properly execute its functions over the course of the event.
- To determine whether WaterNSW actions helped to provide flood mitigation benefits for the local area.
- To show the quality and availability of inflow data and modelling, in particular, the inflows from unregulated tributaries.
- To assess the effectiveness of WaterNSW's engagement and communications with other agencies involved in the emergency response; and
- To identify opportunities to further enhance communications with the local community before and during the event.

2. Background

This section provides background information of relevance to the management and operation of the Menindee Lakes System. This includes a description of the Barwon-Darling system, the Menindee Lakes storages and regulatory structures, how the lakes are operated and managed, the water monitoring network and its operation, the CARM modelling decision support system, as well as the roles and responsibilities of different agencies during floods. The context provided here is important to aid in understanding how the lakes are operated, and the legislative, topographical and asset limitations that apply.

2.1 Barwon-Darling River System

Inflows to Menindee Lakes come from the Barwon-Darling River and its tributaries. The Barwon River flows from Mungindi on the NSW-Queensland Border to Bourke. Upstream of Bourke, the Barwon River joins with the Culgoa River and becomes the Darling (Figure 1). A number of major tributaries such as the Gwydir, Namoi, Castlereagh, Macquarie and Bogan Rivers join with the Barwon River from the south, while the Culgoa River joins from the north. The Darling River flows until it joins the Murray River at Wentworth in south-western NSW. The Barwon-Darling River is considered an unregulated river above Menindee Lakes but many of its headwater tributaries are regulated.

There are only two significant tributaries that join the Darling River downstream of Bourke: the Warrego and Paroo Rivers which only flow during major flooding. The Darling River flows into the Menindee Lakes Scheme downstream of Wilcannia.

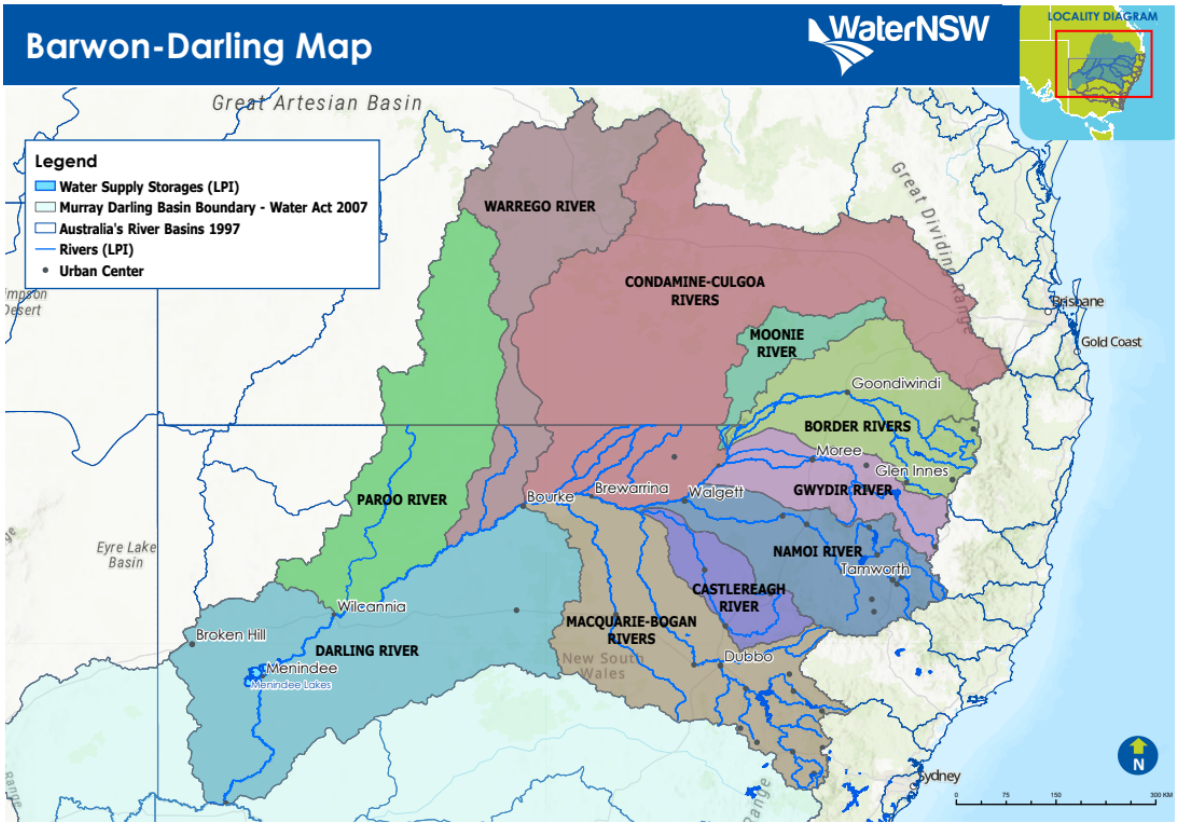


Figure 1. The Barwon-Darling River System and sub-catchments upstream of the Menindee Lakes.

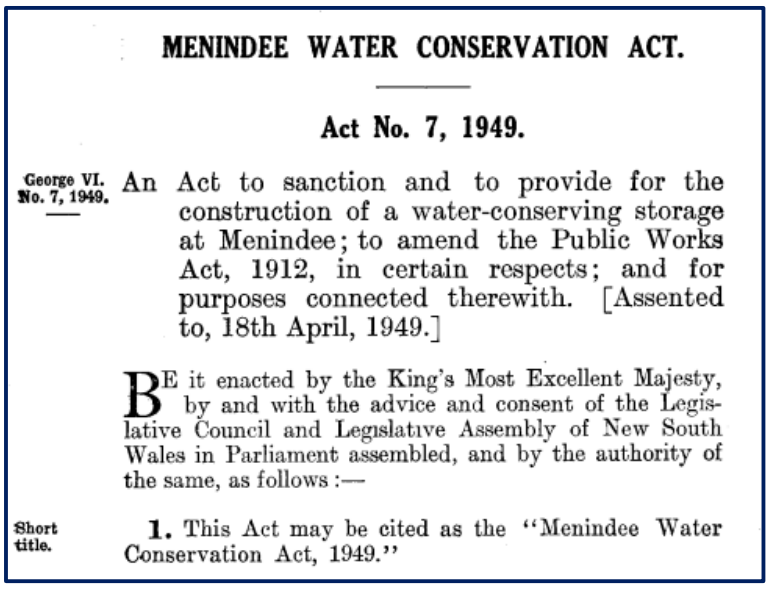
2.2 Menindee Lakes

Menindee Lakes are a naturally occurring series of ephemeral lakes or wetlands located along the lower Darling River, approximately 200 km upstream of the junction with the Murray River at Wentworth. The upstream catchment is vast, comprising of southern Queensland and much of northern New South Wales, west of the Great Divide. The total catchment area is approximately 574,000 km^2.

The Lakes were used for at least 45,000 years by the original Aboriginal inhabitants, the Baakantji people, and later became a lifeline for the original European explorers between 1835 and 1860, including Major Thomas Mitchell, Charles Sturt, and Bourke and Wills. It was initially thought that the Darling River would be navigable and provide a conduit for the development of Australia's interior, with the township of Menindee well placed to be the

gateway to the outback. However, the highly variable hydrology of the river proved to be problematic and caused issues for navigability and reliability of water supply.

The first proposal to develop the lakes for water conservation was in 1894, prior to Australia's Federation. However, works did not start until 1949 with the passing of the Menindee Water Conservation Act in NSW (Figure 2). Major works finished in 1960 and the overall project was completed by 1968 under the supervision of the NSW Water Conservation and Irrigation Commission as the constructing authority.



MENINDEE WATER CONSERVATION ACT.

Act No. 7, 1949.

George VI. No. 7, 1949.

An Act to sanction and to provide for the construction of a water-conserving storage at Menindee; to amend the Public Works Act, 1912, in certain respects; and for purposes connected therewith. [Assented to, 18th April, 1949.]

BE it enacted by the King's Most Excellent Majesty, by and with the advice and consent of the Legislative Council and Legislative Assembly of New South Wales in Parliament assembled, and by the authority of the same, as follows :—

Short title.

1. This Act may be cited as the "Menindee Water Conservation Act, 1949."

Figure 2. An extract from the original Menindee Water Conservation Act 1949 (NSW).

The Menindee Lakes Scheme was constructed at the site of a chain of large natural lakes on the western side of the Darling River in the vicinity of Menindee Township. Before construction of the Menindee Lakes storage, the lakes would fill from the Darling River during floods via creeks and depressions. When the river levels dropped, much of this water flowed back into the river again. The lakes would drain rapidly after the flood passed then remain empty for regular and prolonged periods of time. Some water was retained in the lowest sections of the lake beds for extended periods before they filled again. The lakes acted as balancing reservoirs reducing flood peaks in the lower river and subsequently providing long periods of slowly receding flows.

2.2.1 Lakes and Regulating Structures

The present-day Menindee Lakes Scheme consists of four large, shallow lakes: Wetherell, Pamamaroo, Menindee and Cawndilla, along with several smaller interconnected lakes (Figures 3 & 4). The lakes are located near the town of Menindee in far-west NSW, 100 km south-east of Broken Hill. They cover an area of 457 km^2 at full supply level (FSL) which, combined with the semi-arid climate, can result in losses to evaporation of between 400 and 800 GL per annum.

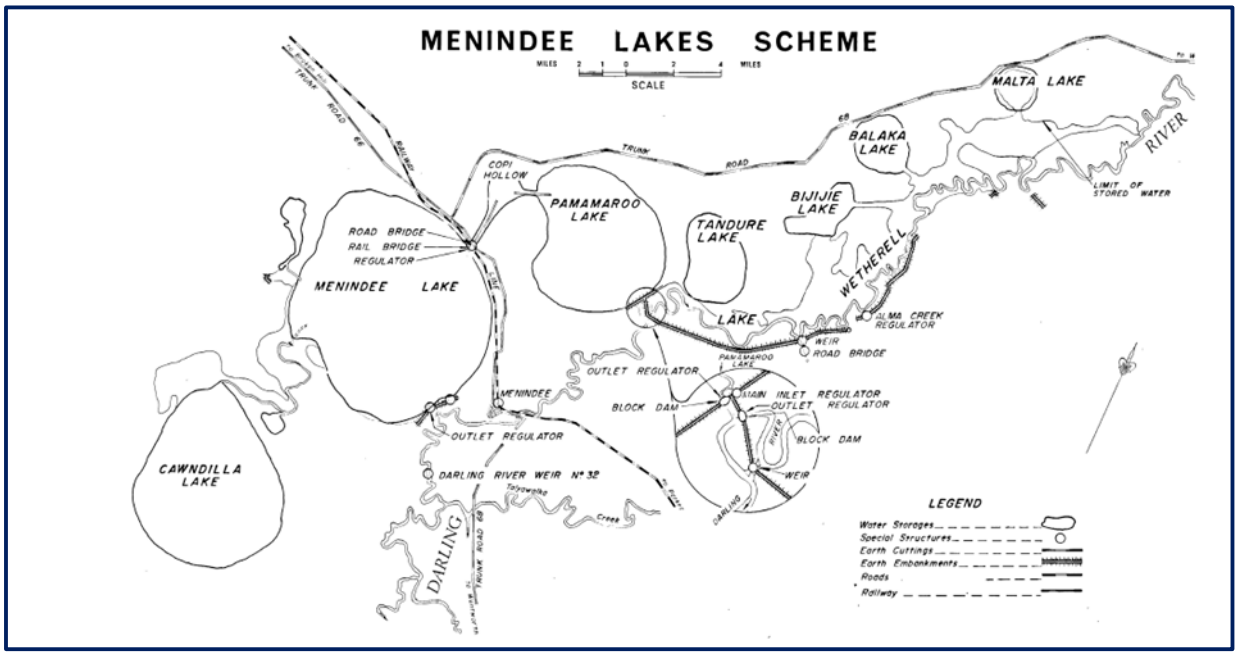


Figure 3. Plan of the Menindee Lakes Scheme. Source: WaterNSW.

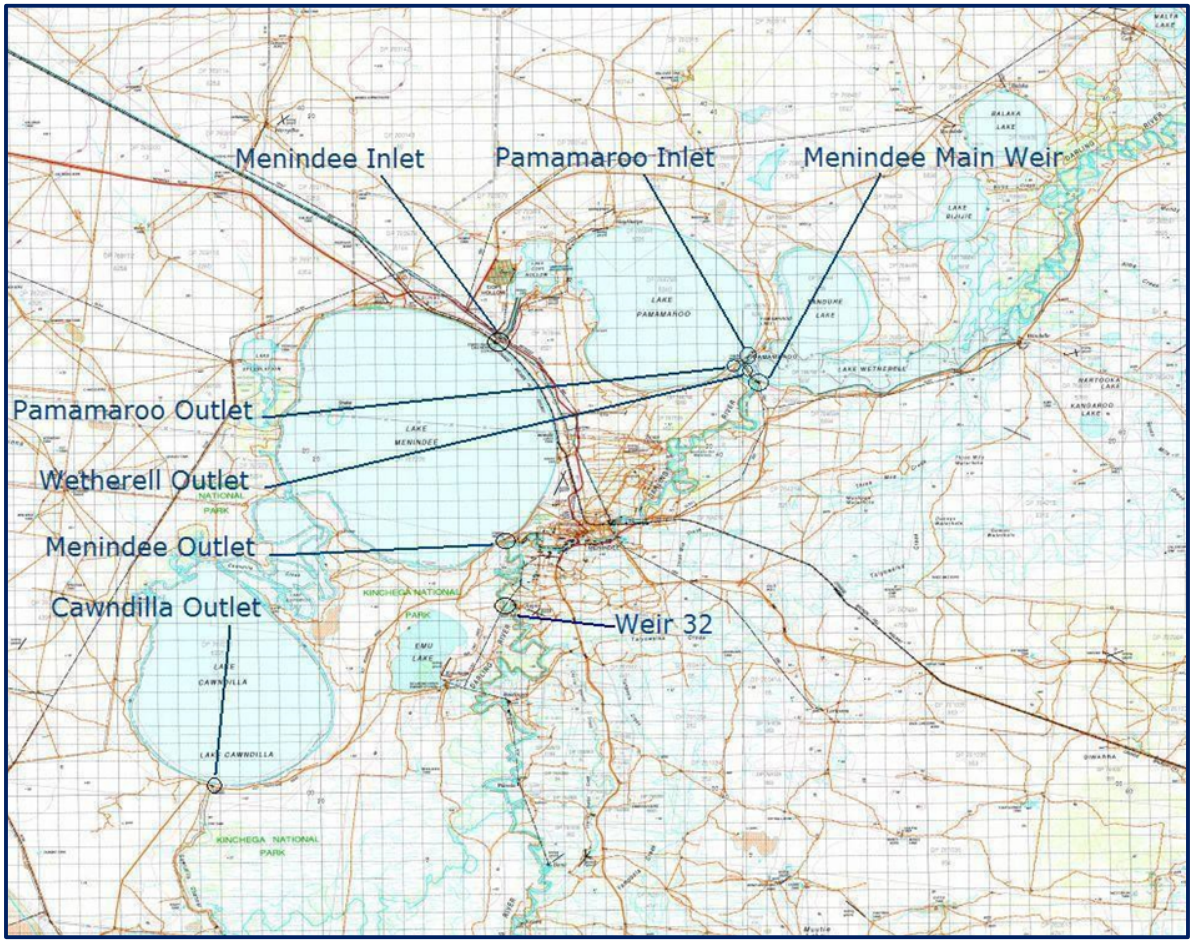


Figure 4. The main structures of the Menindee Lakes scheme. Source: WaterNSW.

The combined storage capacity of the lakes is 1,731,000 ML (1,731 GL) at FSL. The Lakes can be surcharged to a maximum of 2,050 GL (Table 1). However, each lake has its own characteristics, including storage at FSL, and maximum induced surcharge level (MISL). Additionally, there are limits on the rates at which water can pass through and/or be released through the various inlet and outlet regulators between and out of the Lakes.

Storage levels and capacities in the Lakes are summarised in Table 1 below. The full supply level (FSL) for the various lakes is tabulated under "Normal Conservation" level, also known as "restricted levels". Storage up to these levels can occur at any time. Operations over the years has allowed some surcharging of the Lakes above these levels, to varying extents.

The original scheme design allowed for higher surcharge levels in lakes Menindee and Cawndilla. However, surcharging to these levels resulted in significant foreshore erosion,

forming cliffs along parts of the Lakes' perimeters and disturbing archaeological sites and aboriginal burial sites of cultural significance. The "Maximum Surcharged" levels tabulated below have since been adopted. Note that the normal conservation levels have often been exceeded.

Table 1. Summary of Menindee Lakes storage levels and capacities

Lake	Normal Conservation (Full Supply Level)		Maximum Surcharged	
	Storage Level (AHD)	Storage Capacity (ML)	Storage Level m AHD	Storage Capacity (ML)
Wetherell	61.67	192,950	62.30	262,150
Pamamaroo	60.45	277,724	61.50	353,060
Menindee and Cawndilla[1]	59.84	1,260,542	60.45[2]	1,434,760
		1,731,216		2,049,970

[1] At full supply level, Menindee and Cawndilla storages are connected.

[2] The maximum approved surcharged level for Lakes Menindee and Cawndilla was originally higher but was restricted in ~1994 to protect sites of cultural significance.

2.2.1.1 Main Weir and Lake Wetherell

Lake Wetherell is the river diversion storage formed upstream of the other Lakes by a block dam in the river, Main Weir, and a series of levees, mostly on the eastern side of the river, some 32km long. The main block dam across the Darling River diverts the river flow through Main Weir and the Pamamaroo Inlet Regulator. Water can be released directly back into the Lower Darling River through Wetherell Outlet Regulator or through the Main Weir. As a pre-condition

before the Main Weir is operated, water is released through Wetherall Outlet Regulator and/or Pamamaroo Outlet Regulator to avoid bank erosion below the Main Weir.

The Main Weir (Figure 5) that creates Lake Wetherell (Figure 6) is the largest concrete and steel structure in the Menindee Lakes Storage Scheme. The Weir has been constructed in a bend of the river and is fitted with six electrically operated vertical lift steel gates, each 12.2m wide by 4.9m high, to discharge high river flows to the lower part of the Darling River. The Main Weir can store water to a level approximately 8.7m above the bed level, or up to 62.30 m AHD. The elevated level also diverts flows into Lakes Malta, Balaka, Bijijie and Tandure. Water also flows through Pamamaroo Inlet Regulator into Lake Pamamaroo and through Lake Pamamaroo into Lake Menindee and Lake Cawndilla.

The levee between Lake Pamamaroo and the Main Weir is called the West Levee (1.3km long). The Wetherell Outlet Regulator was constructed in a channel beside the Darling River and pierces the West Levee to discharge water into the original riverbed. This structure has a maximum discharge capacity of 4,500 ML/d. The gate tower contains two radial gates.

The levee extending from the Main Weir to sand hills at Windalle Homestead is called the East Levee and is 16km long. A major feature of the East Levee is a fuse plug spillway designed to be operated in the event of very large floods, to prevent overtopping of the levees downstream, and possible failure of the Main Weir. The design flood of the current fuse plug spillway is 220,000 ML/d. The Main Weir capacity is 110,000 ML/d, requiring a fuse plug discharge of 110,000 ML/d. Details of the activation orders and relative heights are set out in WaterNSW' Dam Safety Emergency Plan (DSEP). There is also a small uncontrolled spillway (sheet piles and rockfill) located through the East Levee at Three Mile Creek. Flood waters can flow through the Three Mile Creek spillway and the fuse plug spillway into the Talyawalka Creek and may then join the Darling River downstream of Menindee township.

Figure 5. Main Weir, 1 February 2023 releasing ~25,000 ML/d. Source: WaterNSW.

Figure 6. Lake Wetherell upstream of Main Weir, 1 February 2023. Source: WaterNSW.

2.2.1.2 Lake Pamamaroo

Lake Pamamaroo (Figure 7) adjoins Lake Wetherell via a short channel near Pamamaroo Inlet Regulator. This regulator allows water to flow from Lake Wetherell to Lake Pamamaroo through fifteen steel radial gates, 3.66m wide x 2.81m high (Figure 8). The maximum capacity of Pamamaroo Inlet Regulator is 33,000 ML/d.

Figure 7. Lake Pamamaroo, 1 February 2023. Source: WaterNSW.

The Pamamaroo Outlet Regulator is located in an excavated channel beside the bed of Pamamaroo Creek. It discharges into Pamamaroo Creek and thence into the Darling River. This structure has a maximum capacity of 4,500 ML/d and contains two radial gates. The Interconnecting Channel connects Lake Pamamaroo with Lake Menindee. Water leaves Lake Pamamaroo near its western end, and after flowing through Copi Hollow, which is a natural depression, passes along the Interconnecting Channel to the Menindee Inlet Regulator. The Menindee Inlet Regulator allows water to be stored in Lake Pamamaroo at a higher level than in Lake Menindee and controls the flow rate into Lake Menindee.

Figure 8. Pamamaroo Inlet Regulator, 1 February 2023. Source: WaterNSW.

2.2.1.3 Lake Menindee

Lake Menindee (Figure 9) is the largest of the Lakes in the Menindee Lakes Storage Scheme and is situated west of the township. Water enters through the Menindee Inlet Regulator (Figure 10), which comprises fifteen radial gates, 3.66 m wide x 2.81 m high. The Menindee Inlet Regulator has a maximum capacity of 25,000 ML/d.

The Lake has a substantial levee along its south-eastern side, passing over Menindee and Little Menindee Creeks. The Menindee Outlet Regulator is located in an excavated channel under the levee beside Menindee Creek, which joins the Darling River downstream of the township of Menindee. This structure has an intake tower, a gate tower, and two radial gates with a combined maximum capacity of 4,500 ML/d.

Figure 9. Lake Menindee, 1 February 2023. Source: WaterNSW.

Figure 10. Menindee Inlet Regulator, 1 February 2023. Source: WaterNSW.

2.2.1.4 Lake Cawndilla

Cawndilla is the southern-most lake. It is connected to Lake Menindee by Cawndilla Creek, which allows water to flow in either direction depending on the head difference. Above a storage level of 55.5 m, Lakes Cawndilla and Menindee retain water to the same storage level.

Water from Lake Cawndilla can be released through the Cawndilla Outlet Regulator (Figure 11) which is located in sandhills at its southern side. This regulator has an excavated channel leading to Tandou/Redbank Creek and thence to The Great Anabranch of the Darling River, also known as the Great Darling Anabranch. It has an intake tower and a gate tower with a single radial gate. The Cawndilla Outlet Regulator has a maximum capacity of 2,000 ML/d.

Figure 11. Cawndilla Outlet Regulator, 1 February 2023. Source: WaterNSW.

Water can also be released from Lake Cawndilla back to the Darling River through Cawndilla Creek and Lake Menindee and then through the Menindee Outlet Regulator until Lake Cawndilla falls to the bed level of Cawndilla Creek. At this stage water ceases to flow back into Lake Menindee.

2.2.1.5 Summary of Structures and Operating Capacities

In summary, there are limitations on the capacities of each of the structures in the Menindee Lake scheme. These limitations mean that water NSW must work with these restrictions when operating the lakes during floods. A summary of the operating capacities is provided in table two.

Table 2. Main Structures and Operating Capacities in the Menindee Lakes Scheme

Structure	Capacity ML/d	Comments
Main Weir	110,000	Under flood conditions
Wetherell outlet	4,500	Reduces; with backwater from other outlets, and as lake falls
Pamamaroo outlet	4,500	Reduces; with backwater from other outlets, and as lake falls
Menindee outlet	4,500	Reduces; with backwater from other outlets, and as lake falls
Cawndilla outlet	2,000	Reduces; with backwater from other outlets, and as lake falls
Pamamaroo inlet	33,000	
Menindee Inlet	25,000	

2.3 Managing the Lakes

2.3.1 Basin Agreement

Menindee Lakes are owned by the NSW Government but since 1963, NSW has agreed to share water from the Lakes with the Commonwealth, Victorian and South Australian governments. These arrangements now form part of the Murray Darling Basin Agreement, which can be found in the *Commonwealth Water Act 2007*. Under the Basin Agreement, the Murray Darling Basin Authority (MDBA) leases Menindee Lakes from the NSW Government and pays for three-quarters of the costs of operating and maintaining the storages.

When the volume of water stored in the Lakes is greater than 640 GL, the MDBA can direct WaterNSW to make releases from Menindee Lakes. Water accessed by the MDBA is on behalf of the joint governments of South Australia, Victoria and New South Wales and is used to support entitlements in the River Murray. Whenever the Lakes' volume falls below 480 GL, however, New South Wales may use the stored water as it requires until such time as the volume next exceeds 640 GL. This is the so-called "640/480 rule". To meet consumptive needs in the Lower Darling and River Murray, operational convention is that water is initially released from Lake Menindee and Lake Cawndilla as these lakes suffer the greatest evaporative losses. During dry periods, water is preferentially stored in the upper lakes: Wetherell and Pamamaroo.

2.3.2 Management of the Lakes during Floods

While the Basin Agreement sets out the arrangements for accounting and responsibility for making or directing releases under the "640/480 rule" when the storages exceed full supply level the MDBA hands responsibility for operational decisions back to New South Wales. WaterNSW therefore undertakes flood operations as per its Water Supply Work Approval issued by DPE-W. Further information on flood operations can be found in section 2.7 of this report.

2.4 Water Monitoring

2.4.1 River Gauges

WaterNSW owns and operates a large network of river gauges state-wide. The network of gauges has been developed over time to fulfil the information needs of WaterNSW as well as a variety of stakeholders such as the Department of Planning and Environment – Water (DPE-W), the Murray Darling Basin Authority (MDBA) and local Councils to help them perform their roles. A number of WaterNSW's gauges are also used by the State Emergency Service (NSW SES) and Bureau of Meteorology (BoM) in undertaking their roles in relation to flood planning, forecasting and emergency response.

The information obtained from the monitoring network is used by WaterNSW to plan the management of dam releases and river flows. Some sites only measure level where this is appropriate – for example storages or where flow can be difficult to measure, whilst portions of the network also collect other information, such as water quality data in near to real-time using sensors in the water, or meteorological data such as rainfall. Many of the monitoring sites are instrumented and send the data they collect by telemetry for use in near real time.

The Barwon Darling system has a network of monitoring sites. Upstream of Wilcannia, there are four key sites on the Darling River (Tilpa, Louth, Bourke and Warraweena), with other sites providing additional information and sites on major tributaries, such as the Warrego Rver. Within the area between Wilcannia and Wentworth on the Darling River and Great Darling Anabranch (GDA), there are nineteen water monitoring sites (excluding Menindee Lakes system storage gauges). This includes three sites upstream of the Menindee Lake system storages on the Darling River and on the Talyawalka Creek. The remaining sites are within the Menindee lakes system, and downstream on the Darling River and Great Darling Anabranch.

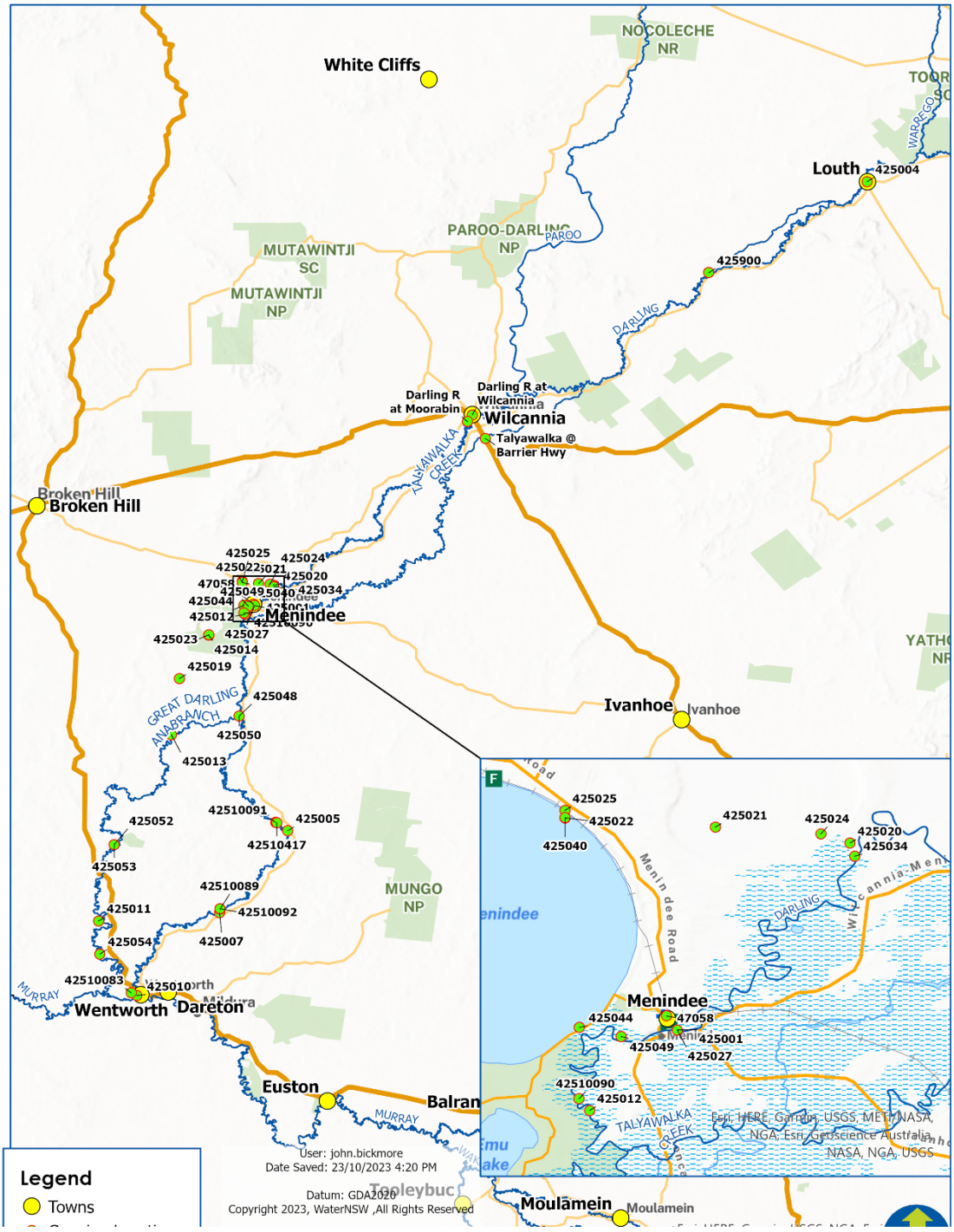


Figure 12. Gauging locations between Louth and Wentworth, Darling River, Talyawalka Creek and Great Darling Anabranch.

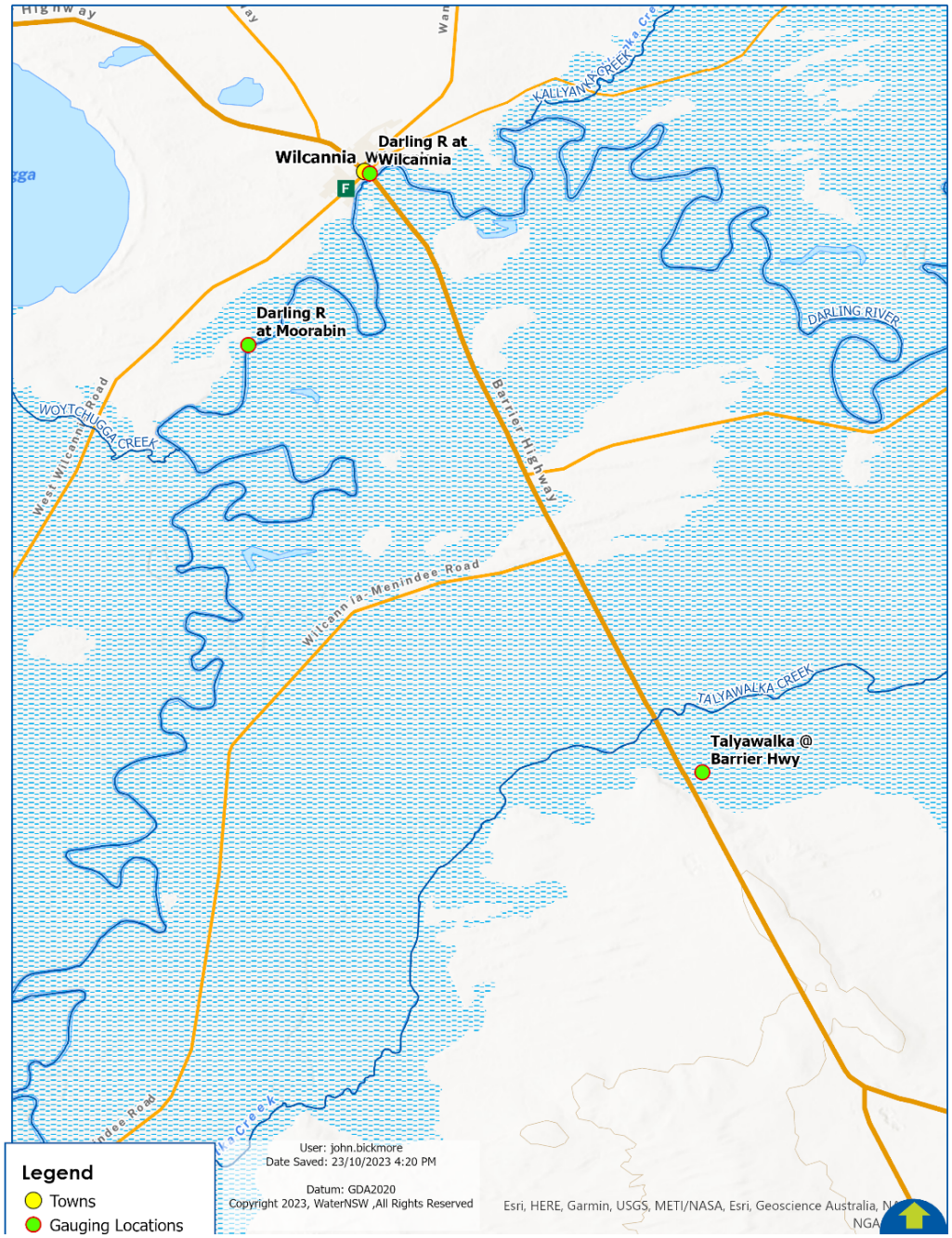


Figure 13. Three gauging locations. Darling River @ Wilcannia, Darling River @ Moorabin, and Talyawalka Creek @ Barrier Hwy (main channel). For full size version, refer to Appendix D.

The monitoring sites are managed under a quality management system (ISO9001) that ensures the sites are visited regularly for checks and maintenance, and any remedial actions taken to ensure they are operational and providing good quality information for use. Break downs are rare but are prioritised for repair in the sometimes-remote areas the sites are located, with staff very active in minimising any down-time.

In addition to the routine checks and maintenance, visits are also targeted to collect field measurements to confirm and improve the accuracy of the values being provided by the sites. This is particularly important for flow information that is based on level measurements from the site. Over time, with changes in the stream channel the relationship between the water level and calculated flows can change, so staff work proactively to obtain additional flow measurements to improve the accuracy of the calculated flows.

2.5 CARM Modelling System

CARM (Computer Aided River Management) is WaterNSW's decision support system for river and storage operations. There is a CARM system for each valley that WaterNSW operates, typically split based on Water Sharing Plan boundaries.

For regional NSW, outside of Murrumbidgee, the system has been developed over the past five years. It has built and improved on pre-existing models, tools and analysis, and encompasses automatic data retrieval from a range of sources. The system aims to enable operators to undertake efficient and effective water delivery decisions.

Daily river operations focus on releases and configuration of dams and weirs, to deliver water to irrigators, urban water supplies, and the environment and considers regulatory, infrastructure and river constraints. For most regional valleys, the underlying model is a reproduction of the Computer Aided Integrated River Operations (CAIRO) daily mass balance across pre-defined river reaches, typically defined by gauged river locations. It accounts for gauged tributary inflows, anabranch outflows, return flows, and effluent creeks and streams and extractive water use. Operators are accustomed to modelling river behaviour based on past behaviour and current meteorological conditions. The CAIRO model was developed in the 1990s based on historical operational procedures.

There is an ongoing program of work to further develop the underlying modelling to improve forecasting capability and to better understand catchment and river behaviour. Additionally,

work to include real time water usage data continues, and is being rolled out in the non-urban water metering project.

For Menindee, two key CARM systems are used to assist operators in decision making, those being the Barwon-Darling and Lower Darling systems.

The CARM Barwon-Darling System was established in 2019. This included the development of a new operational mass balance model based on existing techniques and medium-term planning models, since no previous model existed. Prior to 2019, management of the unregulated Barwon-Darling system was self-regulated by customers based on flow conditions at key locations and not actively managed by WaterNSW.

During the development of the updated Water Sharing Plan for the Barwon-Darling (NSW Govt 2020), WaterNSW was given responsibilities to determine and announce the amount of water available for extractive use and the protection of held environmental water when present. Announcements are published on WaterInsights.

- The system extends from the Barwon River at Mungindi (Figure 14) to the Darling River at Wilcannia (Figure 15) across 14 reaches and:
    - Includes flow forecasts from upstream CARM valleys (Border, Gwydir, Namoi and Macquarie) and includes flows estimates of unregulated tributaries & Queensland tributaries (Culgoa-Bokhara, Warrego, Paroo, Moonie, Bogan and Thalaba).
    - Enables a daily 'expression of interest of water take' from suitable access licences under the IDEC (Individual Daily Extraction Capacity).
    - In each reach, operators:
        - Calculate and submit available water to the water distribution module in WaterNSW's water ordering and licencing enterprise database, in line with Water Sharing Plan rules and account licences, and the protection of held Environmental water.
        - Receive details of the permissible water take by licence and reach based on the available water and licence details.
        - Evaluate flow impacts of the permissible water take on the downstream reach and continue the process until it reaches Wilcannia.
        - This system routinely runs each week, depending on flow availability.

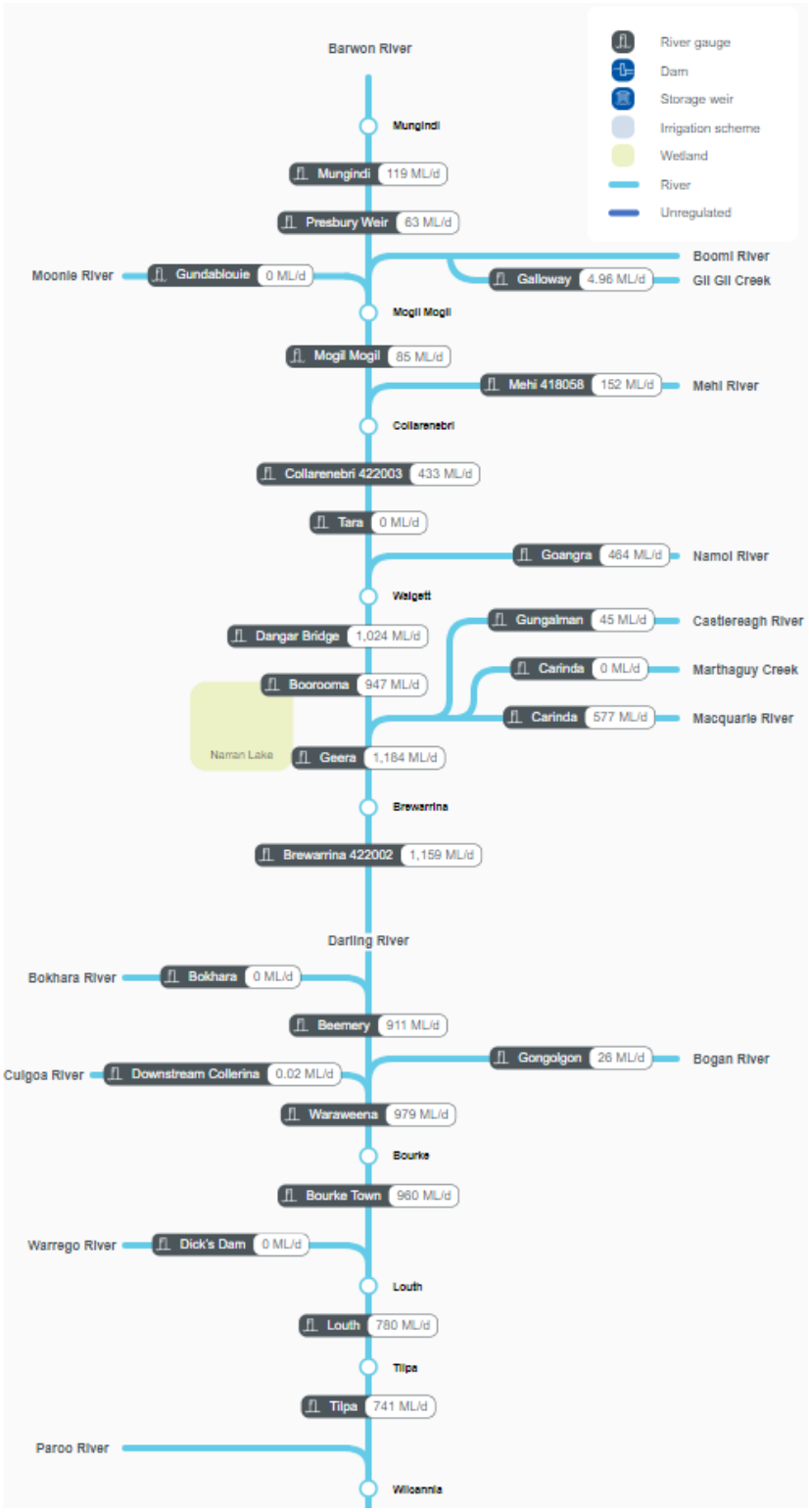


Figure 14. Schematic of the Barwon-Darling River system with example flow figures. Source: Water Insights

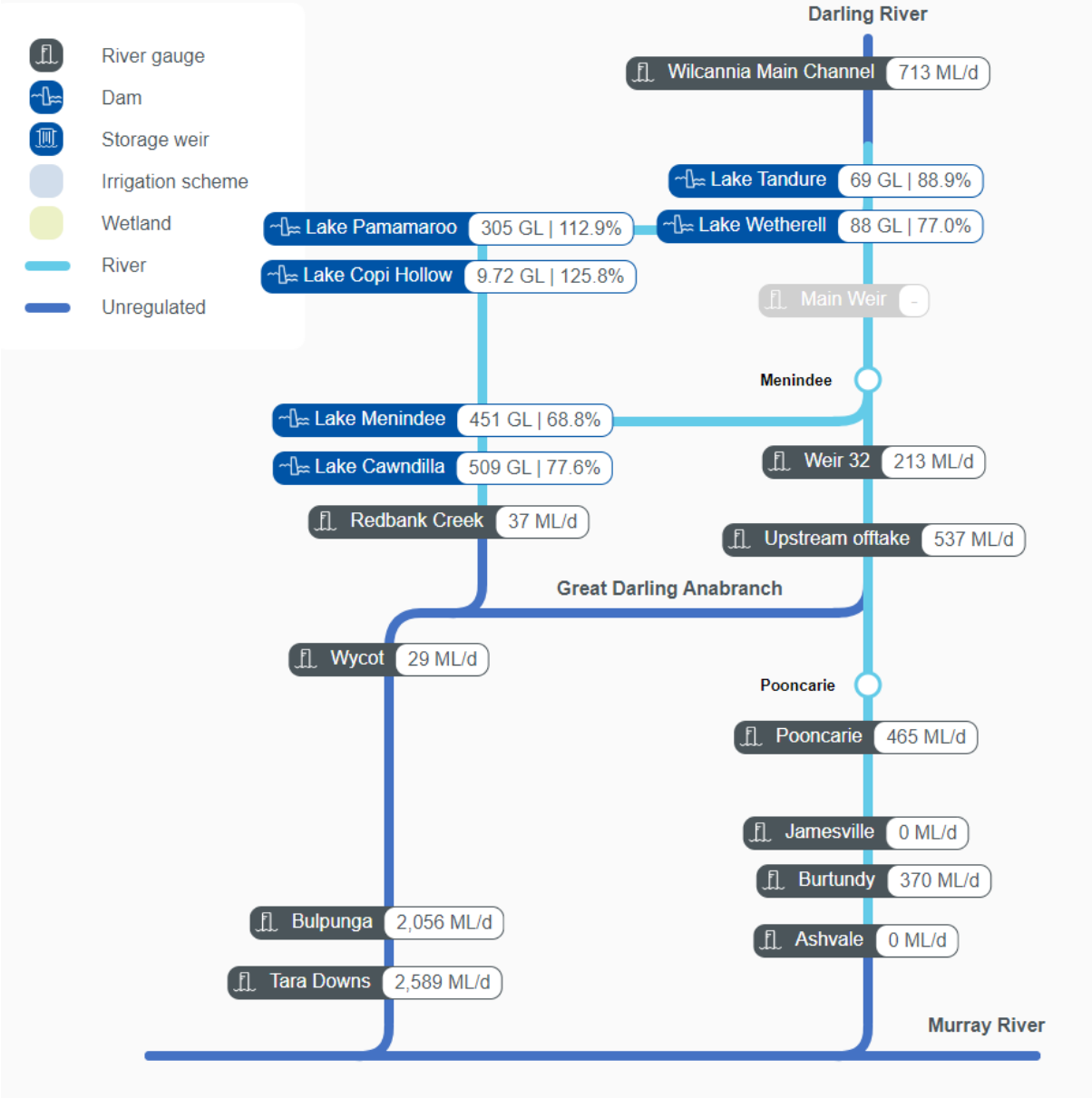


Figure 15. Schematic of the Lower Darling River system showing example flow figures. Source: Water Insights

CARM Lower Darling was established in 2018. It built and improved on the pre-existing operating model for the Lower Darling and expanded its capabilities in representing the storage behaviour. Significant upgrades were made during CARM development, greatly improving the capability of the model.

The system starts at Wilcannia, extends to the Murray confluence and tracks individual lakes and flow distribution. The Lower Darling CARM model also provides information on the Great Darling Anabranch from Cawndilla Outlet through to Tara Downs.

CARM Barwon-Darling forecasts flow to Wilcannia, which is generally representative of inflows to Menindee. The river operations assessment also includes a forecast of up to 4-6 weeks during high flow times to Menindee Lakes, and when required. However, the estimation considers many assumptions and approximations which gives uncertainty to the flow estimates.

2.6 Roles and Responsibilities During Floods

There is a distinct difference between the way dams and rivers are operated during floods and during what would be called 'normal' conditions, where flows are generally within the channel banks. Under normal conditions, storages such as the Menindee Lakes are operated with an aim to capture and store or conserve water within the storages and only release water to meet downstream customer needs or environmental objectives.

When wet weather occurs and there are substantial inflows into storages, these inflows can exceed the capacity or full supply level of the storage. Flood operations therefore represent a change in system operations whereby there is a transition away from 'normal' operations. Under these flood conditions, the roles and responsibilities of the various agencies involved also change. These roles and responsibilities are further described in the following sections.

2.6.1 The State Flood Plan

The NSW State Flood Plan is a sub plan of the State Emergency Management Plan (EMPLAN), endorsed by the NSW State Emergency Management Committee (SEMC). It sets out the state level multi-agency arrangements for the emergency management of flooding in New South Wales. The Plan was written and issued under the authority of the State Emergency and Rescue Management Act 1989 (NSW) ('SERM Act'), the State Emergency Service Act 1989 (NSW) ('SES Act') and the NSW Emergency Management Plan (EMPLAN).

According to the Plan, a 'flood' is defined as:

a relatively high-water level which overtops the natural or artificial banks in any part of a stream, river, estuary, lake, or dam, and/or local overland flooding associated with drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves (including tsunami) overtopping coastline defences.

The primary goals for flood emergency management in NSW are:

- Protection and preservation of life;
- Establishment and operation of flood warning systems;
- Issuing of community information and community warnings;
- Coordination of evacuation and welfare of affected communities;
- Protection of critical infrastructure and community assets essential to community survival during an emergency incident;
- Protection of residential property;
- Protection of assets and infrastructure that support individual and community financial sustainability and aid assisting a community to recover from an incident; and
- Protection of the environment and conservation values considering the cultural, biodiversity and social values of the environment.

The plan makes it very clear that the highest priority is the protection and preservation of human life (including the lives of responders and the community). It also states that evacuation is the primary response strategy for people impacted by flooding.

There are various elements to the State Flood Plan, but the main elements are:

- Prevention or Mitigation – this includes land use planning and floodplain risk management.
- Preparation – which includes flood emergency planning, flood intelligence systems, development of warning systems, training, and community resilience to flooding.
- Response – which includes incident management arrangements, use of information and the collection of intelligence, provision of information and warnings to the community, protection of property and essential services, evacuation and evacuee management and welfare, flood rescue, resupply, and all clear and return activities.

- Recovery Operations – which includes processes involved in returning a flood affected community to its proper level of functioning after an emergency.

Various agencies have differing roles and responsibilities under the State Flood Plan that cover these different elements. Full details can be found in the Plan itself; however, those relevant to the Menindee Lakes are summarised in the following sections.

2.6.2 Role of Central Darling Shire Council

The role of Central Darling Shire Council, as local government, is primarily to manage flood risk within its service area as outlined in the Floodplain Development Manual under the Flood Prone Land Policy. The Manual outlines the main responsibilities of Council to be:

- Land Use Planning – statutory responsibility for land use planning rests with Councils.
- Preparation of Floodplain Risk Management Plans – this includes the planning and management of land that is subject to varying degrees of flood risk. Councils are required to plan and manage flood-prone land in accordance with its flood exposure risk.
- Preparation of Local Environmental Plans – these need to be consistent with the principles of the Floodplain Development Manual and consider the effect of flooding on any development activities.
- Planning Certificates – it is important that any planning certificates issued provide flood related information that is clear and unambiguous.
- Asset Management – Councils are generally responsible for the design, construction and maintenance of flood mitigation works, noting in some situations funding assistance can be made available by the State or Commonwealth governments.
- Flood Education – Councils are encouraged to promote flood readiness in the community, with an aim to reduce social disruption and damage potentially caused by flooding.
- Emergency Response – Council is a key representative on the Local Emergency Management Committee (LEMC). As such, it has a role in supporting the NSW SES with preparation of the local flood plan and also providing resources to assist the SES during flood emergencies.

- Public Infrastructure – Council and the NSW SES are to identify critical public infrastructure to be protected during floods (e.g. water supply and sewage treatment facilities) and then returned to operation post-flood. Council also plays a role in providing use of evacuation centres and key access routes.
- Post-flood Data Collection and Reviews – councils undertake post-flood appraisals and reviews into flood behaviour to assist with the review of local flood plans.

2.6.3 Role of the Department of Planning and Environment

The Department of Planning and Environment (DPE) plays a number of roles, particularly in the areas of planning and policy, as well as water management. In relation to flood planning and management, some of its key roles include:

- Provision of specialist advice and information to councils on flooding and flood risks.
- Assistance to councils in the preparation of management plans and implementation of mitigation measures.
- Advice to councils on evaluation of significant development proposals.
- Financial assistance for flood studies and mitigation measures.
- Licensing and approval of flood works constructed by councils, such as earthworks, embankments or levees that can affect the distribution of floodwaters.
- Overseeing the delivery of the NSW Flood Prone Land Policy through the Floodplain Management Program.
- Working with the NSW SES to improve the provision of flood information through the NSW Flood Data Portal.
- Developing rural Floodplain Management Plans which provide the framework for coordinating the development of flood works on a whole of valley basis.

2.6.4 Role of the Bureau of Meteorology

The Bureau of Meteorology (BoM) maintains, coordinates and delivers operational, 24-hour weather and flood warning services to the NSW community, including communications with State Emergency Services (NSW SES), to meet the agreed Service Level Specification for Flood

Forecasting and Warning Services for New South Wales and the Australian Capital Territory (SLS). The BoM:

- Provides near-real-time rainfall and river level data.
- Issues official forecasts and warnings; and
- Acts as the flood prediction agency for 'non flash flood' catchments.

The BoM's Service Level Specification (SLS) typically only initiates at thresholds around minor flood level (a small flood below the SLS thresholds means there may be no warning services provided by BoM). Nevertheless, the WaterNSW Flood Incident Management Protocol and Flood Manual for a dam, can still be initiated (see section 2.7).

BoM relies, in part, on hydrometric information from WaterNSW for flood forecasting downstream of WaterNSW dams (particularly gated dams). WaterNSW provides planned dam release patterns to BoM. The BoM then use the information for their flood forecasting and warning services to inform local communities.

2.6.5 Role of the NSW State Emergency Service

NSW State Emergency Service (NSW SES) is the designated 'combat agency' or lead agency responsible for dealing the threats and actualities of floods. The NSW SES plans for and respond to flood incidents and emergencies in NSW as outlined in the NSW State EMPLAN'. It coordinates evacuations and supports the welfare of affected communities (SES Act 1989; EMPLAN). The NSW SES works in coordination with WaterNSW to:

- Prevent floods (e.g. providing advice on floodplain risk mitigation and land use planning).
- Prepare for the potential of floods (e.g. controlling flood emergency responses other than dam operations).
- Respond to the realities of an active flood event (e.g. command and coordination of evacuations, logistics, etc.).
- Manage recovery operations.

2.6.6 Role of NSW Police

During flood events, the NSW Police Force operates in support of NSW SES operations, as required. This support can include:

- Incident Management personnel and Liaison Officers.
- Assistance with warning and/or evacuation of at-risk communities, monitoring / reconnaissance of flood prone areas, and assistance with flood rescue operations.

Further, NSW Police:

- Conduct road and traffic control operations in conjunction with council and/or Transport for NSW.
- Coordinate searches for missing people within flood affected areas.
- Coordinate the security of supply lines, evacuated and damaged areas.
- Manage Disaster Victim Registration.

Regional Emergency Management Committee (REMC):

- The NSW Police Force provides executive support facilities for each Regional Emergency Management Committee and Regional Emergency Operations Controller (SERM Act).

2.6.7 Role of the Rural Fire Service

During flood events, the NSW Rural Fire Service (RFS) provides incident management and operational support, as required by the NSW State Emergency Service, including:

- Incident Management personnel and Liaison Officers.
- Aviation support, management and advice as requested through the State Air Desk.
- Speciality aircraft and appropriately trained personnel.
- Assistance with Damage Assessments.
- Strike Teams to assist with specific tasks in support of NSW SES flood operations.

2.6.8 Role of the NSW Reconstruction Authority

The Authority will:

- lead disaster resilience, risk reduction, adaptation and mitigation activities
- provide education and infrastructure before disasters to minimise harm
- ensure the reconstruction process begins swiftly when a disaster strikes
- reduce community devastation.

The Authority's responsibilities include:

- creating and implementing the State disaster mitigation plan
- giving advice as needed to councils and government agencies on disaster adaptation
- supporting communities to help recover from a disaster
- coordinating development in disaster-affected areas
- acquiring and subdividing land for rebuilding communities
- rebuilding infrastructure.

2.6.9 Role of WaterNSW

As an owner of large dams, WaterNSW is required to have various operational and emergency plans in place. In order to meet its statutory and regulatory obligations, WaterNSW must take on specific roles and responsibilities including the following:

Preparedness

- Assist NSW State Emergency Service (NSW SES) with community engagement programs.
- Provide NSW SES with information necessary for response planning and warning distribution.
- Work with NSW SES to identify correlations between water level and/ or discharges at the dam for use in flood response operations (warning and evacuation).
- Consult with NSW SES State Headquarters regarding Dam Safety Emergency Plans (DSEP), including the development of dam failure alerts, in accordance with the Dam Safety Committee Guidelines.

Response

- Where water level monitoring or other instrumentation allows, provide NSW SES with flood advice as per pre-agreed thresholds for use in downstream flood response operations (warnings).
- Notify of potential or actual dam failures in accordance with the DSEP and Dam Safety Committee Guidelines
- In the case of prescribed dams, assist the NSW SES with planning to warn and evacuate people at risk of dam failure. Maintain and operate any special Dam Failure Warning Systems and/or automatic telemetered monitoring devices to assist with early detection of incidents. Ensure these are installed until such time that risks have been lowered to an acceptable level.

Owners of gated dams:

Where the prescribed dam is a gated dam, additional responsibilities exist including:

- Provide all available information to BoM and NSW SES regarding storage levels and actual/prospective water releases, and their likely impacts on downstream river levels.
- Advise the downstream community of actual/prospective water releases, except in those circumstances where BoM would issue flood warnings; and
- Where possible, actively work with NSW SES and BoM to reduce the impacts of flooding on communities through management of water releases within identified parameters and within statutory licencing provisions under the Water Management Act 2000 and Water NSW Act 2014.
- Conducting flood operations at the dam as per the documented hierarchy of objectives outlined in section 2.7 below, prioritising the safety of the dam.

In addition to responsibilities that apply generally to owners of prescribed dams (being an owner under the Dams Safety Act 2015), the following responsibilities apply to WaterNSW in its capacity as a statutory authority having various functions, and agreements with other agencies:

Preparedness

- Management of the state government's water level gauges for the flood warning network in non-tidal areas in NSW.

Provide to SES and BoM:

- Flow rating charts for river height gauges.
- Real-time or near real-time access to river height gauges and height data for the development of official flood warnings.
- Real-time or near real-time advice and information from dams and hydro meteorological stations during floods.
- Provide NSW SES with information about new gauge locations.
- Collect and maintain flood data including data relating to flood heights, velocities and discharges.
- Consult with the FWCC which includes NSW SES and BoM prior to changes to gauge locations and datum.
- Maintain WaterNSW Flood Incident Management Protocols.

Response

- Close and evacuate camping grounds/recreational areas at risk of flooding in WaterNSW managed areas; and
- Convene a regular briefing (written and via teleconference) with BoM, WaterNSW dam operators and NSW SES in the pre-flood stage and during flood operations or other incidents to enable the rapid exchange of information between agencies.

2.7 How does WaterNSW manage its storages during floods?

2.7.1 What is 'airspace' and how is it managed in the lead up to a flood event?

Airspace is the amount of space available in a dam to capture flows, or in other words the difference between the actual volume of water in storage and the volume when the dam is full. Prior to rainfall events (at any time of year), WaterNSW will assess airspace and create additional space by making releases from its dams, while maintaining water security, in

accordance with the rules set out in the Water Sharing Plan. This provides space in the dam to help capture future floods. When it rains, WaterNSW will minimise these releases to allow downstream tributary inflows to pass before making releases from the dams, with the aim of reducing the flood peak downstream.

For most storage dams, WaterNSW must leave the water levels of dams at 'full supply level' (when the dam is full) or at a pre-release target at the completion of the flood event. In the lead up to irrigation season, as per the statutory and regulatory rules of the storage, WaterNSW manages airspace to capture winter inflows.

Managing airspace in the lead up to times of flood is complex and requires dynamic decision making. WaterNSW is constantly monitoring and adjusting releases to create capacity to capture future inflow events.

Airspace operations differ from 'flood operations' in that airspace operations occur prior to the peak of a flood where the storage (or storages) is below the full supply level. Flood operations occur when the storage has exceeded Full Supply Level and need to be managed in accordance with prescribed procedures. During flood operations WaterNSW consults with other agencies but is the sole decision maker on releases.

2.7.2 What rules does WaterNSW use to manage its water storages/dams?

WaterNSW aims to adhere to all relevant legislation, regulations, instruments and guidelines when operating its regional storages and dams. During times of flood, this means careful management of the dam's storage to ensure the safety of the structure, maintain water security, and where possible lessen downstream flooding impacts.

WaterNSW manages flood operations and airspace releases to:

- ensure the safety of the structures
- maintain water security
- mitigate and minimise the impacts of events on downstream communities, where possible.

2.7.3 Flood Incident Management

WaterNSW works together with other flood response agencies when managing flood operations. However, during flood operations, WaterNSW is the sole decision maker regarding releases from its dams. This release information is provided to the BoM and NSW SES, as well as being communicated to the public.

Agency roles and responsibilities are outlined in the NSW State Flood Sub-Plan 2018. This information is also contained in the WaterNSW Flood Incident Management Protocol. The hierarchy of the documents and their relations to each other are shown in Figure 16.

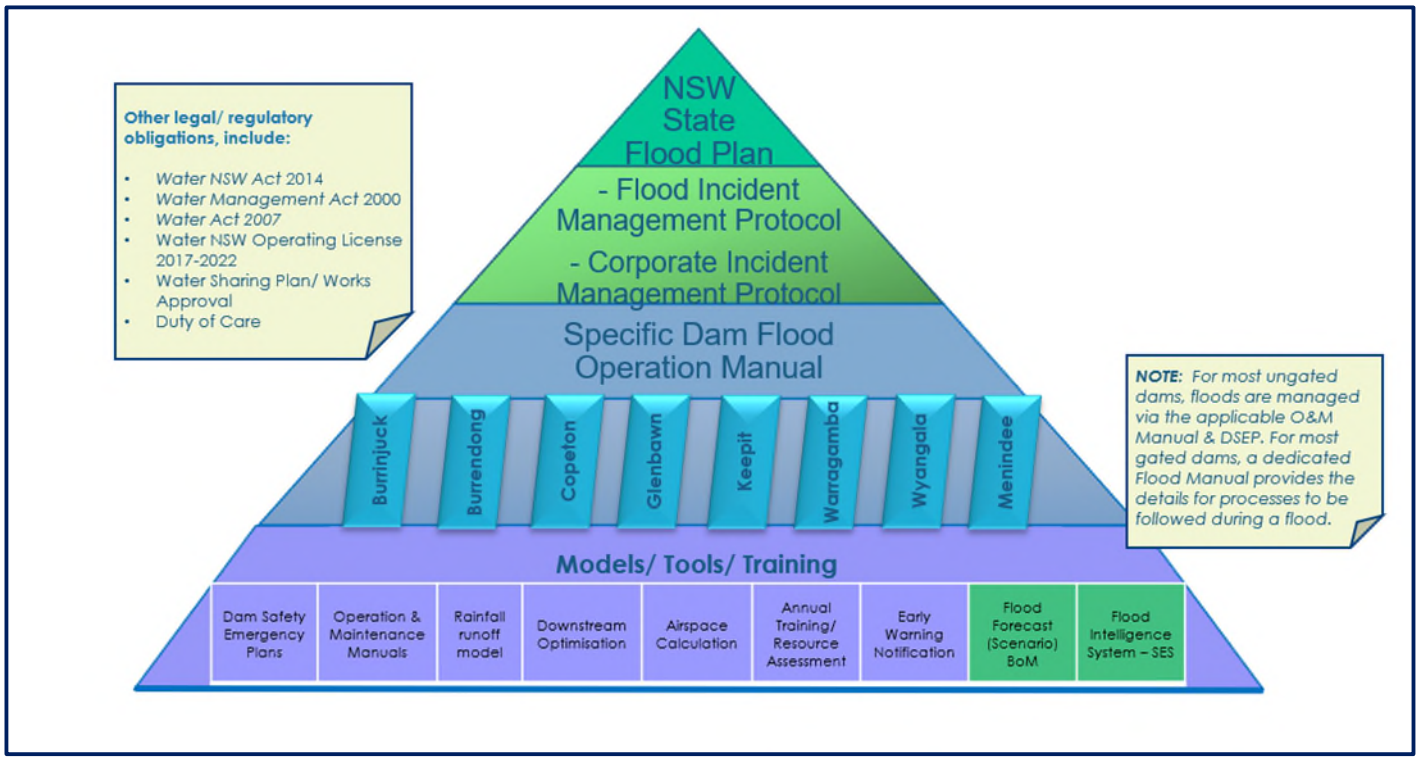


Figure 16. Hierarchy and relationship of WaterNSW flood management documents. Source WaterNSW

2.7.4 Flood Operations at the Menindee Lakes

The Menindee Lakes are somewhat unique when compared to other major storages operated by WaterNSW in that they are a series of interconnected lakes, as opposed to a single storage. Flood operations are defined as periods when the total storage capacity of the lakes is equal

to or exceeds the full supply capacity of 1,731 GL. During flood operations, the following conditions in WaterNSW' water supply work approval apply:

(i) *The approval holder must operate the authorised water supply works during times of flood and spilling of water, to maintain the safety of those works, and to minimise risks to public safety.*

(ii) *Subject to direction from the Minister, the approval holder must ensure that flow release patterns from Menindee Lakes provide a hydrograph of similar shape to that of a natural flood event when total storage volume exceeds 1,680,000 ML (Note: releases made from Menindee Lakes to provide a hydrograph of similar shape to that of a natural flood event should not damage property as far as possible)*

(iii) *Subject to direction from the Minister, the approval holder must apply the following rates of reduction based on the flow at Weir 32, unless otherwise directed by the minister.*

a) a maximum of 1,000 ML each day for flows greater than 10,000 ML/d and less than 20,000 ML/d.

b) a maximum of 500 ML each day for flows greater than 5,000 ML/d and less than 10,000 ML/d.

c) a maximum of 250 ML each day for flows less than 5,000 ML/d; and

d) the rate of recession as measured at Wilcannia when within channel flows exceed 20,000 ML/d.

In addition to the above Work Approval rules, there is a consensus among the agencies (e.g. MDBA, WaterNSW, DPE-W) that Menindee Lakes should not be surcharged between 1 January and 1 March of any given year unless the flow at Weir 32 would otherwise exceed the downstream channel capacity of 20,000 ML/d.

2.8 Flood Classification Levels at the Menindee Town gauge

The Bureau of Meteorology (BOM) determines categories of flooding at different levels based on descriptive categories from previous flooding, historical data or other relevant local

information. The classifications used are for key river height locations and relate to the effect of flooding upstream and downstream of that location. The classifications are defined as follows:

- Minor flooding – Causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.
- Moderate flooding - Moderate flooding - In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required.
- Major flooding - In addition to the above, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted.

The associated flood classification levels for the Darling River at Menindee Town Gauge are:

Table 3. Flood classification levels at Menindee Town Gauge

Classification Level	**Flood Height (m)**[3]
Minor	8.5
Moderate	9.1
Major	9.7

[3] Note there is no established stage-discharge relationship (rating curve) for the Menindee town gauge, so it is not possible to provide an estimate of flow or discharge at these levels.

Flooding that occurs at Menindee town is likely caused by a combination of releases from Lake Wetherell via the Main Weir and Wetherell outlet regulator, releases from the Pamamaroo and Menindee outlet regulators, along with unregulated flows from the Talyawalka Creek and other tributaries that join the Darling River upstream of Weir 32.

3 Hydrology and Operations leading into 2022/23 floods

The intent of this section of the report is to explain the conditions leading up to the floods of 2022/23, including the previous drought and refilling of the lakes. Information on historical floods is provided for comparison in Appendix A.

3.1 The Drought of 2017-2019

Following the inflows experienced during 2016, storage levels in the Menindee Lakes increased but remained below the Full Supply Level (Figure 17). Storage levels then rapidly declined during the drought that followed, with the Lakes' total storage capacity falling below the 480 GL trigger level, whereby control of the lakes returns to NSW, in December 2017. Lake levels remained very low during the ensuing severe meteorological drought that coincided with extreme heat and major fish deaths in the lower Darling in December 2018 and January 2019.

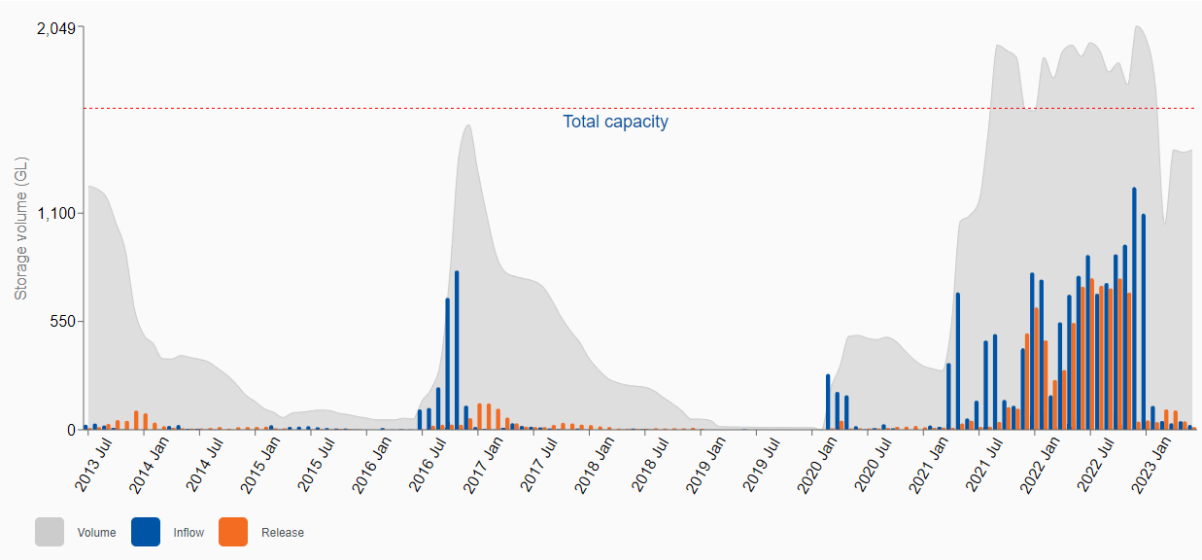


Figure 17. Inflows, releases and total storage volume for the Menindee Lakes System, over a 10-year period from 2013-2023. Source: WaterInsights. For further detail an up to date plot can be found here.

3.2 Refilling of the Lakes in 2020-2021

It wasn't until the first flush event of early 2020 that inflows began to increase storage levels in the Menindee Lakes System during March of that year. Overall storage levels, however, remained relatively low throughout 2020 (Figure 18). The storage capacity did not surpass the 640 GL trigger, whereby the MDBA could again call on water, until May 2021 following some substantial rainfall across the Northern Basin. Further significant rainfall through the middle of 2021 resulted in significant inflows to the lakes, with the total storage levels exceeding Full Supply Level in September 2021 for the first time since 2012.

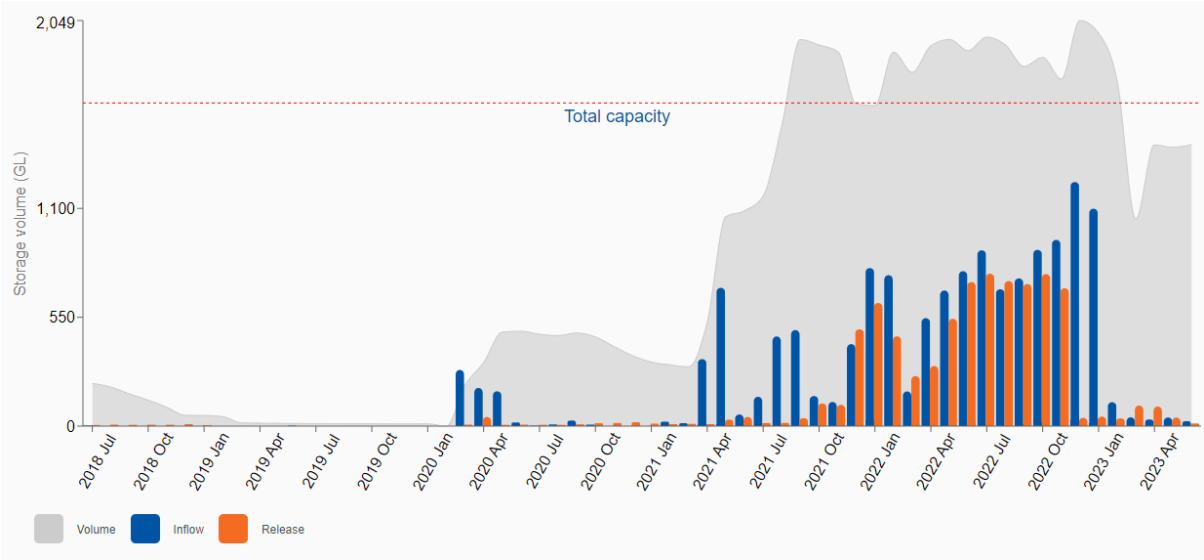


Figure 18. Inflows, releases and total storage for the Menindee Lakes System, over a 5-year period from 2018-2023. Source: WaterInsights

3.2.1 Releases to the Great Darling Anabranch

As the lakes were above FSL and with further inflows forecast due to the floods in the Northern Basin, WaterNSW commenced held environmental water releases from Cawndilla Outlet on 24 September 2021 at a rate of 250 ML/d rising to 1,500 ML/d by 2 October 2021. This decision was made following consultation with the River Operations Stakeholder Consultation Committee (ROSCCo) and the Commonwealth Environmental Water Holder which placed the environmental water order. The decision considered the volume of surplus water available and potential outcomes to be achieved through the release, whilst balancing risks to native fish breeding in the Darling River downstream of Weir 32.

Provision of a flow down the Great Darling Anabranch was a high priority for the Commonwealth given the high ecological, social and cultural benefits at a local scale, and the Basin-scale environmental benefits that are achieved from the dispersal of golden perch into the southern Basin. WaterNSW and the CEWH received positive feedback from the local community and Lower Darling stakeholders as a result of this decision.

3.3 Airspace Operations in January-February 2022

As the flows from the Northern Basin floods of November 2021 continued to arrive at the Menindee Lakes in January-February 2022 airspace in the storages began to reduce. It was therefore necessary to increase releases from the storages to capture as much of the incoming floodwaters as possible. In mid-January, releases from Cawndilla were 2,000 ML/d, while releases to the Darling were targeting 18,000 ML/d[4] at Weir 32, and the total lakes storage sat at approximately 92%.

WaterNSW held Menindee Operations Community update sessions in Pooncarie on 18 January 2022 and in Menindee on 19 January 2022, in the company of other agencies. Following discussions with community members and Lower Darling stakeholders, a WaterNSW Operations Update released on 22 January stated that "from 26 January 2022, releases will increase from main weir to target 21,000 ML/day at Weir 32." It was also stated that the "increase to releases will be a gradual process at 500 ML/day over 48-hours, and the water level at Weir-32 will be monitored closely and the release plan will be amended with active feedback from SES". The aim was to attain a potential flow of 21,000 ML/d at Weir 32 by around 5-6 February 2022. It was acknowledged at the time that such flows would exceed the Minor flood level at the Menindee town gauge. The plan was confirmed on 26 January as the flows were to increase.

After two days of gradually increasing releases, however, feedback was received that some properties were being impacted by the rising water levels. The NSW SES therefore requested WaterNSW to reverse the plan of increased releases, which WaterNSW made a decision to do. At the time the Menindee gauge peaked at 8.49 m on 27 January 2022 (Figure 19), just below the Minor flood level (8.50 m). WaterNSW released an Operations Update to the community on 28 January advising: "Following feedback from NSW SES and a review of release plans, WaterNSW is advising customers and community that releases from the Menindee Lake storage will not increase further and will be reverted to 18,000 ML/day at Weir-32". At that stage the total lake volume was below full capacity. Further Community Information was also

[4] Releases from the lakes to the Darling River do not necessarily match the targeted flows at Weir 32. This is because there can be losses and/or gains in flows between the lake outlets and Weir 32. For example, in mid-January 2022, releases of ~21,000 ML/d were required from the lakes to the Darling River to attain a flow rate of 18,000 ML/d at Weir 32.

published on 28 January. The impacts to property access below the Minor flood level was likely due to there being limited information available in terms of a floodplain study or data from previous floods (see section 3.3.1 for further details).

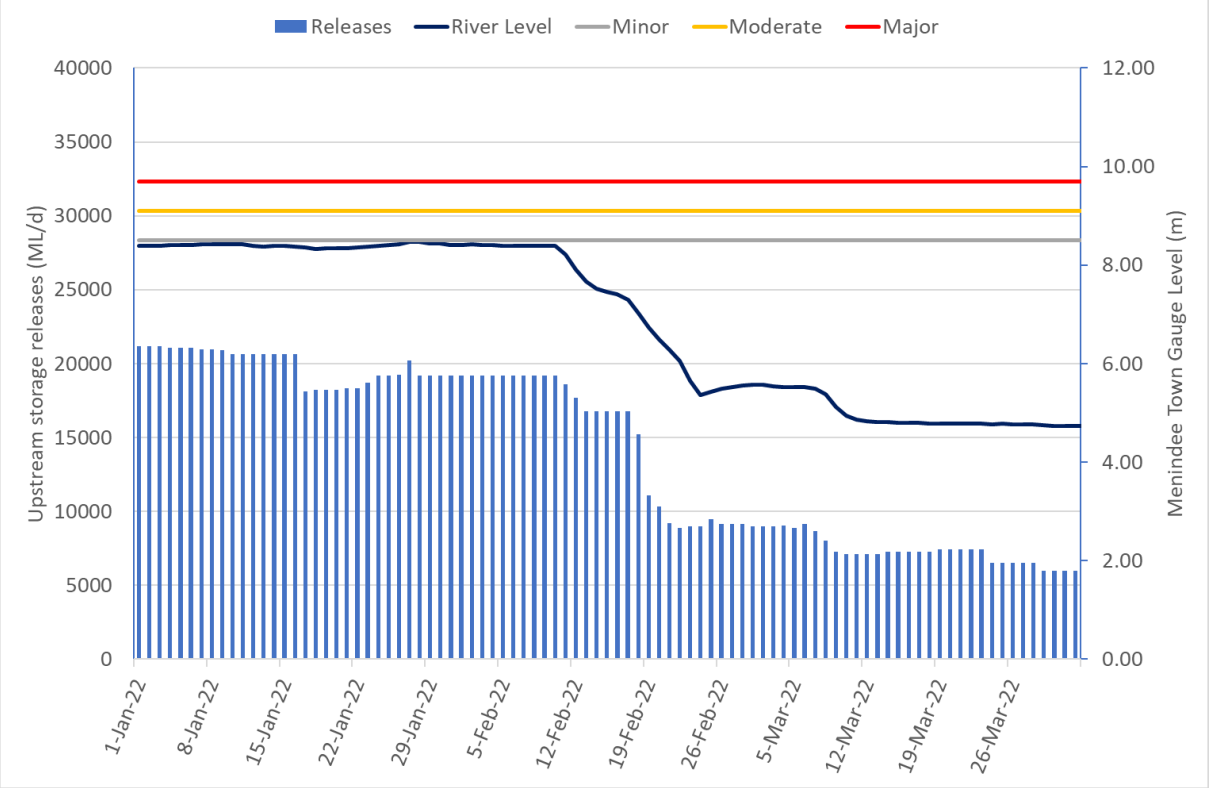


Figure 19. Releases from the storages to the Darling River, and river levels at the Menindee Town Gauge from January to March 2022 in relation to the flood classification levels. Further information on inflows, releases and flood levels is provided in section 4.

On 7 February, WaterNSW published an operational update advising that releases would gradually be decreased. WaterNSW held a River Operations Consultation Committee (ROSCCo) meeting on 8 February 2022 to seek feedback from stakeholders on the plan to continue decreasing releases into the Darling River. A substantial amount of feedback was received regarding the trade-offs between providing environmental benefits through flooding of wetlands, and the inundation of homes in the vicinity of Menindee. A subsequent operational update was issued on 9 February stating that the releases would decrease from 10 February. Later that month, in an operational update issued on 22 February, WaterNSW advised that the lakes had reached Full Supply Level on 19 February 2022. At that stage it was stated that "as the inflows recede the lake level is forecast to peak by the first week of March at about 111% or 1,910 GL. WaterNSW is closely monitoring the upstream flows to manage the

releases from the Menindee Lakes storage system, so that inflows can be safely captured within the Maximum Induced Surcharge Level (MISL)."

3.3.1 Hydraulic Modelling Study

As there was limited information available on flooding levels in the vicinity of Menindee township, the Department of Planning and Environment Water (DPE-W) engaged the Manly Hydraulics Laboratory (MHL), itself a part of DPE, to model the potential impacts of releases as measured at Weir 32. MHL utilised a two-dimensional hydraulic model that it had previously developed for the Lower Darling River. The model was calibrated and validated against flows that had occurred between December 2021 and February 2022, along with data obtained from a previous flood in December 2010.

The model outputs focused on the reach of river between Lake Wetherell and Weir 32. Inundation maps were produced at 500 ML/d increments between 18,000 ML/d and 23,000 ML/d and related to surveys undertaken by MHL of house floor levels, septic tank levels, driveways, as well as the crest of Irrigation Road, Menindee.

The draft results of the MHL study were not available to WaterNSW until April 2022. As a result, releases from the lakes were kept below 18,000 ML/d during February 2022. When produced, the results were made available to the NSW SES to determine which septic tanks and driveways would be affected by inundation as flows potentially rose above 18,000 ML/d to 23,000 ML/d. In terms of road access, the study found that the following roads become unsuitable for a small car at these flows:

- River Road at 18,000 ML/day
- Pamamaroo Road at 18,500 ML/day
- Budgie Street and Orchard Road ay 19,000 ML/day
- Loop Road at 19,500 ML/day.

The full report and modelling study were not made public by DPE to protect the privacy of impacted landowners at the time. The final report was published in August 2022.

3.3.2 Feedback from Stakeholders

The Department of Planning and Environment organised a visit to the Lower Darling with WaterNSW from 14-15 March 2022. Stakeholders were visited in Menindee, including the Central Darling Shire Council, local landowners who may be impacted by flooding, and representatives from the Australian Floodplain Association, South Western Water Users (SWWU) Association, NSW Farmers and Anabranch Water.

Stakeholders raised issues on the day; some also provided written feedback, while others spoke with the media about their concerns. In summary, issues raised included:

- In response to the WaterNSW Operations Update of 22 January 2022 stating that releases would be increased, many landowners removed stock from paddocks adjacent to the river. Lake beds along the Anabranch were also opened to enable flows to enter.
- Downstream landowners were seeking increased flows to inundate floodplains, replenish native pasture and floodplain vegetation, recharge aquifers and provide flows in the Anabranch that could enable lakebed cropping.
- A subsequent report provided to WaterNSW by Anabranch Water via SWWU suggested that a total of $66.68 million in revenue could be generated by a major flood in the lower Darling and Anabranch. This consisted of $35 million from lakebed cropping, $11.88 million from lakebed grazing and $19.8 million from floodplain grazing. The report also highlighted the benefits of a watering event for apiarists, as well as the environmental benefits of maintaining a wetting and drying cycle in the Anabranch:
    - Increased vegetative health of black box and spiny lignum
    - Ability of floodplain vegetation to germinate and also provide a viable seed bank for future floods
    - Providing habitat for fauna, including invertebrates
    - Recharging groundwater.
- When a decision was made to not increase flows above 18,000 ML/d the downstream community highlighted the impacts this would have including the lost environmental, economic and social opportunity.

- Downstream landholders expressed concerns that the advice from the NSW SES was inappropriate. The theme of the feedback was that locals were concerned none of the NSW SES were local, so it was assumed no local knowledge or input had been sought in making the decision. The downstream landowners also expressed that in their opinion the economic and environmental benefits of a flood would outweigh the costs of inundating local residences in Menindee.
- Members of the Menindee community whose houses were likely to be impacted by higher flows, however, were grateful that the decision had been made not to increase flows at that time.

While WaterNSW engages and consults with the BoM and NSW SES to determine the amount of water to be released from Menindee Lakes, the final decision in relation to any releases is the sole responsibility of WaterNSW.

3.4 Airspace Operations March to May 2022

Following the events of summer 2021/22, the inflows receded during February and March 2022. However, from late March the inflows began to increase (see Figure 18 above). An operations update issued on 17 March 2022 indicated that a further 450-750 GL of inflows could be expected at that time to the end of May. A River Operations Stakeholder Consultation Committee (ROSCCo) meeting was held on 22 March 2023 where WaterNSW updated the community and stakeholders on the latest forecast inflows. A decision was made at that time to hold releases steady to target a flow of 6,000 ML/d at Weir 32 for a period of 5-6 weeks to early May. This was confirmed in an operations update published on 25 March 2022.

On 7 April 2022, due to rainfall received in the Border Rivers and Culgoa catchments, WaterNSW issued an operations update advising that an additional 500 to 800 GL of inflows was expected to the end of May, with the peak expected to arrive around the fourth week of April. As a result, the releases were planned to increase to 9,000 ML/d over a number of days and be held at that level for 2-3 weeks in order to create airspace to capture the additional modelled inflows and then ensure the lakes were full at the end of the event. Further rainfall in the North saw the forecast for inflows increase again during April. At a meeting on 20 April 2022 with the MDBA, DPI Fisheries and DPE Water, among other stakeholders, a decision was taken to increase releases over a few days to target 12,000 ML/d at Weir 32 and be held at that level for approximately four weeks. This was published in an operations update by WaterNSW on 22 April.

Due to further rainfall in the North and rainfall in the local catchment near the lakes, on 29 April 2022, WaterNSW advised that an additional 80 GL of inflows above what had previously been modelled, was likely to reach the lakes system. A decision was made to increase releases to target 14,000 ML/d at Weir 32 for approximately 3-4 weeks. It was noted at the time that there was "considerable uncertainty in the inflow volumes to the end of June." The uncertainty in the modelling was due to there being widespread flows across the floodplains in the Border and Culgoa rivers with a long travel time to the Menindee Lakes. At that stage, the storages were expected to be surcharged and peak by the last week of May 2022.

WaterNSW convened an Airspace Reference Panel meeting on 10 May 2022 with relevant government and community stakeholders. At that meeting it was explained that the forecast inflows continued to rise, with 500-900 GL of inflows expected between 7 May and 31 July 2022. It was noted by WaterNSW at the time that water in the floodplains made modelling the inflows quite uncertain, hence the 400 GL range of potential inflows. The uncertainty in modelling was due to the difficult task of estimating the volume and timing of upstream floodplain flows that may return to the river channel based on limited information. The objectives of airspace operations at that time included:

- Gaining as much airspace as possible ahead of the inflows
- Lowering the lakes with environmental and/or cultural implications of high water levels, those being Wetherell (floodplain vegetation) and Menindee/Cawndilla (cultural sites)
- Limiting airspace releases to have low or no impact (below Minor flood level)
- Scheduling releases to provide as much environmental, social and economic benefit as possible.

It was decided that releases should be increased to target 18,000 ML/d at Weir 32 for a period of approximately two weeks into early June, whilst continuing releases of 2,000 ML/d from Cawndilla outlet to the Great Darling Anabranch. These plans were published in an operations update on 13 May 2022.

3.4.1 Community Feedback

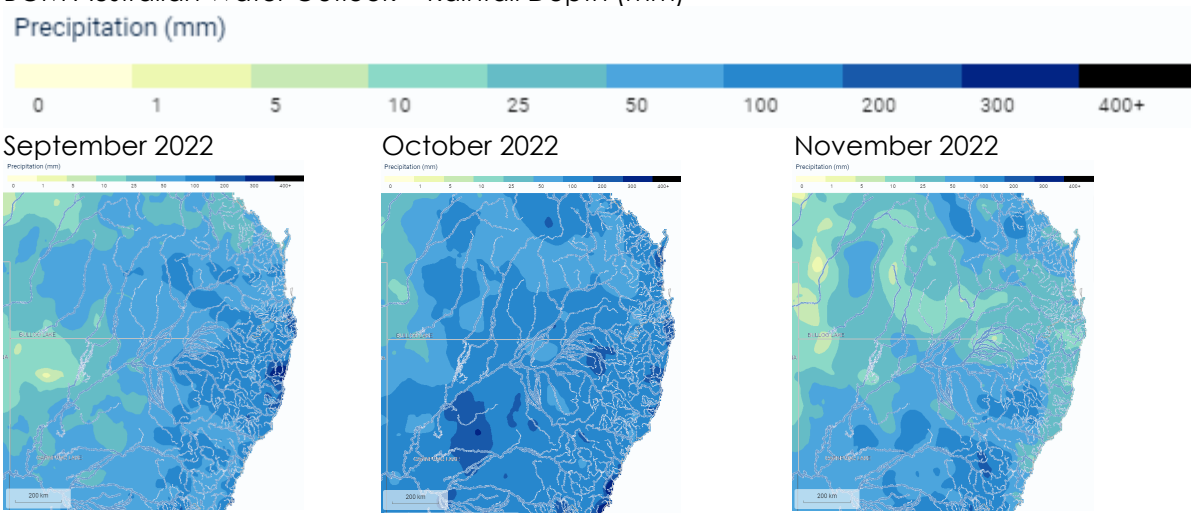
Similar feedback to that received earlier in 2022 was provided by Lower Darling and Anabranch stakeholders. The theme of the feedback was that releases should be made that would inundate the floodplains and wetlands for economic benefit (for lakebed cropping,

grazing etc) and environmental benefit. Downstream stakeholders, such as the South Western Water Users (SWWU) Association, again expressed that higher releases should be made as the benefits downstream would outweigh the costs of inundating properties in and around the Menindee township.

3.5 Northern Basin Floods

This section describes the conditions in the large upstream catchment that resulted in floods in the Barwon Darling and Lower Darling systems. In 2022, New South Wales received the second highest annual rainfall since 1900. Some areas of the state recorded their highest annual totals. BoM reported that October 2022 was the wettest October on record for the state. March, April and September were in the top ten wettest on record for their respective months (BoM 2022 Climate Summary). Figure 20 displays rainfall depth estimates and percentile rank over 100 years across the Murray Darling Basin. The widespread rainfall resulted in large flows into the Barwon Darling and its western tributaries. The highest flows at Bourke in 2022 occurred in December following two prior peaks in January and June. These high river and tributary flows resulted in a large amount of water in the Darling River.

BOM Australian Water Outlook - Rainfall Depth (mm)



BOM Australian Water Outlook - Relative Rainfall against 100+ years

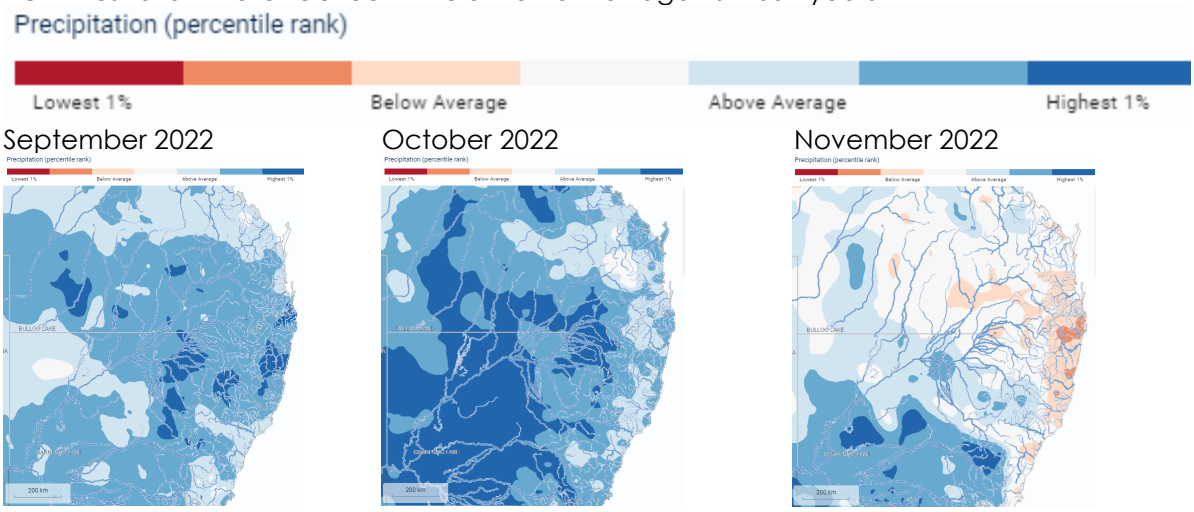


Figure 20. Rainfall across the Murray Darling Basin – September, October, November 2022.

3.5.1 November 2021 to September 2022

Over the 12-month period from November 2021 to September 2022, flow in the Darling River at Bourke was continuous with periods of higher flows over January to February 2022 and June to July 2022. Recorded instantaneous flows along the Barwon and Darling rivers are presented in Figures 21 and 22 for the river reaches from Mungindi to Bourke, and Bourke to Wilcannia (including Talyawalka Creek), respectively. Total flow volumes at various river gauges for this

period are shown in Table 4. Total flow volumes at Bourke and Wilcannia were in the order of 8,600 GL and 6,400 GL, respectively.

The total flow volume at Bourke over this period was ~8,600GL. Around 25% of this flow was recorded at Mungindi and 15% in the Culgoa, with the remainder coming predominately from NSW tributaries (regulated and unregulated). The total flow volume at Wilcannia over this 12-month period was ~6,400 GL which is three times the total volume of the Lakes, including surcharge volume.

Instantaneous flow in the Darling River from Bourke to Wilcannia was above 10,000 ML/d for an extended period commencing in December 2021. In mid-February 2022, instantaneous flow at Wilcannia peaked at around 29,000 ML/d. Following the recession of this peak, from late March 2022, the flow started to increase again, reaching another peak of 29,000 ML/d in late July 2022. After a brief recession, another rise followed; continuing to rise until the end of December 2022.

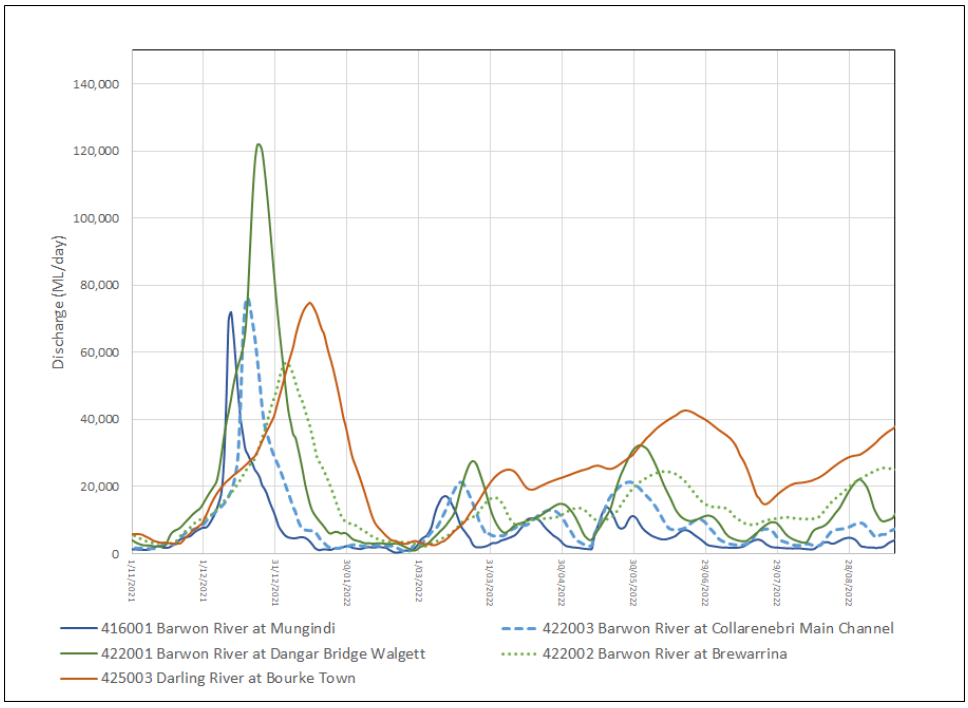


Figure 21. Recorded Instantaneous Flow Mungindi to Bourke - November 2021 to September 2022

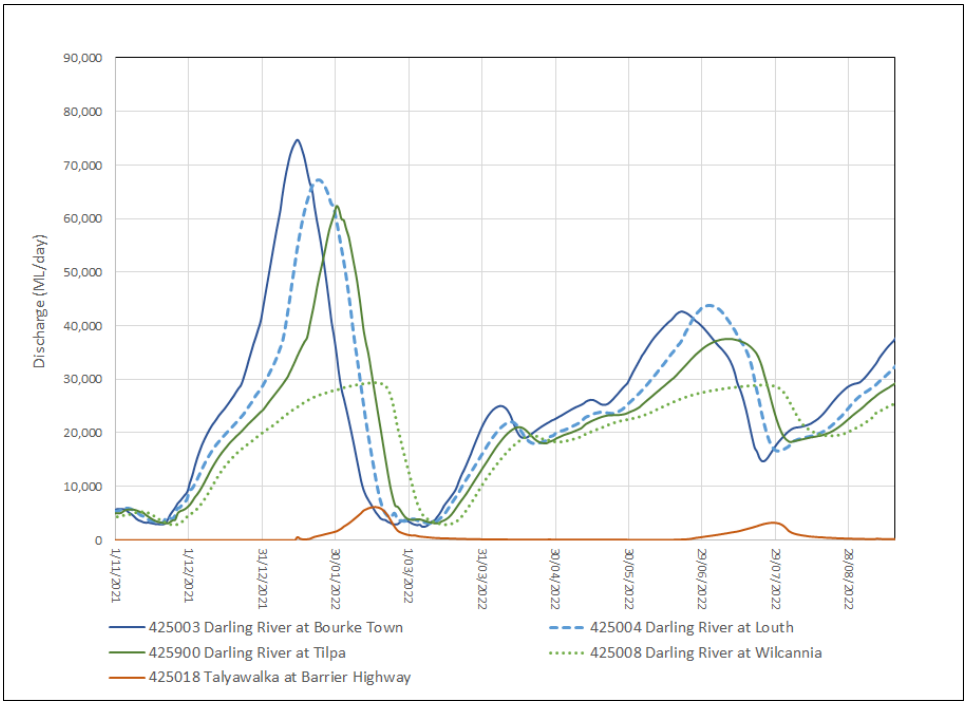


Figure 22. Recorded instantaneous flow Darling River Bourke to Wilcannia, November 2021 to September 2022.

Table 4. Total Flow volumes at gauging stations from Mungindi to Wilcannia for the period November 2021 to September 2022.

Main River Gauge / Name	Total Flow volume (GL)
Barwon River a ***Mungindi (***Gauge ***416001)***	2140
Barwon River ***at Collarenebri (***Gauge ***422003)***	3340
Barwon River ***at Dangar Bridge Walgett (***Gauge ***422001)***	5700
Barwon River ***at Brewarrina (***Gauge ***422002)***	5200
Darling River ***at Bourke (***Gauge ***425003)***	8600
Darling River ***at Louth (***Gauge ***425004)***	8100

Darling River ***at Tilpa (***Gauge ***425900)***	7600
Darling River at Wilcannia (Gauge 425008)	6400
Talyawalka Creek at Barrier Highway (Gauge 425018)	240

3.5.2 October 2022 to January 2023

Significant inflows to the Menindee Lakes from October 2022 onwards resulted from large rain events in the Northern Basin, including in the Macintyre, Moonie, Gwydir, Namoi, Culgoa, Bokhara, Macquarie, Castlereagh, Paroo and other catchments. Table 5 shows the total flows at upstream gauging stations on the Barwon River as a proportion of the total recorded flows at Bourke for the period October 2022 to January 2023. The Bourke gauge peaked at ~222,500 ML/d (Figure 23).

Table 5. Recorded flow at Stream Gauges Mungindi to Bourke, October 2022 to January 2023

Main River Gauge / Name	Total Flow Oct 2022 to Jan 2023 (GL)	Volume comparison to total flow at Bourke (%)
Barwon River at Mungindi (Gauge 416001)	1,000	10%
Barwon River at Collarenebri (Gauge 422003)	2,900	29%
Barwon at Dangar Bridge Walgett (Gauge 422001)	6,600	66%
Darling River at Bourke (Gauge 425003)	***10,000***	***100%***

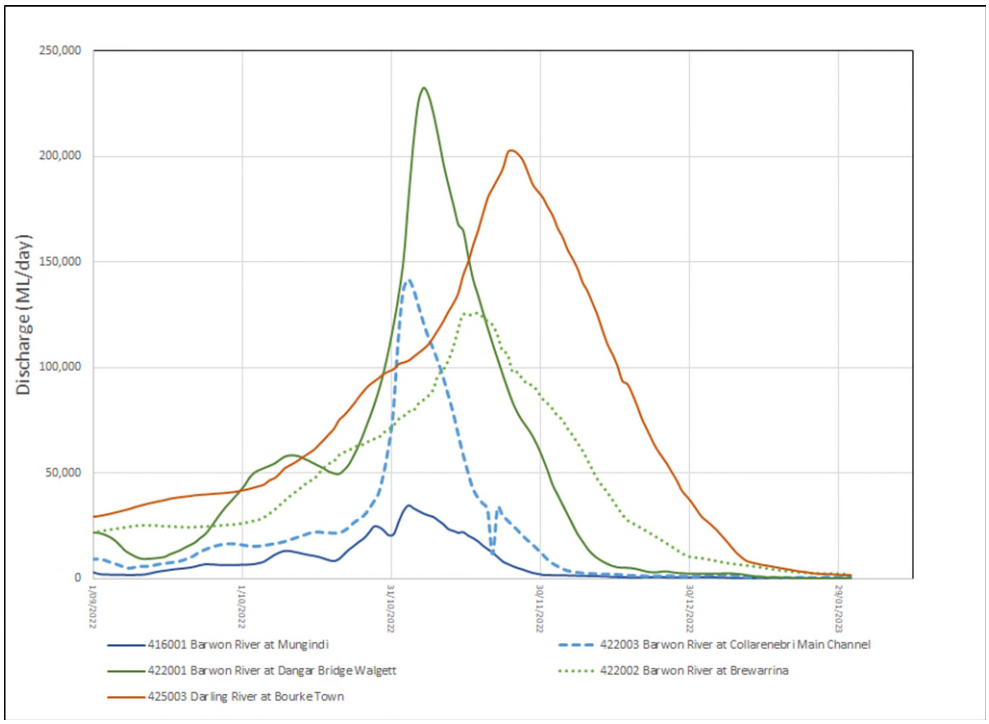


Figure 23. Recorded flow Mungindi to Bourke - September 2022 to January 2023

The northern tributaries contributed a large proportion of the flows at Bourke (Table 6 and Figure 24 to 28), with the Namoi contributing ~24%, Macquarie-Castlereagh Rivers ~27% and the Bogan River ~11%. A graphical summary of the main river and tributary contributions is presented in Figure 24.

Table 6. Recorded Flow Tributary Stream Gauges, October 2022 to January 2023

Stream Gauge Name (Reference number)	**Total Flow Oct 2022 to Jan 2023 (GL)**	**Volume comparison to total flow at Bourke (%)**
Gil Gil Creek at Galloway (Gauge 416052)	290	3%
Moonie River at Gundablouie (Gauge 417001)	110	1%
Gwydir River at Millewa (Gauge 418066)	Missing data – rating table out of range	

Mehi River near Collarenebri (Gauge 418055)	Missing data	
Thalaba Creek at Belarre (Gauge 418091)	200	2%
Pian Creek at Waminda (Gauge 419049)	Missing data	
Namoi River at Goangra (Gauge 419026)	2400	24%
Castlereagh River at Gungalman (Gauge 420020)	590	6%
Marthaguy Creek at Carinda (Gauge 421011)	1100	11%
Macquarie River at Carinda (Gauge 421012)	1030	10%
Marra Creek at Billybingbone Bridge (Gauge 421107)	560	6%
Bokhara River at Bokhara (Gauge 422005)	90	1%
Culgoa River US Collerina (Gauge 422011)	470	5%
Bogan River at Gongolgon (Gauge 421023)	1100	11%
Darling River at Bourke (Gauge 425003)	***10,000***	***100%***

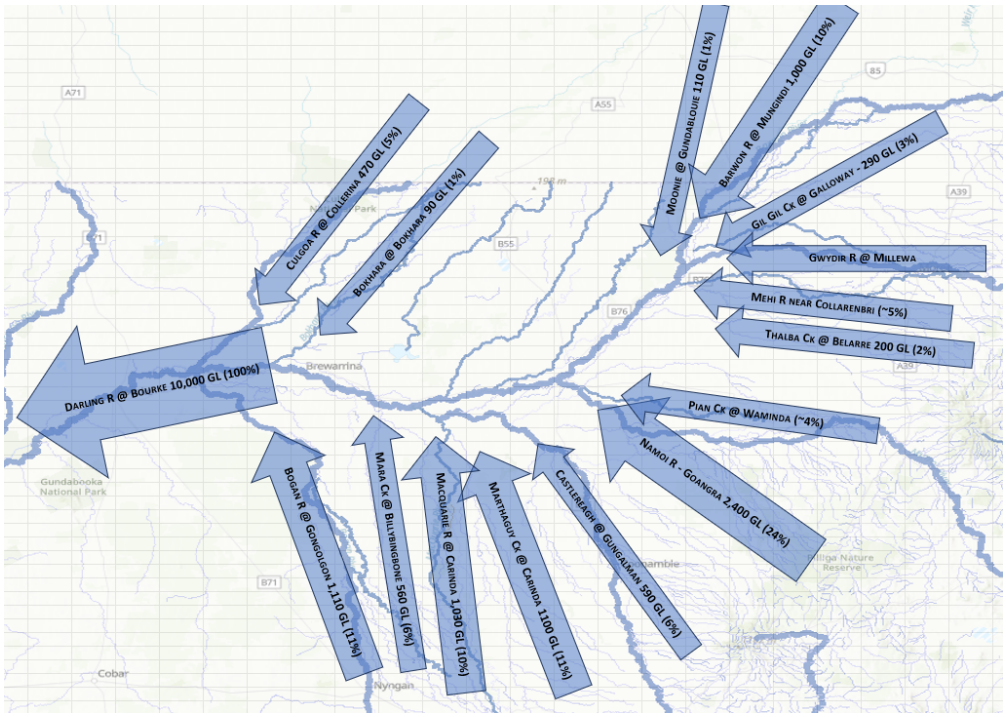


Figure 24. Summary of total main river and tributary flow volumes, Mungindi to Bourke, September 2022 to January 2023

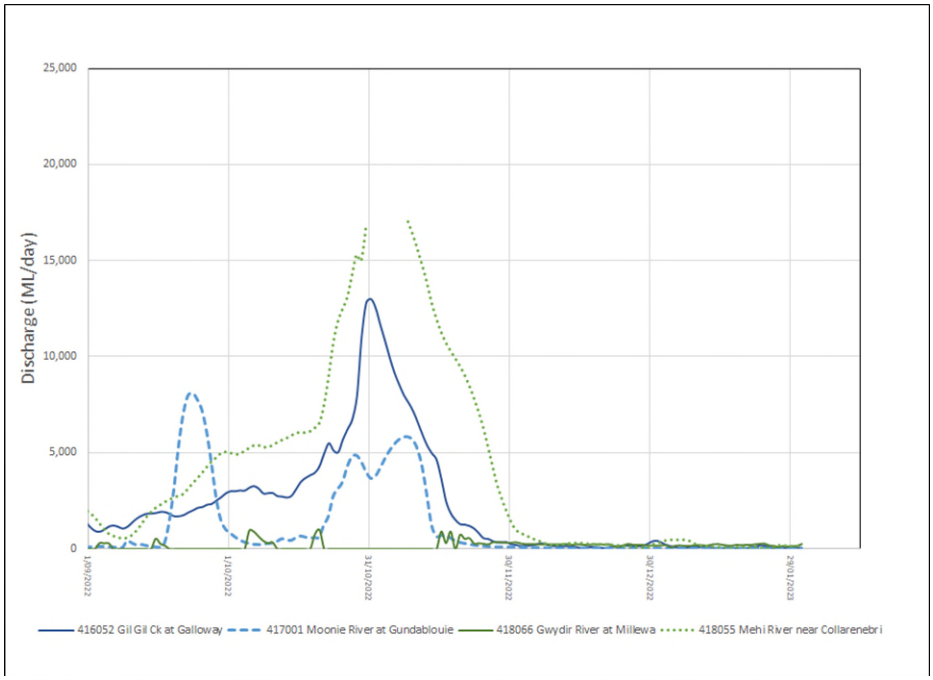


Figure 25. Recorded instantaneous tributary flows, Mungindi to Collarenebri, September 2022 to January 2023

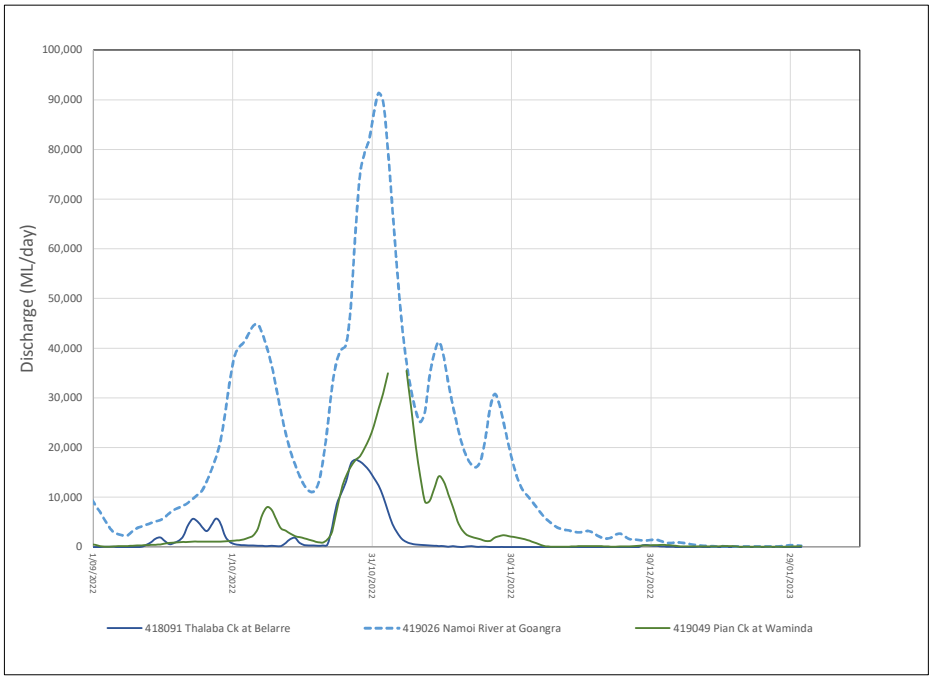


Figure 26. Recorded instantaneous tributary flows, Collarenebri to Walgett, September 2022 to January 2023

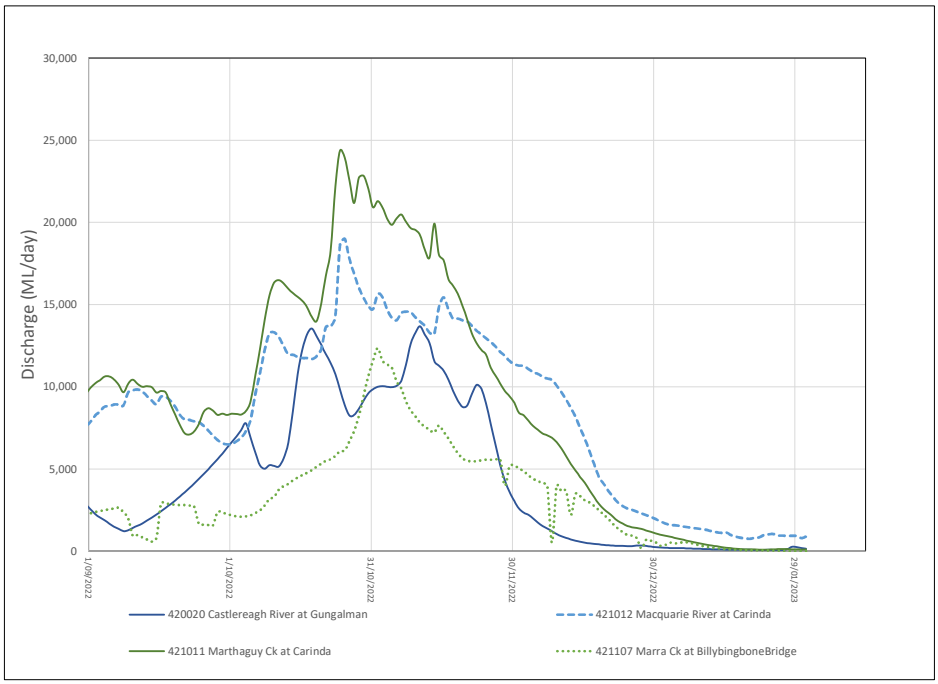


Figure 27. Recorded instantaneous tributary flows, Walgett to Brewarrina, September 2022 to January 2023

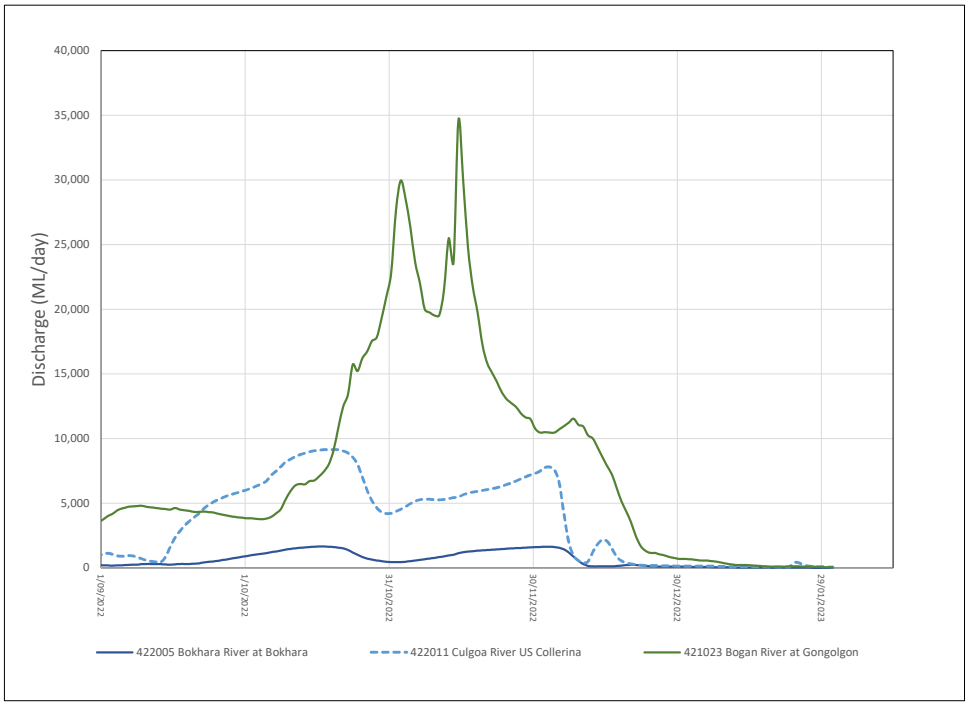


Figure 28. Recorded instantaneous tributary flows, Brewarrina to Bourke, September 2022 to January 2023

The flood peaked at Bourke on the 24th of November 2022 at around 222,500 ML/d. Eight days later the peak at Louth was around 197,000 ML/d on the 2nd of December, followed by a peak at Tilpa of around 207,000 ML/d on the 8th of December (Figure 29).

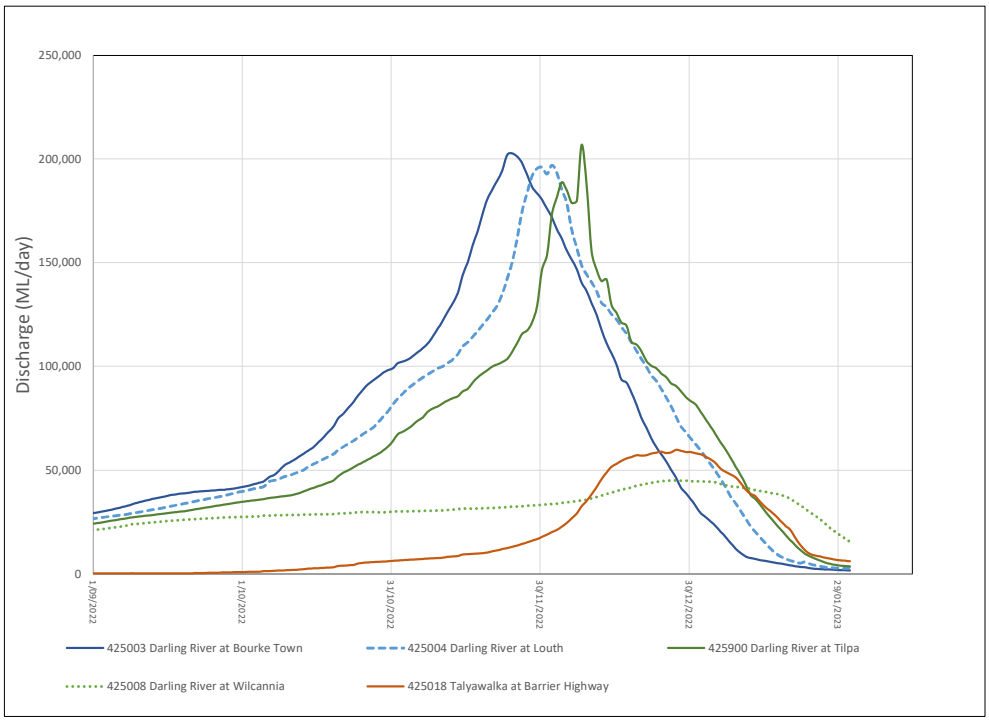


Figure 29. Recorded instantaneous flow Bourke to Wilcannia, September 2022 to January 2023

3.6 Inflows to the Menindee Lakes

In Appendix B several satellite images across the event from Tilpa to Wilcannia and Wilcannia and Lake Wetherell, show the changes in flow behaviour and floodplain inundation. Notable aspects are:

- Inundated areas to the east of the Darling River downstream of Tilpa contribute to flow in the Talyawalka Creek.
- Inundation of the floodplains between Wilcannia and Lake Wetherell, along both the Darling River and Talyawalka Creek and the timing of the connection between them.
- The inundation of the floodplains between Wilcannia and Lake Wetherell, along both the Darling River and Talyawalka Creek and the timing of the connection between them.

Inflows to Lake Wetherell are not gauged directly. An estimate has been made by standard water balance calculations using changes in storage volume, outflows and rainfall and evaporation from the Lakes' surface. These inflow calculations can be done on a daily or

hourly basis and, whilst generally overall reliable, can be unreliable during certain periods for several reasons including wind and wave dynamics of large lake bodies, small variations in water level resulting in large storage volumes changes and propagation of outlet changes through a storage. Care should be taken when referencing inflow rates as they are not measured and are estimates only.

Estimated inflows to Lake Wetherell were more than the flow recorded in the Darling River at Wilcannia (which is the location generally used to indicate inflows to Lake Wetherell). Table 7 shows the recorded flows at gauges on the Darling River and the estimate of inflows to Lake Wetherell. Peak estimated inflow was double the peak flow at Wilcannia. The larger flows into Lake Wetherell are attributed to the inundation on the Talyawalka floodplain flowing southwest towards the Darling River. Past modelling and observations of historical floods indicates that flow moves between the Darling River and the Talyawalka Creek at multiple locations at high flows. In 2005 the Department of Infrastructure Planning & Natural Resources (DIPNR) undertook a study which included analysis of flood frequency at the Wilcannia main channel gauge (425008), Talyawalka gauge (425018) and combined flows at Wilcannia (425002 – the sum of 425008 and 425018) in relation to Lake Wetherell inflows. The study found that peak inflows into Lake Wetherell could be estimated to be 60% of the peak combined flow at Wilcannia (425002). In 1976, the third largest flood on record and the largest since the scheme was built, the combined flow at Wilcannia peaked at 204,000 ML/d, while peak inflows to Lake Wetherell were estimated at 115,000 ML/d. A further modelling study found that the ratio of Wetherell inflows to combined Wilcannia flows would reduce below 60% during larger floods as progressively more flow would be passed down the Talyawalka Creek.

Figure 30 shows the estimated inflows to Lake Wetherell between January 2022 and February 2023. There is a steep increase in inflows from 20 December 2022 with a peak around late December 2022 of 106,000 ML/d. Inflows remained steady at around 85 GL/d until 10-11 January 2023. Inflows gradually decreased up to the end of January 2023. The combined flows at Wilcannia (425002) peaked on 27 December 2022 at 104,925 ML/d which is comparable to the estimated peak inflows to Lake Wetherell and therefore the inflows were much greater than the 60% ratio from past events.

Table 7. Summary of peak flow and total volume between October 2022 to January 2023

River Gauge / Name	Peak Flow (GL/d)	Total Flow (GL)
Darling River at Bourke Town (425003)	203	10,000
Darling River at Louth (425004)	197	9,800
Darling River at Tilpa (425900)	171	9,100
Darling River at Wilcannia (425008)	45	4,200
Talyawalka Creek at Barrier Highway (425018)	60	2,700
Inflow to Lake Wetherell (Menindee Lakes)*	106	5,800
Release from Menindee Lakes to the Darling River*	79	5,100

*Calculations sourced from CARM

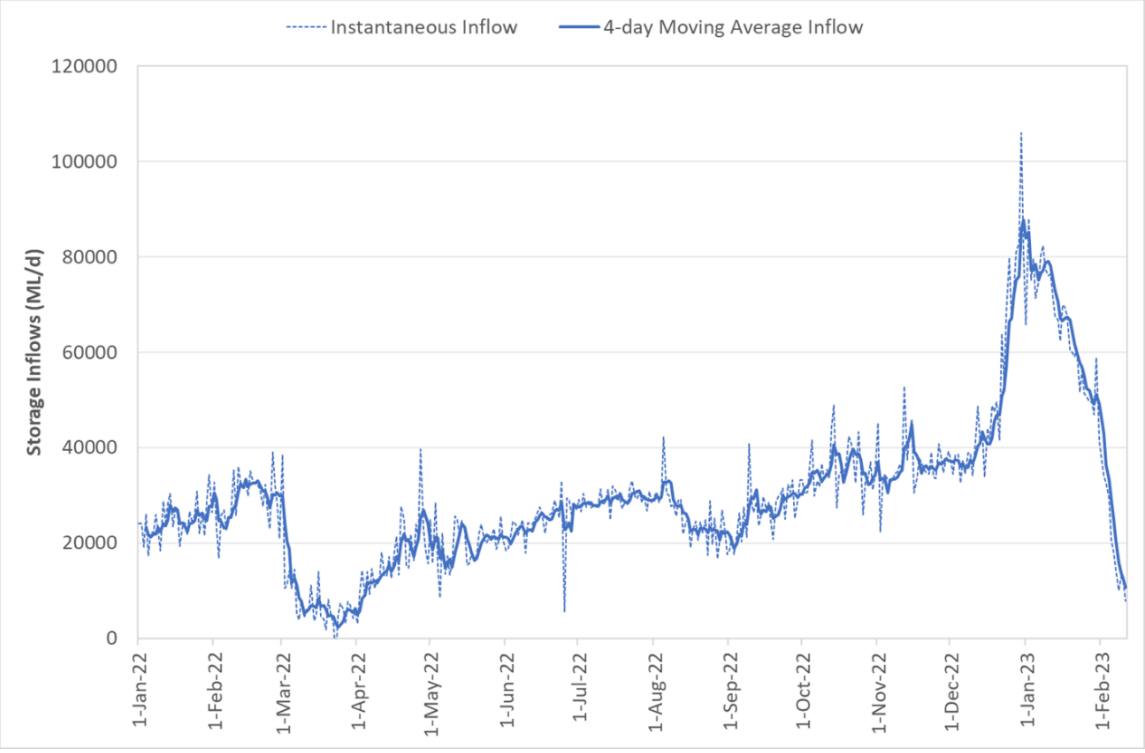


Figure 30. Inflows to Lake Wetherell between January 2022 and February 2023.

4 Flood Operations 2022/23

Flood operations are described in this section, for three distinct time periods:

- May to August 2022, when flows at the Menindee Town gauge exceeded the Minor flood level.
- September to November 2022, when flows at Menindee Town gauge exceeded the Moderate flood level.
- December 2022 to February 2023, during which flows at the Menindee Town gauge exceeded the Major flood level from 30 December 2022.

Data in Figures 31 and 32 will be referred to in the following sections.

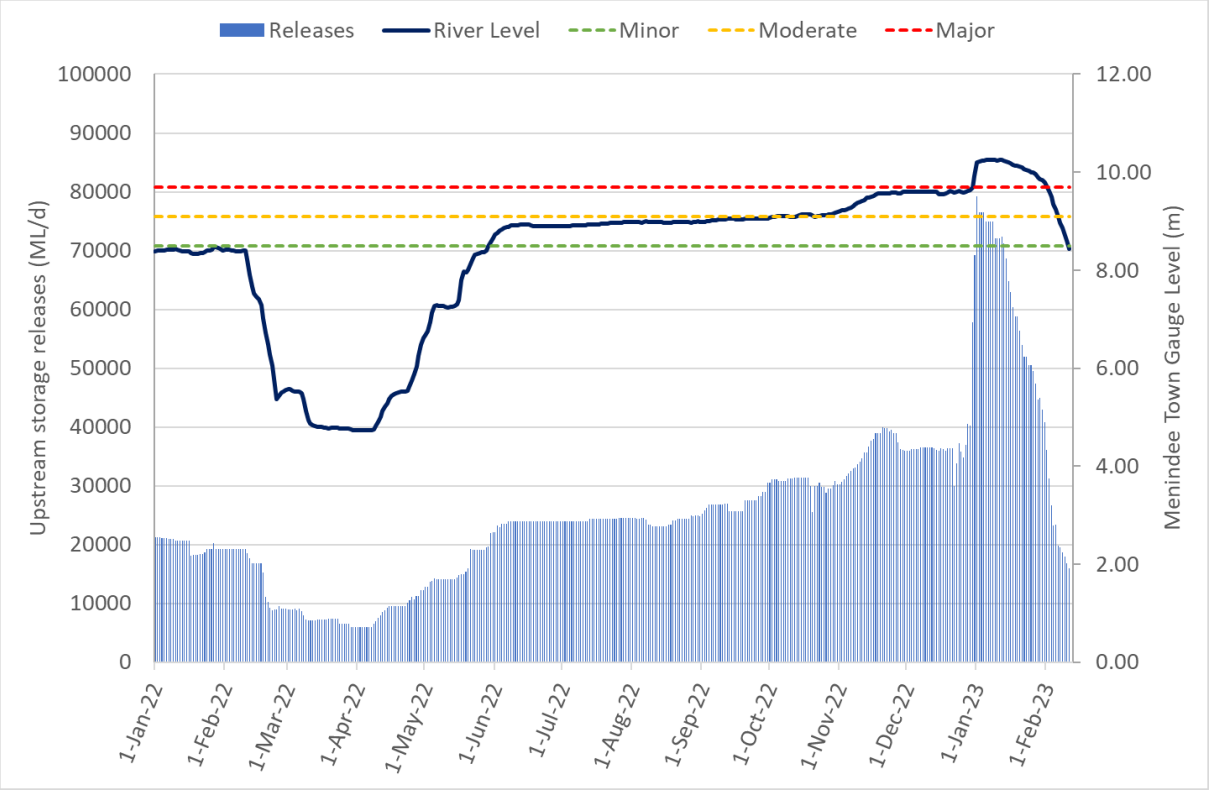


Figure 31. Time series of Menindee Lakes releases and river level at the Menindee Town Gauge with respect to the Minor, Moderate and Major Flood levels.

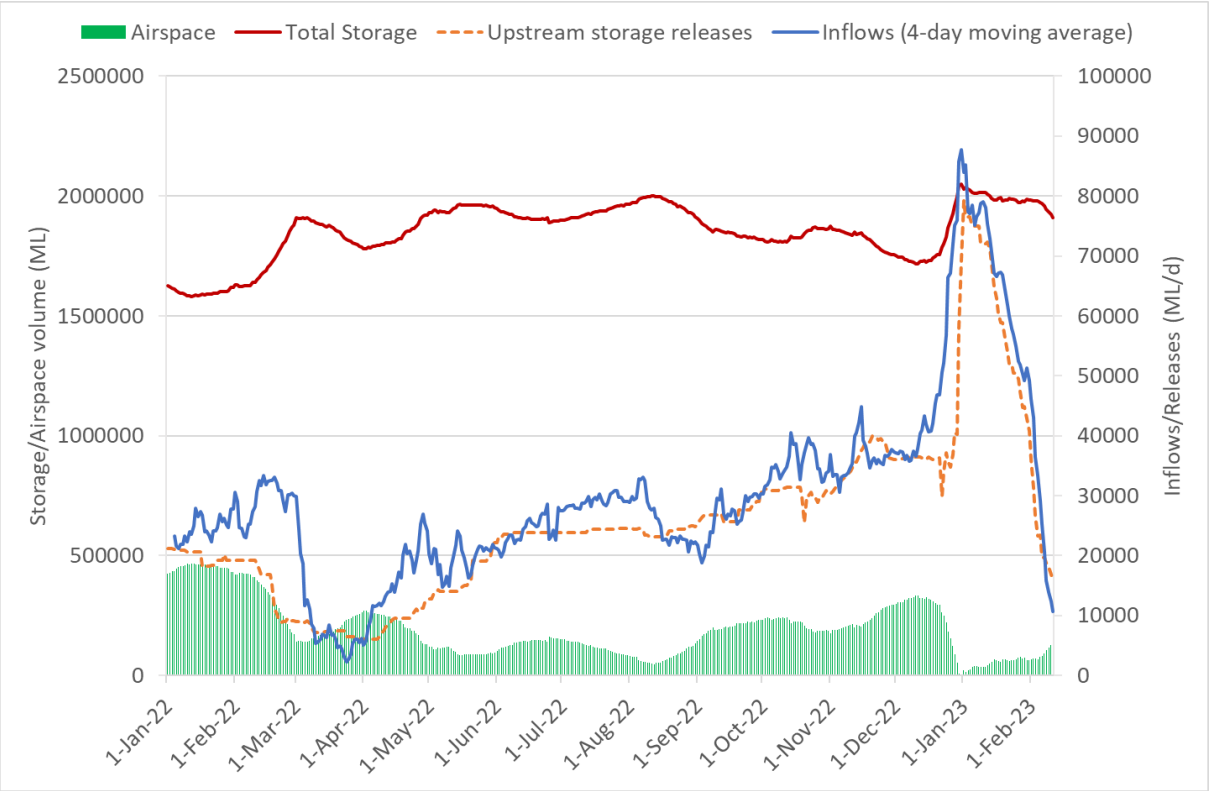


Figure 32. Time series plot of total storage volume, storage airspace, inflows and releases for the period January 2022 to February 2023.

4.1 May to August 2022

Throughout the airspace and flood operations, CARM modelling for lake operations was run by WaterNSW multiple times per day, while CARM modelling of inflow forecasts from the Barwon-Darling system model was run several times per week to estimate the likely flows arriving at Wilcannia, upstream of the lakes. As conditions in the upstream catchment continued to change, the forecasts were consistently revised upwards throughout the month of May (Figure 33). As a result, WaterNSW stood up its Incident Management Team (IMT) on 24 May 2022 as per its Flood Incident Management Protocol.

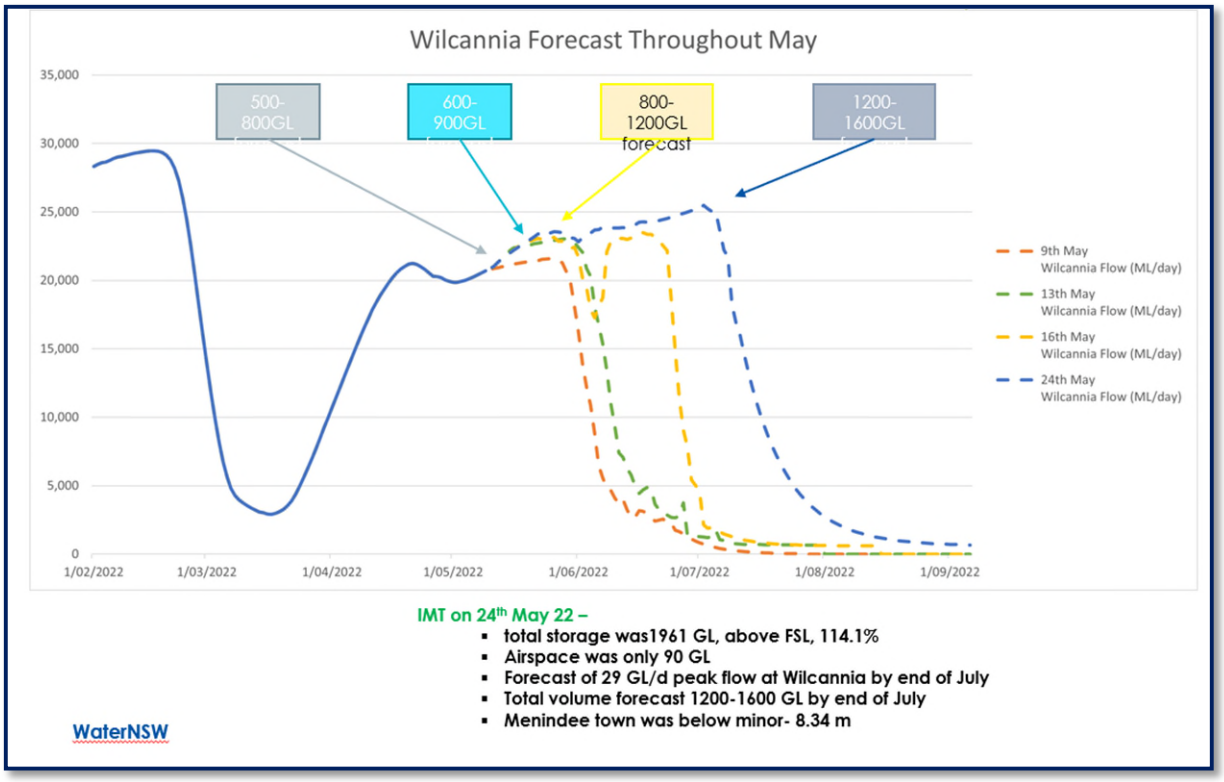


Figure 33. Forecast flows at Wilcannia for May 2022 showing how the estimated inflows rose from a total of 500-800 GL on 9 May 2022 to 1200-1600 GL on 24 May 2022.

On 24 May 2022, after consultation with the NSW SES and BoM, WaterNSW issued an operations update advising customers and the community that releases would be increasing to target 23,000 ML/d at Weir 32 by early June. Figure 34 provides an example of the typical Menindee operations plan which was developed at that point in time (24 May 2022). This plan details the strategy to increase releases, generate airspace enabling management of revised forecast inflows. The plan also outlines the aim to keep the lakes below the surcharge level with a forecast total storage volume of approximately 1930GL by mid -July 2022. Downstream this operation plan resulted in the river exceeding the Minor flood level at the Town Gauge. At that stage, it was forecast that 1150-1550 GL of inflows would arrive at the lakes system by the end of July. Cawndilla releases were reduced to 1,900 ML/d to reduce backwater impacts, manage erosion and maintain the integrity of the outlet structure.

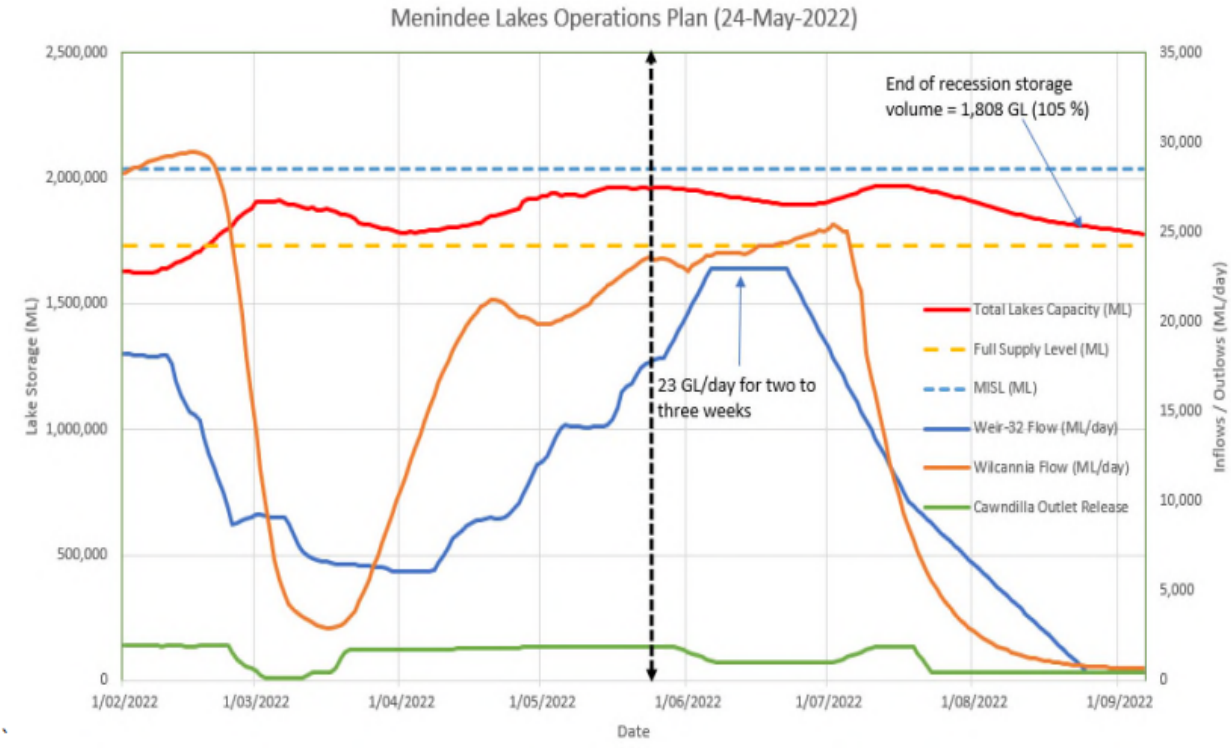


Figure 34. Menindee Lakes Operating Plan 24 May 2022

On 3 June 2022, WaterNSW issued an operations update advising that a further 1,200-1,600 GL of inflows was expected by the end of July. A Menindee Community Drop In Session was organised by the Central Darling Shire Council Local Emergency Management Committee (LEMC) to provide an opportunity for persons to meet with key agencies involved in the Menindee flood operations, ask questions and obtain the latest information. The meeting was held on 8 June 2022 in the Menindee Town Hall. Agencies in attendance included:

- NSW SES
- WaterNSW
- Central Darling Shire Council
- NSW Police.

Further modelling indicated on 9 June 2022 that additional inflows of 1,300-1,700 GL were forecast by the end of July. Following feedback received at the community drop-in session, the agencies were consulted and WaterNSW decided to increase releases at 500ML/d

increments to achieve a target flow of 25,000 ML/d at Weir 32. At that stage, releases from Cawndilla were reduced to 1,700 ML/d to reduce backwater affects and manage erosion, while it was noted in WaterNSW' operations update that flows down the Great Darling Anabranch would increase due to increased connectivity with the main river as a result of main weir releases.

The agencies continued to monitor the situation and in an operations update issued by WaterNSW on 15 June 2022, it was advised that the releases at that time, resulting in Weir 32 flows of 23,500 ML/d, were meeting the required objectives. The releases therefore, would not be increased at that time and would be held steady at 23,500 ML/d for approximately one month. Releases from Cawndilla at that time were 1,900 ML/d. In an operations update issued on 22 June 2022, WaterNSW confirmed that the plan remained unchanged at that time. In a further operations update issued on 29 June 2022, WaterNSW advised that the release plan was creating sufficient airspace to capture the flow peak which was expected to arrive at Wilcannia in a few weeks, with a further 1,000-1,400 GL of inflows to the lakes expected by the end of August. At that stage the lakes were forecast to peak at a storage volume of ~2,000 GL.

In an operations update issued on 6 July 2022, WaterNSW confirmed that the release plan would remain unchanged until mid-late July. In early July, heavy rain in the catchment, as displayed in Figure 35, resulted in additional inflows to the lakes, with there being 300 GL of inflows received from 1 to 13 July. As a result, on 13 July 2023, WaterNSW issued an operations update advising that due to an additional 200 GL of inflows, the release plan would remain in place until early August. One week later on 20 July 2022, it was noted that 520 GL of inflows had been received since 1 July, meaning the storage volume had increased to 1,937 GL (112%). Releases remained unchanged. On 27 July 2022, over 725 GL of inflow had been received since the start of July, with the total storage volume rising to 1958 GL (113%). In the operations update issued on 3 August 2022, it was noted that the inflows were expected to soon peak, while the storage volumes had increased slightly to 1972 GL (114%) but still below the MISL of 2,050 GL.

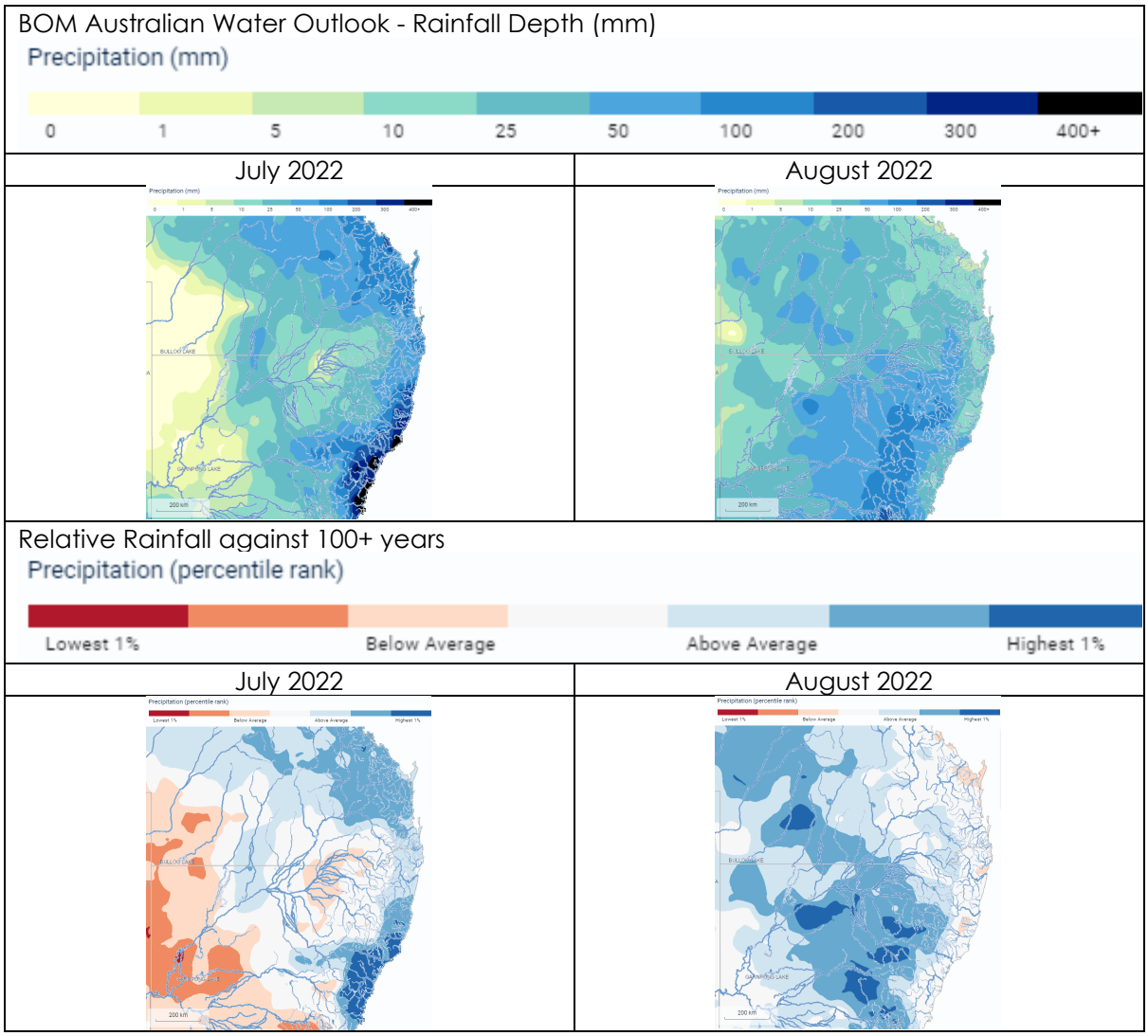


Figure 35. Rainfall across Murray Darling Basin – July and August 2022

In the operations update issued 10 August 2022, WaterNSW advised that the storages were expected to peak in the coming days and were at 1,997 GL (115%) at that time. Lake Wetherell was forecast to peak at 62m AHD, Lake Pamamaroo at 61.5m AHD and Lake Menindee was forecast to peak at 60.5m AHD. The update also made mention of some changes to the data being reported at downstream gauges:

> *"Stakeholders may have recently seen a reduction in the reported flow at gauging stations Darling River at Weir 32 (425012) and Pooncarie (425005) via WaterNSW*

websites, apps and emails. This is not a result of changes made to releases downstream of the Menindee Lakes system, rather an adjustment to the rated flow of the gauges. The changes are a result of repeated measurements that have provided evidence to adjust the reported flow. These adjustments have not affected the management of river level and targets downstream at the Menindee town gauge, nor has it changed the release plan from the storages. WaterNSW have simply updated information to provide the highest quality data to internal and external users. The changes were updated based on the most up to date information, as it was collected."

Such changes to the ratings are considered best practice in managing river gauges to provide the most accurate data possible for river operators and the public. The dynamic river environment and adjustments to downstream gauge stage-discharge relationships (ratings) added to the challenges of managing the lake system during the course of the floods.

In an operations update published 17 August 2022, WaterNSW advised that the storages had peaked and begun to recede, being 1,986 GL (115%) at that time. Owing to a forecast of an additional 1,250-1,650 GL of inflows from the start of August to the end of October, the release plan at that time was not changed and expected to be extended until at least the middle of September. Significant rainfall continued to occur throughout August in the Northern Basin, however, and by 24 August 2022, an increase in flows at Wilcannia was observed. At that time, WaterNSW advised that the current release plan would be maintained until at least the end of September noting that incremental increases may be needed.

As such, following consultation with the NSW SES, BOM and LEMC, an operations update issued on 29 August 2022 advised that the plan had been updated to incrementally increase releases by 500 ML/d to target a river height of 9.05m on the Town Gauge to remain below the Moderate flood level of 9.1m. The NSW SES played a key role in monitoring on-ground impacts and providing feedback to WaterNSW and the LEMC, allowing the plans to be actively reviewed and updated.

4.2 September to October 2022

In early September 2022, the strategy of releasing below the Moderate flood level had continued to maintain the peak storage levels within the maximum surcharge limits. However,

as noted in the operations update issued on 7 September, it was anticipated that a further 1,700 GL of inflows would arrive at the lakes system by the end of November. At that time the outlook was for a wetter than average Spring, with the Town Gauge sitting at 9.03m. The plan was to continue increasing releases by 500 ML/d until the Town Gauge reached 9.05m, as notified to the NSW SES. Releases had increased by 2,000 ML/d from the main outlets to the Darling River to a total of 26,800 ML/d[5] on 7 September while Cawndilla releases remained at 1,900 ML/d.

In the operations update issued on 14 September 2022, it was stated that a further 1,800 GL of inflows was expected by the end of November; this being 100 GL higher than forecast the week before. At that stage the Town Gauge was sitting steadily at 9.05m. The forecasts continued to rise such that on 21 September 2022, WaterNSW advised that a further 1,750-1,950 GL of inflows was expected to reach the lakes by the end of November. Given that forecast and the BoM's confirmation of a third La Nina weather pattern, WaterNSW flagged that in consultation with the LEMC, NSW SES and BoM it would review the latest information and consider increasing releases to target 9.15m on the Town Gauge.

In the operations update issued on 28 September 2022, WaterNSW advised that releases would be increased over the next weekend to target 9.10m on the Town Gauge as a further 1,650-2,050 of inflows was forecast to the end of November. This would be equal to the Moderate flood level, so WaterNSW advised that:

> *"Once increases commence over the weekend monitoring and feedback via SES will be considered over several days as the river levels settle at the increased flow before planning further increases in release. Each increment will be assessed on a case-by-case basis to understand and establish local impacts. This plan will allow WaterNSW, the SES, BOM and on ground responders to actively manage current releases as well as establish future release plans."*

The plan to target 9.1m on the Town Gauge was confirmed in the operations update published on 5 October 2022, where it was stated that a further 1,875-2,275 GL in inflows was forecast to the end of December. In that update WaterNSW advised that such a river level would likely

[5] From 7 September 2022, WaterNSW operations updates started to refer to releases from the storages, as opposed to targeted flows at Weir 32.

extend to at least the end of November. The following week, on 12 October 2022, WaterNSW advised that Wilcannia flows had increased to 30,000 ML/d, but with sustained airspace operations some 240 GL of airspace had been created in the lakes system. In the operations update issued on 19 October 2022, WaterNSW flagged that due to sustained inflows and the La Nina weather pattern, it may be necessary to increase flows again.

Significant rainfall in the range of 50-300mm fell across the Barwon-Darling catchment in the following week, causing major flooding in a number of the northern tributaries. Accordingly, in an operations update issued on 24 October 2022, WaterNSW advised that in consultation with the NSW SES, LEMC and BoM, releases from the lakes would be increased to target 9.2m on the Town Gauge. As further information came to light, WaterNSW and the response agencies began preparing the community for further increases in releases. In an operations update issued on 31 October 2022, WaterNSW advised that at least another 2,000 GL of inflows was expected to the end of the calendar year. As such, it was stated that releases would need to be increased to target 9.4m at the Town Gauge, with flows at Weir 32 expected to exceed 30,000 ML/d. There was significant uncertainty in the forecast at that time, with WaterNSW noting:

> *"We are unable to forecast exact volumes at this time as a large proportion of the upstream flows are extending over floodplains in the tributaries and along the river, with further rainfall forecast throughout the catchments. You can find the latest and most up to date forecast for the area on the Bureau of Meteorology (BOM) website."*

In the same operations update, WaterNSW advised that the LEMC was organising another community drop-in session, to be held at the Menindee Community Hall on Friday 4 November from 1-3pm. Agencies in attendance included:

- WaterNSW
- NSW SES
- Family and Community Services (FACS)
- NSW Police
- Central Darling Shire Council.

It was further noted in the update on 31 October 2022 by WaterNSW:

> *"Ongoing event planning is also considering higher than expected inflow scenarios which could potentially see the main weir gates lifted clear of the water and inflows*

passed downstream, similar to release operations from the 2011 and 2012 events. These plans aim to maintain the safety of residents and the structures, while trying to mitigate downstream impacts as much as possible."

In the operations update published on 4 November 2022, WaterNSW advised of further increases to the inflow forecast, with there being some 2,300-2,700 GL of flows expected to arrive at the lakes by the end of the calendar year. At that stage there was 192 GL of airspace in the storages, but with the Wilcannia gauge expected to peak at around 46,000 ML/d, WaterNSW advised that it would be necessary to gradually increase releases from the lakes again to target 9.6m on the Town Gauge, keeping below the Major flood level (9.7m) at that point. The aim was to create as much airspace as possible ahead of the incoming flood peak to mitigate downstream impacts as far as practicable. This would see flows at Weir 32 exceed 36,000 ML/d until at least early January 2023. On 9 November 2022, in its operational update WaterNSW advised that the airspace had increased to 206 GL, but it was noted that the flood had yet to peak at Wilcannia. To that point, more than 7,000 GL of inflows had been passed through the lakes in the calendar year, with the storages continuously above FSL since February. On 16 November 2022 WaterNSW advised that the Town Gauge had risen to 9.53m and that there was 214 GL of airspace in the lakes.

In its operations update of 23 November 2022, WaterNSW advised that the current flood was likely to peak at Bourke in the coming week. The BoM at that time was advising that the flood was likely to peak at Wilcannia in mid-December at around 11m corresponding to a flow of about 43,000 ML/d. The plan to target 9.6m was resulting in flows at Weir 32 of around 32,000 ML/d and had created some 263 GL of airspace in the lakes. A decision was taken, in consultation with DPI Fisheries and other agencies to raise all of the gates on the Main Weir to provide for fish migration:

"With the lakes continuing to create airspace, an advantageous event is currently occurring where all of the Main Weir gates have been raised, passing on current inflows downstream. The removal of these gates is allowing for the movement and migration of native fish species from the Lower Darling and Great Darling Anabranch to the Northern Barwon-Darling catchment. The gates will remain raised until higher inflows reach the storage where the gates will be reinstated to manage flows and downstream levels aligned with the operational strategy."

On 30 November 2022 the gates of the Main Weir remained lifted from the water, the Town Gauge had fallen below 9.6m and there was 296 GL of airspace in the lakes. The Main Weir gates would remain out of the water until 20 December 2022.

4.3 December 2022 to February 2023

The plan throughout the first three weeks of December continued to target a river level at the Town Gauge of 9.6m. On 7 December 2022 in its operations update WaterNSW advised that nearly 323 GL of airspace had been created in the lakes, and that the peak of the flood was at Tilpa. By the 14 December 2022 update, observations indicated that at both Weir 32 and the Town Gauge, flows in the Darling were being affected by backwater from the Talyawalka Creek. The releases from Main Weir were therefore reduced to keep the Town Gauge level to 9.6m. At that time, WaterNSW also advised:

> *"The Main Weir gates have been raised and passing on inflows since the 22nd November. Coupled with this in collaboration with DPI Fisheries, a series of fish passage baffles have been installed at the Menindee inlet regulator. The installation of these fish passage baffles and the raising of the Main Weir gates are collectively allowing for the movement and migration of native fish species throughout the storages as well as the main river and Lower Darling catchment to the Northern Barwon-Darling catchment. The Main Weir gates are likely to be raised until next week where higher inflows begin to reach the storage and the fish passage baffles will remain in until late December."*

As mentioned above, the Main Weir gates were reinstated on 20 December. It had become apparent to WaterNSW and other agencies that additional inflows were reaching the lakes system, over and above the forecast peak flows at Wilcannia. The situation was extremely uncertain which led WaterNSW to issue an operations update on 21 December 2002 in which it was stated:

> *"Observations over the past week have indicated total inflows to the Menindee Lake system are now potentially being influenced by the connectivity of the main river channel and Tallyawalka creek (sic) between Wilcannia and Menindee. This occurrence is likely contributing to unaccounted water and additional inflow to the lake's storage above the previously forecast peak inflows (43-46GL/d). As a result, WaterNSW is currently undertaking on ground monitoring to better ascertain total flows below Wilcannia to inform any potential amendments to future operating*

arrangements. Due the dynamic nature of the current flood event and the terrain on which water is passing, the quantification of the total inflows is extremely variable… The current releases are expected to continue throughout January 2023 and given variability in inflows, higher releases maybe considered if the total unaccounted inflows exceed the current forecast volumes."

Monitoring of the situation over the following days confirmed that the unaccounted inflows continued to rise. On Christmas Day, 25 December 2022, WaterNSW published an operations update in which it was stated:

"Observations since the last update on the 21st of December are indicating much higher volumes of unaccounted water are now entering the Menindee Lake system. This unique occurrence is a direct result of flows entering the Darling River and flood plain below Wilcannia being heavily influenced by inflow from the Talyawalka Creek. As a result, the additional flows are filling the available airspace within the Lake system at a rate greater than previously forecast. Total airspace has seen a reduction of some 110GL in the past 4 days period with an estimated 183GL still available in the storages today. Flows at Wilcannia are beginning to peak siting (sic) currently at 44.5GL/d, this peak is expected to continue throughout the next week."

Furthermore:

"Due to this unique connectivity of the Talyawalka Creek contributing additional flow into the Darling River below Wilcannia, inflows to the Menindee system are currently being observed at a rate greater than 70GL/d. Should this trend continue on a similar pathway over the next 5 – 14 day period, there will be insufficient airspace available in the lakes to absorb the flood peak. Should insufficient airspace be realised, adjustment to operating arrangement may result in increased releases from the storages to pass addition water once storages are full. This would inherently result in a rise to the levels observed at the Menindee town gauge."

Throughout this period, WaterNSW and the NSW SES, BoM and LEMC remained in regular contact as the situation unfolded. On 25 December 2022 the Town Gauge was still sitting at 9.6m. In its operations update of 27 December 2022, WaterNSW advised that the trend of higher volumes of unaccounted inflows was continuing to fill the storages which still had an estimated 123 GL of airspace available. WaterNSW reiterated that should the trend continue the changes to the operating arrangements would likely result in increased releases to pass

inflows when the storages are full, inherently resulting in a rise to the levels observed at the Town Gauge. As it had done in many previous updates, WaterNSW reiterated that:

> *"As the water levels continue to rise, under the State Flood Plan, the Bureau of Meteorology is responsible for providing information of river heights and flood warnings, while the State Emergency Service is the lead combat agency. You can find the latest and most up to date forecast for the area on the Bureau of Meteorology (BOM) website."*

The unaccounted inflow trend continued and on 28 December 2022, WaterNSW issued an operations update advising that the inflows to the lakes were being observed at greater than 70,000 ML/d, which was much higher than observed at the Wilcannia gauge. At that stage there was 90 GL of airspace left in the lakes, so WaterNSW notified affected landholders and residents "to prepare for further increases to the town gauge in the **coming days**."

At 1600 hours on 28 December 2022, the SES Broken Hill ICC Situation Report (Event 98/2223 SitRep 12) advised that the Menindee Town was likely to reach 10.0m from early January, which would inundate approximately 20 houses. The Watch and Act Warning for Menindee at that time was "Prepare to Evacuate". This followed door-knocking of the 15-20 houses that may be inundated. At that stage the NSW SES was planning a Town Hall meeting for the evening of 29 December 2022 in Menindee. The meeting in Menindee on 29 December went ahead. WaterNSW was unable to attend as flood operations and planning took priority for operational staff. NSW SES ran the Town Hall meeting as the lead combat agency, with advice from WaterNSW.

As the Main Weir gates were reinstated on 20 December, with inflows increasing rapidly, the Lake Wetherell storage rose from a low of 40% on 15 December to reach FSL (100%) on 27 December 2022. Lake Pamamaroo had also reached FSL again by 24 December and was being surcharged. Given the asset limitations associated with releasing water from Lakes Menindee and Cawndilla, each of these storages had been above FSL since February 2022. On 29 December 2022, WaterNSW issued two separate Flood Notifications advising in the first notification that flows would be increasing "from 35,000 Megalitres per day to 45,000 Megalitres per day" through the Main Weir by 1300 hours, and in the second notification that flows would be increasing from "45,000 Megalitres per day to 55,000 Megalitres per day" through the Main Weir by 1800 hours. The Menindee Town Gauge was at 9.82m at that time.

At 12:06pm on 30 December 2022, the SES issued an Evacuate Now Emergency Warning, which stated:

*"The NSW SES is directing people in the following area(s) to **EVACUATE NOW** due to fast rising flood waters major flooding:*

- *Irrigation Road, Menindee*
- *McInnes Road, Menindee*
- *Budgie Street, Menindee*
- *Wilcannia-Menindee Road, Menindee*
- *Pooncarie Road, Menindee*
- *Little Menindee Creek Road, Menindee (alternate access via Kinchega Road subject to weather)*
- *Pumpkin Point Road, Menindee*
- *Orchard Road, Menindee Loop Road, Menindee*
- *Racecourse Road, Menindee*

You must evacuate now because evacuation routes will be closed due to the rising flood waters."

The NSW SES Emergency Warning also advised:

"The Bureau of Meteorology advises RAPID RISES TO 10.7 METRES (ABOVE THE 1976 RECORD LEVEL) ARE EXPECTED AT MENINDEE TOWN FROM EARLY SATURDAY MORNING.

Major flooding is likely at Menindee Town during Friday morning with further rapid rises expected into Saturday.

Levels may reach 10.70 metres during Saturday morning (above the 1976 record of 10.47 metres)."

On 30 December 2022, WaterNSW issued a flood notification stating that flows would be increasing from 55,000 ML/d to 65,000 ML/d through Main Weir by 9am the following day. On 31 December 2022, WaterNSW issued a flood notification advising that flows would be increasing from 65,000 ML/d to 75,000 ML/d through Main weir by 9am. Main Weir releases peaked at 75,000 ML/d on 1 January, which was below the peak inflows to the Wetherell storage of 106,000 ML/d, meaning that the peak to peak flood mitigation provided by WaterNSW' operation of the lakes was ~29%. Rather than the BoM's peak forecast of 10.7m,

the Menindee Town gauge would instead peak at 10.26m, some 44cm lower than the BoM and NSW SES had advised was possible.

The higher releases were maintained for a period of two weeks, with WaterNSW issuing a flood notification on 13 January 2023 advising that flows through the main weir were being reduced to 65,000 ML/d that day. Main weir releases were further reduced to 62,000 ML/d on 14 January 2023, then to 59,500 ML/d on 15 January 2023, and further reduced to 57,000 ML/d on 16 January 2023. WaterNSW then advised on 17 January 2023 that flows through the Main Weir would be progressively reduced from 57,000 to 50,000 ML/d over the next few days. A flood notification on 21 January 2023 advised that flows through Main Weir would be further reduced from 50,000 ML/d to 45,000 ML/d over the coming days, followed by a flood notification on 26 January 2023 advising that main weir flows would be decreasing from 45,000 to 40,000 ML/d over the next few days.

On 29 January 2023, WaterNSW issued a flood notification advising that main weir flows would be reducing from 40,000 to 30,000 ML/d, followed by a flood notification on 1 February 2023 advising that flows through main weir would be further reduced from 30,000 to 20,000 ML/d over the next few days. The Menindee Town Gauge fell below the Major flood level of 9.7m on 1 February 2023. On 3 February 2023, WaterNSW issued a flood notification advising that flows through the main weir would be progressively reduced from 20,000 to 10,000 ML/d over the next week. The Menindee Town Gauge fell below the Moderate flood level of 9.1m on 6 February 2023, then below the Minor flood level of 8.5m at 16:00hrs on 10 February 2023.

On 17 February 2023, WaterNSW issued an operations update on the Lower Darling release plan where it advised that operations would be transitioning out of flood operations to standard operations at that time. This would mean gradually reducing the flows as part of the flood recession planning in keeping with its Work Approval requirements. WaterNSW was also working with key stakeholders, including the Murray Darling Basin Authority, Environmental Water Holders and DPI Fisheries, at that time to identify future demand targets and to address environmental and water quality requirements. WaterNSW advised that operations plans for that week were as follows:

- *"Main weir regulator gates are being closed off today*
- *Lake Menindee, Wetherell, and Pamamaroo outlet regulators to remain open to release flows into the Lower Darling River.*
- *Menindee Inlet was closed in the second week of February 2023.*

- *Weir 32 to continue to release flows into the Darling River and maintain flow of 1,100 ML/d from early to mid-March 2023 for base flow and environmental delivery.*
- *Lake Cawndilla outlet regulator to maintain flow of 1,000 ML/d for environmental delivery to Great Darling Anabranch to third week of March."*

At that stage the storages remained above full supply capacity and eventually returned to FSL on 1 March 2023.

5. Consultation

WaterNSW undertook consultation with a number of Menindee community members and key stakeholders throughout the floods of 2022/23, including other government agencies, First Nations communities, Menindee and Lower Darling communities and customers. Following the floods, WaterNSW carried out further consultation including two community drop-in feedback sessions in Menindee in June 2023 and discussions with First Nations groups and the WaterNSW Customer Advisory Group. The feedback received has been incorporated as part of this review to identify learnings and inform WaterNSW' operations and communications during future floods. Specifically, the community feedback sessions aimed to:

- Listen to concerns and insights from stakeholders and community members on the summer flood event of 2022-23 and hear recommendations on how operations and communication could occur in the future.
- Inform stakeholders and community members about WaterNSW's management of the Lake Menindee system during the floods of 2022-23.
- Deepen WaterNSW' understanding of the impacts experienced during the summer flood event of 2022-23.

The feedback received has been incorporated as part of this review to identify learnings and inform WaterNSW' operations and communications during future floods.

The drop-in feedback sessions were promoted in print media (Barrier Truth newspaper), on social media (Facebook), via email to key stakeholders and community flyers at local shops, community noticeboards and Council buildings, including the local library.

Frequently asked questions and answers were provided to attendees at the community feedback sessions and available on the website. Diagrams and maps of the affected area were displayed at the community feedback sessions to enable attendees to help inform discussions with WaterNSW on its management of the Menindee Lakes system and enable attendees to raise their concerns and recommendations about the floods of 2022-23. Attendees were encouraged to fill out a questionnaire to help WaterNSW capture feedback.

5.1 Summary of Feedback

During the community sessions, WaterNSW received feedback from a range of stakeholders. Some of the issues raised are not within the remit of WaterNSW; however, for completeness these issues have been collated below.

Table 8. Summary of community feedback provided to WaterNSW

Issue category		Feedback provided
1. Communications	a. Communication with other government agencies	• Concern raised about the established systems designed to enable government agencies to collaborate and share information during flood events. • Concern raised, government agencies lack agility to solve problems during flood events.
	b. Transparency concerns	• Concern raised about a lack of transparency in the information being provided. • Concern raised about 'surveyors' seen working in Menindee in days preceding the flood impacts; there were fears agencies knew of issues that were not being communicated; lack of trust.
	c. Timing of public communications	• Concerns raised about the timing of the public communications; many vulnerable community members (elders, restricted mobility, or people without standard communication methods) did not have sufficient time to evacuate; noting a 24-hour notice period is not enough time to act.
	d. Accuracy concerns	• Observation that operational reports were not accurate and did not incorporate real time data or align with what the community witnessed during the flood throughout the event.

Issue category		Feedback provided
	e. Recommendations	• Requests for more opportunities for cross-agency collaboration before and during emergency events, including pre-planning sessions, roundtables, and 6-weekly information sessions. • Print out newsletters including current information to be distributed around Menindee • Identify other ways to provide timely and critical information to the community. • Improve how we educate each government agency's roles and responsibilities and priorities during flood events. • More community information sessions during the event; more community feedback sessions after the event • Provide community with evidence of how feedback is being considered and acted on. • Consultation needs to be broader; everyone needs a say
2. Operation and management	f. Town water supply	• Concerns raised about quality of town water supply during flood events.
	g. Poor management's impact on recreational activities	• Concerns raised that letting go surplus water would result in minimal water in the lake and would affect the community's ability to swim in the water due to hot temperatures.
	h. Poor management's impact on environment	• Concerns raised that letting go surplus water would affect biodiversity.
	i. More water should have been released earlier	• Concerns raised that more water should have been released months earlier to create airspace to receive floodwaters later in the year.

Issue category		Feedback provided
	j. Decommissioning Lake Menindee	• Concerns raised about decommissioning the Menindee Lakes system to mine for sand minerals.
	k. Flood management plan	• Concerns about a lack of flood management plan for Menindee.
	l. Intelligence gathering	• Discussions about how to screen and incorporate local feedback into decision- making processes to supplement WaterNSW surveillance, intelligence, and data.
	m. Modelling	• Concern raised about accuracy of modelling. • Discussion about reviewing our models against this event and test for completeness. • Concern that a lack of ground truthing occurred to confirm the accuracy of models.

6. Review of Flood Operations

6.1 Effectiveness of Systems and Procedures

6.1.1 Asset Management

WaterNSW has established an Asset Management System (AMS) as required by the WaterNSW operating licence, which is audited annually by IPART. The AMS is also certified to ISO55000:2014 – Asset Management. An overview of the AMS is provided in Figure 36 below.

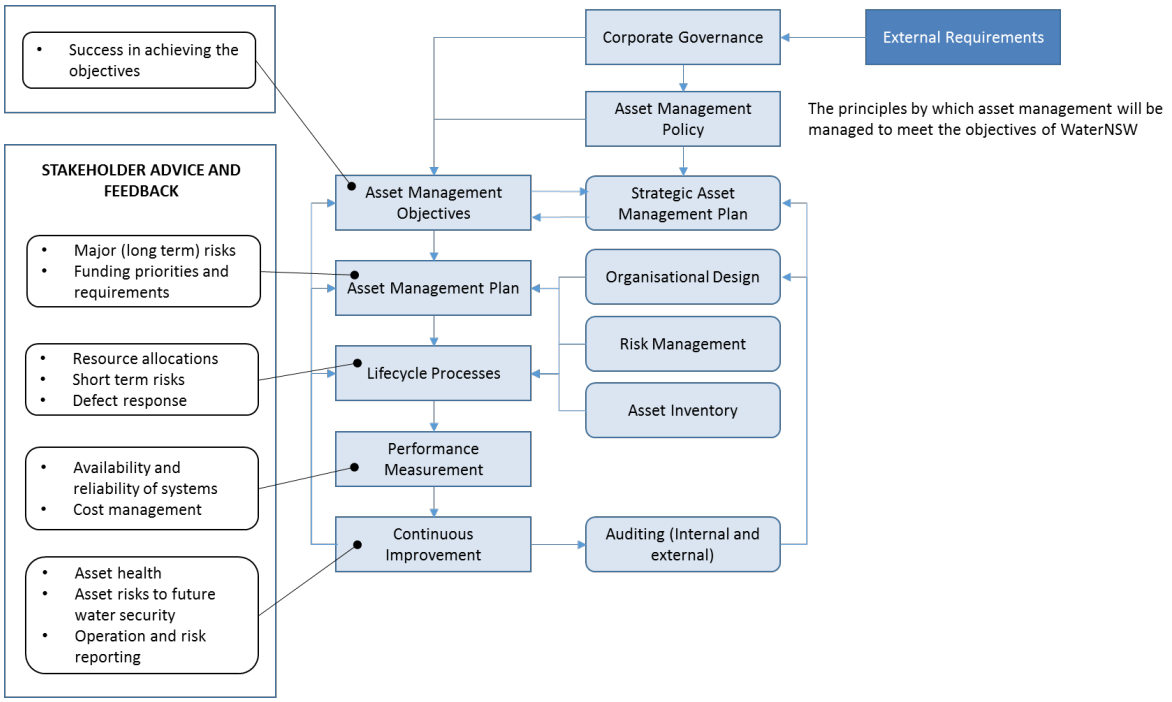


Figure 36. Overview of the WaterNSW Asset Management System

The Asset Management Plan is the specification of work, strategic or tactical, to be undertaken on or in association with the assets to meet the Asset Management Objectives. All work is undertaken with the support of an Organisational Design which is well defined and ensures suitably competent people deliver their role as required. Decisions are prioritised based on Risk Management.

The Asset Inventory is the comprehensive set of assets which must be managed in accordance with the AMS. Lifecycle Processes include the project, maintenance, and engineering (including technical integrity) processes essential for WaterNSW to ensure assets are safe and fit to deliver the required business outcomes.

Continuous Improvement (CI) is achieved as a formal process which commences with Performance Analysis and includes both internal and external Auditing. Feedback can enhance asset capability and condition, or how the organisation undertakes asset management.

The Asset Management System (as specified in the AMS Framework) is linked to other key WaterNSW processes and the associated governance, which are linked to the asset management function. These linked processes are essential requirements to ensure that WaterNSW assets remain safe and fit for purpose, and have their own policies, strategies, and methods to ensure their consistent delivery in accordance with WaterNSW business requirements. All linked processes are aligned with the principles and goals within the Asset Management Policy and are aligned with the Asset Management Objectives. Individuals with a role in their delivery must understand how their role contributes to the overall asset management approach within WaterNSW.

Asset management within WaterNSW is delivered by a combination of external processes, asset management-specialist processes and supporting processes tailored from the Business Management System. The WaterNSW AMS identifies key control documents and methods utilised by the different sections and teams across WaterNSW which can be aligned with these linked processes shown in the Asset Management Landscape. The external elements of the Asset Management Landscape define the operating environment of WaterNSW, specifying obligations the organisation must meet. Asset management is a key process enabling this outcome. As such these elements specify targets and requirements which must be met by various asset management processes such as projects or maintenance work, or contingency planning or simply competence in asset management planning.

6.1.2 Dam Safety

WaterNSW has a robust dam safety management system. This system has been designed to effectively manage the risk of dam failure throughout the life of each dam, including the Menindee Lakes storages. Dam safety is essential, not only to meet statutory obligations, but to ensure the safety of employees and communities.

Dam safety requirements are achieved through a structured program of surveillance and monitoring. WaterNSW' professional and technical staff are responsible for all aspects of dam safety including:

- Surveillance
- Investigations
- risk analysis
- planning and prioritisation
- project initiation and oversight
- regulatory compliance and reporting

WaterNSW complies with a strict set of requirements for each of the dams we manage as outlined under the NSW Dams Safety Act 2015. These include:

- proper operation and maintenance of all dams by trained personnel regular dam surveillance by trained personnel
- appropriate dam safety emergency plans for dams whose failure could cause of loss of life
- ongoing assessment of dams behaviour based on surveillance and information
- periodic review of our dams compliance with current safety requirements
- review of all dam information and assessment by experienced personnel
- responding to dam assessment with appropriate actions to ensure all dams remain safe.

Complying with dam safety requirements ensures these critical public resources continue to provide safe and reliable water delivery today, and for future generations.

6.1.3 Flood Operations

How WaterNSW operates its dams during a flood event is determined primarily by the following:

- WaterNSW Act 2014
- Operating Licence - WaterNSW may undertake flood mitigation only if authorised to do so
- Water Sharing Plan (WSP) / works approval - specifies dam operations during floods along with airspace operation rules

Along with the rules outlined above, WaterNSW has various responsibilities including adhering to best practice flood operations and the NSW State Flood Plan. The latter includes:

- Information sharing with The Bureau and NSW SES
- Where applicable, work with The Bureau and NSW SES to manage releases to reduce impacts
- Hydrometrics
- WaterNSW Flood Incident Management Protocol

In regional NSW, WaterNSW is able to act in a flood mitigation capacity. This means that it is able to release water before an event in order to create airspace for the forecast rain. During a flood event WaterNSW can then hold releases, if possible, until flood waters have receded subject to other objectives such as preserving the water resource and ensuring dam safety.

In general the flood operations objectives include:

- Ensure the safety of the structure
- End the flood with the storage at target level (Full Supply Level or a pre-release target)
- Mitigate the effect of flood where possible.

All of these requirements and how they are implemented is contained within the WaterNSW Flood Incident Management Protocol, a controlled document that is regularly reviewed to include best practice methods. Further details on flood operations protocols and procedures were provided in section 2.7 of this report which summarise the operations and maintenance procedures relevant to the Menindee Lakes.

6.1.4 Incident Management

WaterNSW maintains an Incident Management Procedure which is a guidance framework used to support the Incident Management Team (IMT) in response to a major disruptive event. The procedure is a flexible tool to assist manage an actual or potential incident, irrespective of the type of incident. The procedure provides information that will help:

- establish the IMT, drawing assistance and expertise from across the business (e.g., Operations, Safety, Finance, Risk & Compliance and Technology teams);

- support a coordinated response by all affected business units and teams, as required
- to develop and implement an appropriate incident response.

The procedure establishes:

- Incident Identification & Escalation;
- criteria for incident assessment;
- defined incident management roles and responsibilities;
- guidelines for response actions reflecting the severity and nature of the incident and the ongoing risks to the business;
- Principles and Underlying Concepts.

WaterNSW's incident management approach is aligned to the five fundamental principles of the Australian Inter-Service Incident Management System (AIIMS) 2017, which are:

- flexibility,
- management by objectives,
- functional management,
- unit of command; and
- span of control.

Table 9 sets out the AIIMS 2017 Incident Management Principles.

Table 9. AIIMS incident management principles

Flexibility

- An all-hazards approach, that enables a flexible approach to the application of AIIMS.
- The system must be able to be applied across the full spectrum of incidents, where the nature of the hazard, scale of incident, complexities presented, number involved and duration can all vary.
- A rigid application of the structures and processes may compromise the effectiveness of the response.

Management by objectives

- Consultative management process where the Incident Controller, consults with the Incident Management team, and determines the desired outcomes of the incident.
- Objectives are communicated to all involved.
- This is to ensure that all incident personnel are working towards a common goal.

Functional management

- Defined as the activity or grouping of activities that address core responsibilities of the Incident Controller.
- Functions are performed and managed by the Incident Controller.
- When required, the Incident Controller can delegate one or more of the functions.
- However, at all times, the Incident Controller still remains accountable.

Unity of Command

- Each individual should report to only one Supervisor.
- There is only one Incident Controller for any incident, directing and co-ordinating the actions of all forces, with one set of objectives.

Span of control

- The number of groups or individuals that can be successfully supervised by one person.
- A supervisory ratio 1:3 to 1:7 reporting groups or individuals is considered optimal, as this maintains a supervisor's ability to effectively task, monitor and evaluate performance.

Stages in the incident management process are outlined in Figure 37.

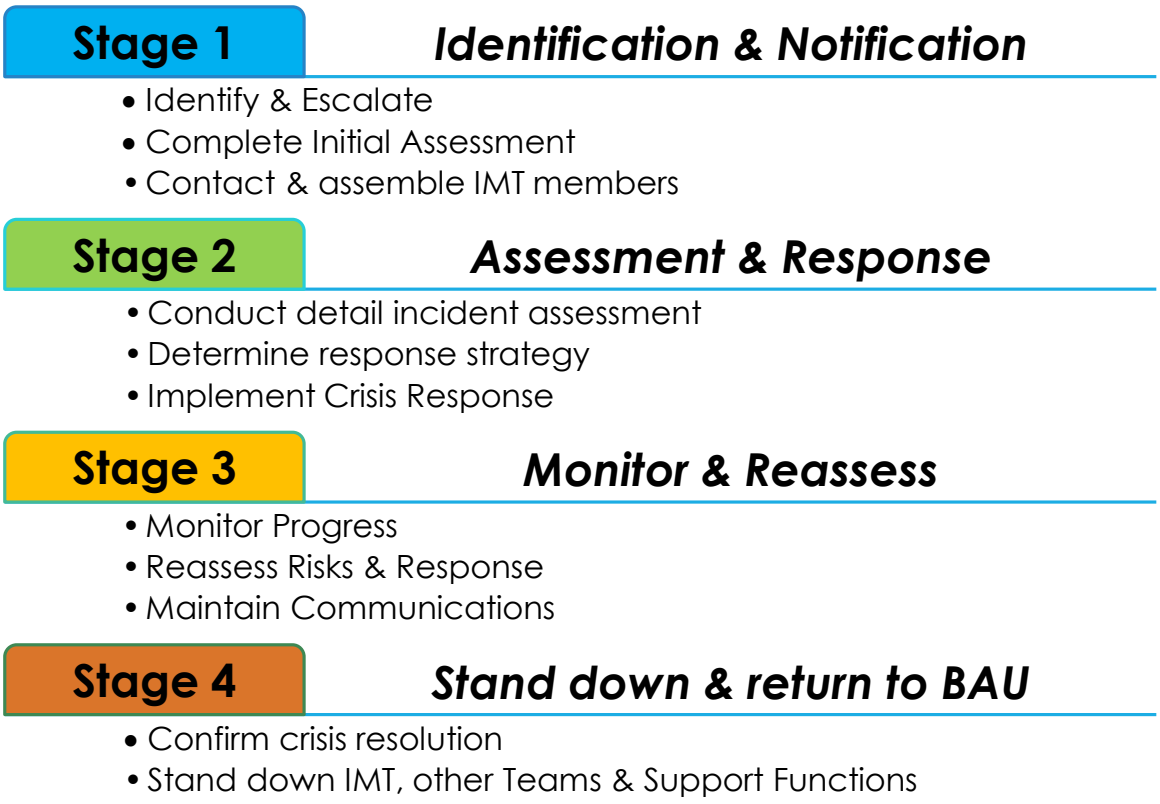


Figure 37. Stages involved in the Incident Management Process.

6.2 Flood Mitigation

The actions that WaterNSW took throughout 2022/23 supported, where possible, mitigation of the effects of flooding on the local community subject to the flood operations objectives and forecast modelling uncertainty. In any airspace or flood operations there are trade-offs that need to be evaluated and assessed relative to a range of risks and risk factors. As described in section 4, this was a constantly changing situation throughout 2022 as successive flood peaks travelled from the Northern Basin through the Barwon-Darling to the Menindee Lakes system. WaterNSW managed airspace and flood impacts on the local community throughout 2022 in consultation with the NSW SES, BOM and community members. Section 6.2.1 details the effectiveness of these actions on the flood peak experienced in December 2022 and January 2023, while section 6.2.2 retrospectively assesses these actions in comparison to two alternate hypothetical scenarios.

6.2.1 Actual versus Forecast flood peak

If focusing only on the period of December 2022 to January 2023, it is possible to evaluate the flood mitigation benefits provided by WaterNSW operations by comparing the peak inflows into Lake Wetherell with the peak releases from the storages. In effect, the peak inflows represent the magnitude of flows that would have occurred if WaterNSW simply removed the Main Weir gates from the water to pass the flows downstream.

As discussed above, on 30 December 2022, the BOM forecast that the flood peak at the Menindee Town gauge could reach 10.7 metres. As it happened, the flood ended up peaking at 10.26 metres. The difference between the forecast and actual peaks can be at least partly attributed to the WaterNSW flood operations which included surcharging of the Main Weir and Lake Wetherell. As such, the peak inflow was 106,000 ML/d but the peak release was 75,000 ML/d (Figure 38).

The flood mitigation benefit provided was a reduction in the flood peak discharge of 29.2%.

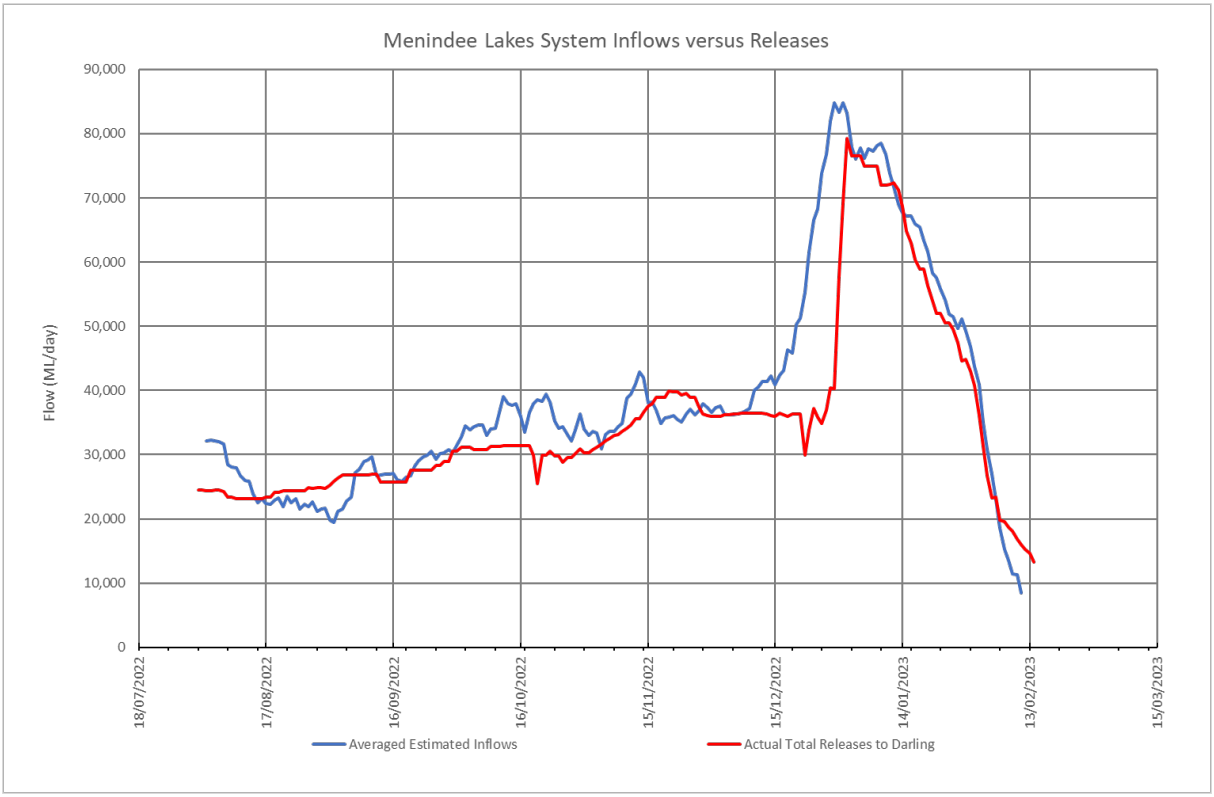


Figure 38. Time series of inflows to the Menindee Lakes versus releases, July 2022 to February 2023.

The number of dwellings that experienced over-floor flooding at the peak of the event was 27 while a further 30 dwellings had access cut-off and were isolated. In addition, the yards of 19 dwellings were also inundated. If the peak had been 10.7m, as forecast by the BOM, some 0.44m higher than the actual flood peak, data from the NSW State Emergency Service (NSW SES) estimates that the number of dwellings likely to have been impacted by over-floor flooding would have been around 55 while some 60 would have had access cut-off and become isolated. The actions of WaterNSW flood operations over the late December 2022 to early January 2023 period therefore contributed to a flood mitigation benefit for a significant number of dwellings.

6.2.2 Alternative Scenarios

During flood operations, as with any water system operations, decisions need to be made on any given day based on the best information that is available at the time. With the benefit of hindsight, it is possible to evaluate the effectiveness of those decisions (based on the available information at the time) and to test alternate hypothetical scenarios that presume certain other data or information were available (but that wasn't at the time) or could potentially be available if such a scenario were to occur in the future.

In terms of flood mitigation, two key factors affecting the benefits provided are:

(i) The amount of airspace available in the storage to capture inflow peaks; and

(ii) The timing and magnitude of releases made in relation to the inflows received into the storage.

The focus of the following analysis is the effects on the storage volumes and peak releases from the Menindee Lakes that eventuated in the summer of 2022/23. Two scenarios were tested:

1. The effects of creating increased airspace within the storages in the lead-up to the December-January flood peak.
2. The effects of optimal timing and magnitude of flood releases in the weeks leading up to the December/January flood peak.

It is stressed that these scenarios depend upon data and information that was not available at the time. See section 6.3 for further information relating to the quality and availability of water monitoring and inflow data used in decision making.

The maximum airspace scenario (Scenario 1) is a hypothetical assessment of the impacts of creating the maximum airspace that could physically be created in the lakes, noting that there are limitations on how much water can be released through the various inlet and outlet regulators. Based on these limitations, it was calculated that the maximum airspace that could have been created was equivalent to 15% corresponding to a total storage volume of 1,445 GL (Figure 39).

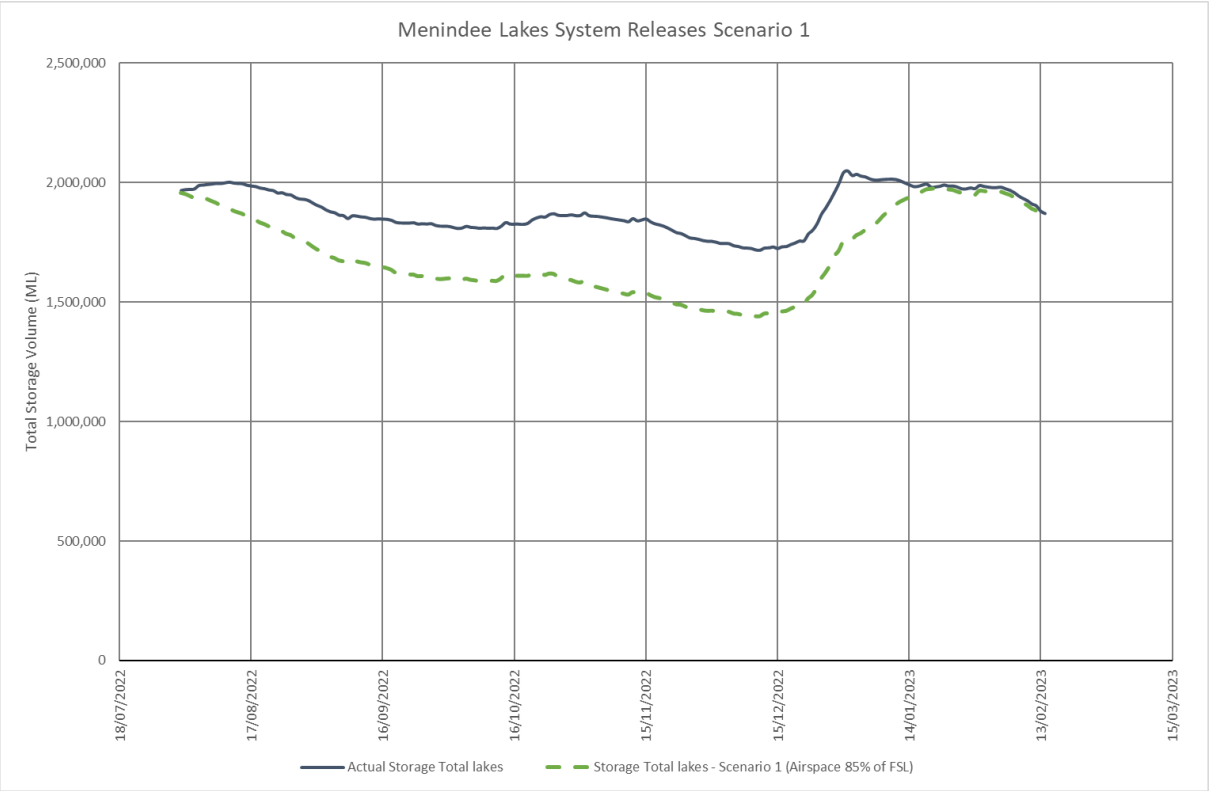


Figure 39. Hypothetical release scenario 1 showing the maximum airspace potentially achievable within the lakes.

If it is assumed that Scenario 1 was possible, if all other actions were the same as occurred in December 2022, the resultant flood operations releases could have been reduced to a peak of 64,200 ML/d as opposed to the actual peak release of 75,000 ML/d (Figure 40). There are some important caveats with the Scenario 1 analysis:

- To have created this additional airspace, releases above the Moderate flood level would have needed to be made continuously from 1 August 2022.
- This was not an option that WaterNSW could reasonably pursue at that time as the significant floods in the Northern basin in valleys such as the Namoi, Macquarie, Gwydir did not occur until at least mid-October (Section 3.5). There was no "crystal ball" available on 1 August 2022 to predict the occurrence of these floods or their likely magnitude. No reasonable operator of the Lakes would act based on the absence of this information and in any case it would not have been consistent with the Menindee Lakes operational procedures.

- Even if this information was available (no such technology or forecasting exists), it would have meant maintaining a 'man-made' Moderate flood, impacting access to a lot of properties, for five continuous months. Again, this was not a reasonable option available to WaterNSW or the response agencies.

In summary, creating increased available airspace (Scenario 1) was theoretically possible, but was never a practical option due to the uncertainty of rainfall forecasts that are not available months in advance. While Scenario 1 may have reduced the flood peak in Menindee, it would have still resulted in a Major but lower flood peak, but this cannot be considered as a viable alternative scenario.

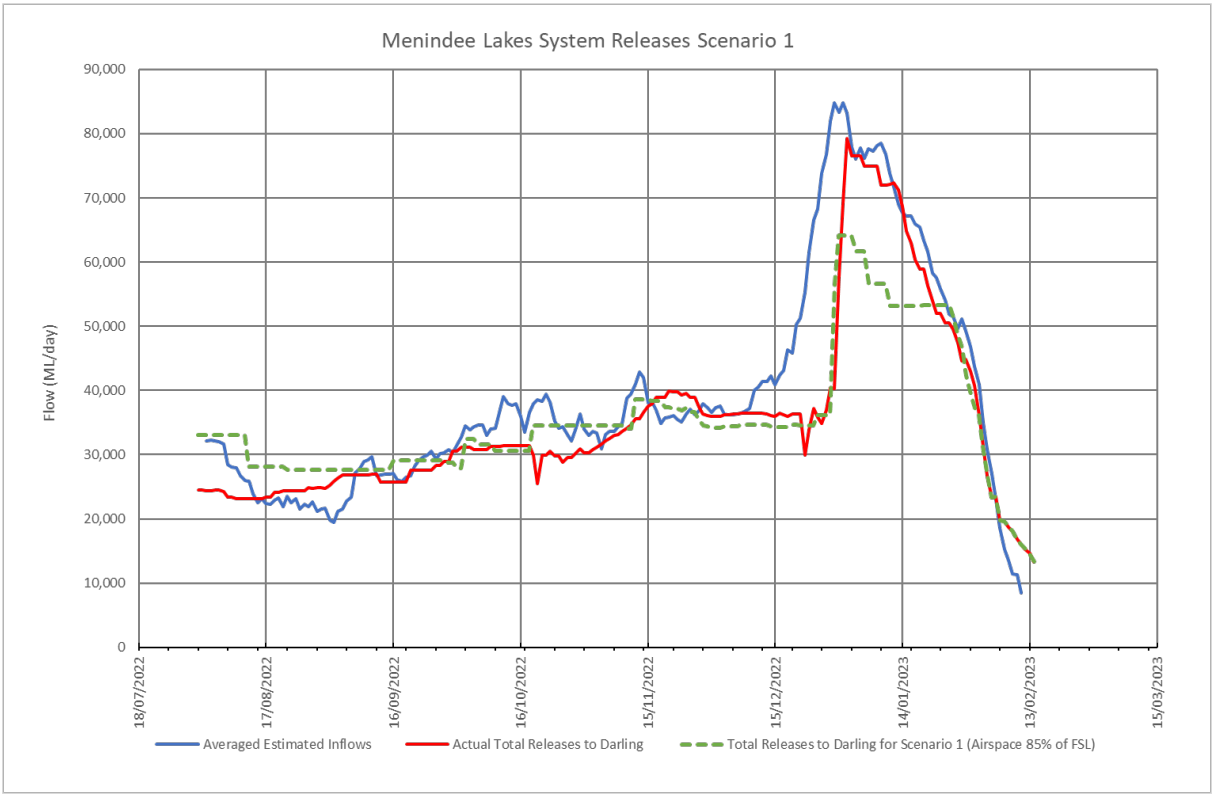


Figure 40. Hypothetical release scenario 1 showing the effects of creating maximum airspace within the lakes on potential releases versus actual releases made during 2022-23.

The second alternative scenario (Scenario 2) presumes that better information and data was available and used by operators to more aggressively make pre-releases as the flood peak approached in December 2022. In other words, all other actions were considered to be the same up until mid-December 2022. From that point incrementally higher releases were modelled to create greater airspace in Lake Wetherell (Figure 41).

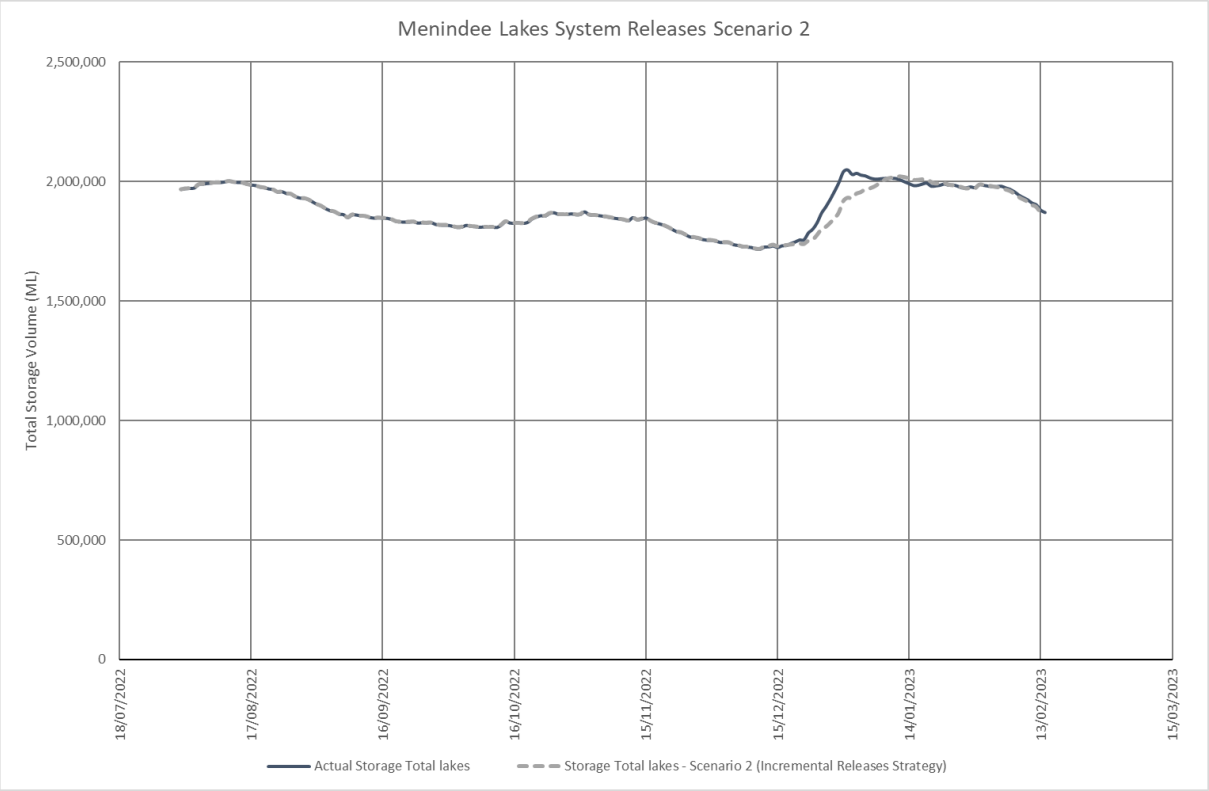


Figure 41. Hypothetical release scenario 2 showing the effect of greater releases from mid-December 2022 on airspace achievable within the lakes.

Under alternative scenario 2, it is proposed that to have reduced the eventual flood peak, higher releases above the Moderate flood level would have been required earlier, starting with increases from 15 December 2022. The resultant hydrograph (Figure 42) would have 'smoothed' the releases creating a lower overall peak of around 66,100 ML/d reducing the magnitude of the peak instantaneous discharge by 37.6%. The flood peak would likely still have been in the Major flood level, but the analysis indicates the peak would have arrived later than actually occurred (Figure 42). This alternative scenario is considered a practical option but would have been dependent upon a better understanding of the uncertainties associated with the monitoring of inflows from upstream, as discussed in section 6.3.

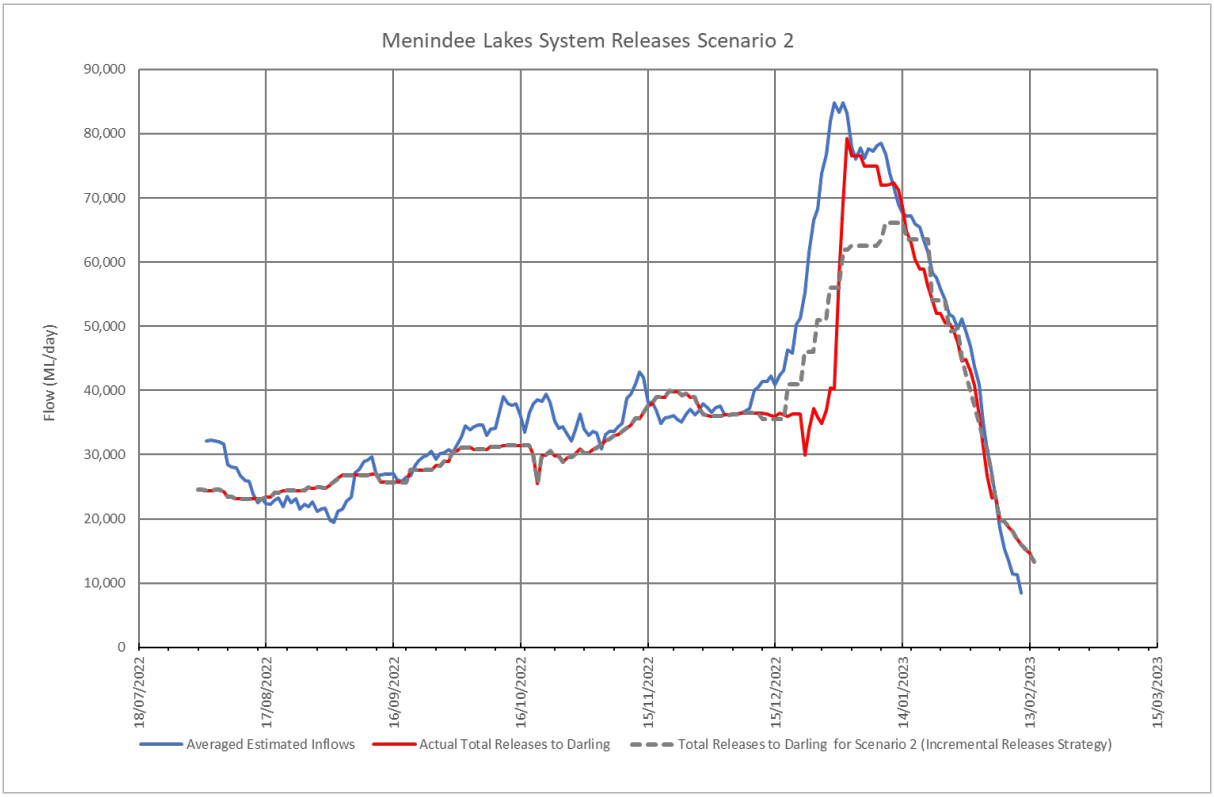


Figure 42. Hypothetical release scenario 2 showing the effects of greater pre-releases from mid-December 2022 on the potential timing and magnitude of the peak releases.

6.3 Quality and Availability of Inflow Data and Modelling

This section details the current and potential future need for water monitoring data, specifically streamflow (river gauge) data, to inform the estimation and forecasting of inflows to the Menindee Lakes storages during floods. Observations regarding the quality and availability of such data are provided, noting that this refers to the data quality or its appropriateness, rather than to water quality data which is beyond the scope of this report.

6.3.1 River Gauge Data

As outlined in section 2.4, there is a network of river gauges in the Barwon-Darling river system upstream of the Menindee Lakes storages. However, in terms of modelling inflows into the storages, i.e. into Lake Wetherell, there is in effect only two gauges currently in use capable of providing streamflow data that meets Quality Management System requirements:

- 425008 – Darling River at Wilcannia Main Channel

- 425018 – Talyawalka Creek at Barrier Highway.

A third upstream gauge exists, Darling River at Moorabin (425058), however this has been installed immediately downstream of the Wilcannia gauge in preparation for the Wilcannia weir to be moved. In terms of data on inflows into the lakes, it is effectively a duplicate of the Wilcannia Main Channel gauge (425008). During the floods, a temporary site was installed between Moorabin and Lake Wetherell, at Nelia Gaari (425060) on 3 January 2023 primarily to measure dissolved oxygen levels. It was able to provide information on water level but there is no established rating (stage to discharge relationship) meaning that streamflow data cannot yet be provided.

The limited availability of streamflow data upstream of the lakes proved problematic during the 2022/23 floods. There are several challenges with the current gauging network:

- The Talyawalka Creek gauge (425018) is situated adjacent to the Barrier Highway on the southeastern side of Wilcannia. When the Darling River is not in flood, water does not pass into the Talyawalka Creek. However, as flows rise, some Darling River water branches off into the Talyawalka Creek. During smaller floods, such as occurred in 2016, the Talyawalka gauge is representative of flows passing further down the Talyawalka Creek. However, during larger floods, as occurred in 2022/23, a lot of Talyawalka Creek flow branches out downstream of the gauging site and some of these flows rejoin the Darling River between Wilcannia and Lake Wetherell. There are currently no other gauges on the Talyawalka Creek. As such, during 2022/23 this created a high degree of uncertainty regarding how much of this flow passed down the Talyawalka Creek versus how much made its way back to the Darling and into Lake Wetherell.
- Between Wilcannia and Lake Wetherell flood runners take high flows away from the Darling across the floodplain to join the Talyawalka and/or to rejoin the river downstream of the lakes. These include Two Mile, Seven Mile and Three Mile Creeks which are located on the left bank (southeastern side) of the Darling River in that reach. There are no river gauges on any of these streams, which increases the uncertainty in estimating how much water that passes the Wilcannia and Talyawalka gauges will make it to Lake Wetherell.
- Other losses and gains are also not accounted for, including any ungauged tributaries that join the Darling in the reach between Wilcannia and Lake

Wetherell, such as Bolo Creek, or losses to some of the floodplain lakes such as the Talyawalka Lakes to the South.

If the temporary gauge at Nelia Gaari (425060) is made permanent and upgraded to included rated streamflows, this will no doubt assist in reducing some of the uncertainty. However, as depicted in Figure 43, this still leaves a lot of water unaccounted for in the landscape upstream of the Menindee Lakes.

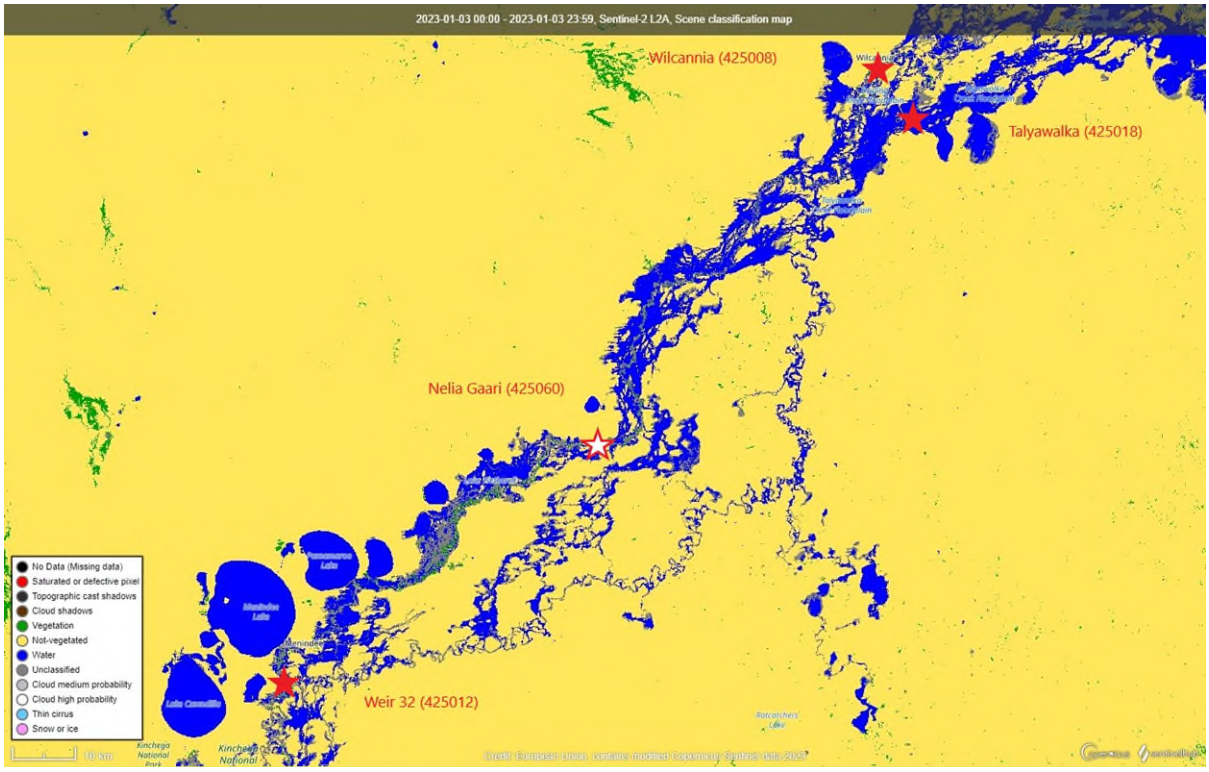


Figure 43. Sentinel land classification map based on satellite imagery taken on 3 January 2023. Closed red stars show the location of river gauging stations where flow data are available. The open red star shows the location of a temporary level-only (and DO) site.

To supplement the permanent gauge locations, WaterNSW' water monitoring teams undertook additional field measurements at various times in an attempt to quantify some of the uncertainty. This helped guide the planning of flood operations but is not considered a viable long-term solution as the measurements are effectively one-off data points and do not constitute a continuous record.

Several river gauges experienced flows beyond those previously measured which meant that the ratings were unverified and streamflow data could not be displayed. Similarly, if a site was affected by backwater from downstream tributaries, it was also not possible to show the streamflow values. To verify the accuracy of any ratings under such circumstances requires attending site and performing a gauging; however due to the widespread floods precluding access to some locations, this made such gaugings impossible at certain gauges. As a result, the ratings are turned off in these circumstances such that only the water level is displayed. The following sites were only providing level data during the peak flow periods:

- Weir 32 (425012)
- Anabranch offtake (425048 and 425050)

During their various field visits the WaterNSW water monitoring team built a better understanding of the flow paths of flood runners and the various tributary and distributary creek systems. They also spent time speaking with locals who had experienced this and previous floods to help them determine where and qualitatively how much water passed through the system. To that end, a schematic diagram was produced showing likely flow paths and highlighting the parts that were not adequately covered by the existing gauge network (Figure 44).

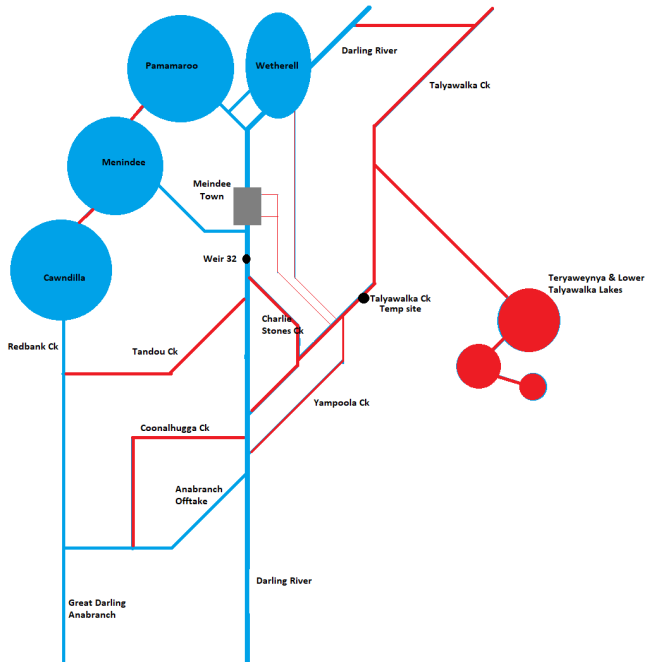


Figure 44. Schematic diagram of flow paths in the Darling River, Talyawalka Creek and Great Darling Anabranch based on field observations made during the 2022/23 floods.

6.3.2 Modelling and Forecasting Assumptions

The current design of the gauging network and subsequent uncertainties in assessing Menindee Lakes inflows had a bearing on the inflow modelling undertaken by WaterNSW. As this is a WaterNSW report, the scope of this discussion is restricted to WaterNSW' modelling and assumptions.

During the majority of 2022, WaterNSW utilised the Wilcannia gauges, including the combined main channel and Talyawalka flows (station number 425002), as a basis for estimating inflows to the storages. Certainly, at lower flows and the main channel flow (gauge 425008) correlates well with the inflows observed at Lake Wetherell. Such close correlation was also observed during the 2016 flood, as well as the flood that arrived in late 2021. As described at 6.3.1, however, at higher flows there was a high degree of uncertainty around the inflows to Lake Wetherell due to gains and losses to and from the main channel of the Darling via tributaries, flood runners, distributaries, floodplain lakes and the like.

As the peak flows began to arrive at Lake Wetherell in late December 2022, WaterNSW came to realise that the uncertainty in its inflow estimates was greater than it had accounted for in its forecasting in the lead up to the flood peak. An hourly model established that the rate of inflows being experienced greatly exceeded the Wilcannia main channel flows. Indeed the Lake Wetherell inflows in late December 2022 were closer in magnitude to the combination of Wilcannia main channel flows and Talyawalka flows at the Barrier Highway (station number 425002). As discussed in section 3.6, the 2005 DIPNR study found that peak inflows into Lake Wetherell could be estimated to be 60% of the peak combined flow at Wilcannia (station number 425002). This relationship did not hold during the 2022/23 Darling River floods as the combined Wilcannia flows peaked at 104,925 ML/d, whereas peak inflows to Lake Wetherell peaked at 106,000 ML/d.

In essence, the modelling was hindered by the limited river gauge network; a situation that will need to be rectified if more accurate quantitative estimates of inflow uncertainty are to be modelled during future high flow events.

6.4 Effectiveness of Engagement with Other Agencies

Consistent with its obligations under the State Flood Plan, Basin Agreement and water management legislation in NSW, WaterNSW sought to effectively engage with the relevant

agencies during the floods of 2022/23. WaterNSW listened to feedback from community, customers and First Nations people about the way it communicated and has reflected on how it might do this better.

6.4.1 Information sharing with other agencies

During the floods, WaterNSW coordinated and attended formal and informal meetings, briefings and corresponded with other agencies including:

- Bureau of Meteorology (BoM)
- State Emergency Service (NSW SES)
- Murray Darling Basin Authority (MDBA)
- Department of Planning and Environment – Water (DPE-W)

These agencies met regularly to share information. The frequency of these meetings varied depending on urgency and weather forecast. The meetings were an opportunity for WaterNSW to gain weather and forecasting advice from BoM, while the NSW SES provided flood emergency and on-the-ground advice. These meetings were key to providing WaterNSW with information to make operational decisions.

Frequent consultation and communication with DPE-W and MDBA was undertaken to keep those agencies abreast of operations as related to their own operations and obligations with respect to floods, water accounting, and water quality management.

6.4.2 Local Emergency Management Committee

WaterNSW participated in The Local Emergency Management Committee (LEMC). The committee is responsible for the prevention of, preparation for, response to and recovery from emergencies and disasters within the Central Darling local government area (LGA). These responsibilities include activities such as the development of emergency management plans, emergency risk management, multi-agency training and exercises, and supporting combat agency public education programs.

The LEMC membership includes local representatives from NSW Police, NSW Rural Fire Service, State Emergency Service, Fire and Rescue NSW and other support agencies. The Chair of the LEMC is a Council appointed staff member (General Manager) who also sits on the Regional Emergency Management Committee.

6.4.3 Summary

The floods occurred over an extended time period, during which there was frequent and appropriate sharing of information between agencies. WaterNSW attended more than 200 meetings with other agencies including the BOM, NSW SES, MDBA and the LEMC between April 2022 and February 2023. In summary, WaterNSW sought to engage effectively with the other agencies throughout the floods, consistent with its obligations.

6.5 Effectiveness of Engagement with the Local Community

WaterNSW is an organisation that is embedded in the Menindee community employing more locals than any other water agency. It has multiple staff that grew up in the local community and who have spent their entire working lives in Menindee. These staff were affected by the floods, as were other community members.

Effective engagement with the local community in Menindee should take into account complicating factors including:

- The complexity of water management in NSW and the Murray Darling Basin
- The changing roles of water agencies over recent decades, which can be different relative to previous floods
- The differing roles of water agencies and combat agencies during non-flood versus flood situations
- The representativeness, or otherwise, of diverse community groups in customer advisory forums
- Community members' access to various forms of communication and/or preference for certain types of communication.

That said, the following forms of communication were utilised by WaterNSW in communicating with the local community during the floods.

6.5.1 Murray-Lower Darling Customer Advisory Group

Customer Advisory Groups are the primary forum for WaterNSW to regularly consult, on an area basis, with a broad cross-section of its customers. These meetings cover issues relevant to the performance of WaterNSW's obligations to customers under the WaterNSW Operating Licence or WaterNSW Customer Service Charter.

Membership may include WaterNSW customers from the regulated and unregulated streams, groundwater irrigators, stock and domestic water users, major water utilities, local water utilities, local government, environmental water users and Aboriginal Cultural Heritage water users. Further information on the CAGs can be found at this link.

During the course of the 2022 Darling River flood events, the Murray-Lower Darling CAG met twice, on 20 July 2022 and 2 November 2022. The current membership of the Murray-Lower Darling CAG consists of representatives from:

- West Corurgan Private Irrigation District
- Western Murray Irrigation Limited
- Wakool System Advisory Group
- Murray Valley Private Diverters
- Murray Irrigation Limited
- South West Water Users
- Ricegrowers' Association of Australia
- Lower Edward River Landholders
- Lower Darling Pastoralist Group
- NSW Environment and Heritage Group (DPE)
- Commonwealth Environmental Water Office

6.5.2 Airspace and River Operations Stakeholder Consultation Committee meetings

Airspace Reference Panels and River Operations Stakeholder Consultation Committee (ROSCCo) meetings are two forums that WaterNSW utilises to engage with local stakeholders

on its operations. When regional storage dams that have control gates are at risk of spilling, WaterNSW sets up Airspace Reference Panels to consult with downstream stakeholders. These stakeholders and WaterNSW consult on the necessity, timing, and circumstances for controlled releases of water and how that might affect communities downstream. Issues discussed include water irrigation and environment demands and targets, river constraints, and other local water related issues. At these meetings, WaterNSW provides various options in terms of target airspace and dam release patterns. The role of the panel is to examine trade-offs with each of the options for management and provide advice to WaterNSW on the preferred options for management of the particular flood event.

ROSCCo meetings provide a similar function whereby WaterNSW consults with relevant stakeholders about its current and planned operations. These committees, however, generally operate outside of floods meaning that the airspace reference panels are more relevant to flood operations. Both reference panels and ROSCCos are open to any interested stakeholders, while the customer advisory groups have a set membership.

A summary of relevant customer forums held during the 2022 Darling River flood events is provided in Table 10.

Table 10. Summary of key external meetings held 1 April 2022 to 21 February 2023

Customer and Stakeholder Meetings	**No.**
Menindee Lakes - Airspace Meetings	1
Lower Darling ROSCCo Meetings	1
Murray ROSCCo Meetings	1
Murray-Lower Darling Customer Advisory Group (CAG) meetings	2

6.5.3 Local Community Meetings

Throughout 2022 as the situation changed, WaterNSW convened and/or participated in with other government agencies, a number of local community town hall and drop-in sessions. The format of these sessions was the provision of information by WaterNSW with an opportunity for

community members to ask questions, raise concerns or to provide WaterNSW and other agencies with feedback or local information that could assist in the operation of the lakes and the emergency response. The following meetings were attended by WaterNSW:

- 18 January 2022 – Pooncarie
- 19 January 2022 – Menindee
- 8 June 2022 – Menindee
- 4 November 2022 – Menindee

6.5.4 Stakeholder Communications

WaterNSW provides operational information and data via a website called WaterInsights. WaterInsights provides in one place, comprehensive information about how water is managed and shared in NSW, presented in a way that is both transparent and easy to understand. The aim is to help customers and stakeholders to make more informed decisions and to help communities to be better informed. It shows what water is present in storages and aquifers, what is allocated to licences, what has been used and what is available for use, the purposes for which water is used, the prices and volumes of water trading, our operational plans and the rules by which water is managed.

Throughout the floods of 2022/23, access to near real-time data was provided via WaterInsights, along with regular operational updates that outlined WaterNSW' current and planned operations at Menindee Lakes and the Lower Darling regulated river system. Users are encouraged to register for WaterInsights, which allows them to subscribe to notifications, including operational updates.

In addition, WaterNSW provided regular updates to community via other forms of communication including:

- Regular Media Releases and media interviews
- WaterNSW Social Media – Facebook and Twitter accounts
- Early Warning Network (EWN) notifications - WaterNSW has an automated notification system, the Early Warning Network (EWN) that alerts people who register to dam

activities. When you register, you nominate the dam(s) you are interested in, and to receive notifications of a significant dam release and/or an emergency situation.

- Daily emails - distribution of daily Menindee Lakes operational data and information to an extensive internal/external email list. This email list is to be replaced by WaterInsights but was maintained throughout the floods to maintain continuity.
- Community updates –distributed via electronic direct mail to customers and community members and published on the WaterNSW website.

6.5.5 Community Feedback on Engagement

Section 5 outlined community feedback provided to WaterNSW at various community meetings and drop-in sessions, including post-flood. Other direct feedback was also provided by Customer Advisory Group members and customers who contacted WaterNSW. Overall, despite the communication provided by WaterNSW, a number of people within the community believe that engagement during the floods was not effective. Examples of feedback included:

- In previous floods, the 'Department' would provide regular updates on the flood conditions occurring throughout the Barwon-Darling, including its forecasts of possible flood conditions that may occur at Menindee and other locations in the Lower Darling.
- Locals expressed that the BoM flood updates were inadequate in comparison to the lengthy updates provided by 'the Department' in previous floods. Similar concerns were raised about WaterNSW' operational updates.
- A further concern raised by Lower Darling stakeholders was that the BoM only issues flood warnings for certain locations, such as townships, leaving floodplain landowners between towns without adequate information to assess the potential impacts on their properties.

During the 2022/23 floods, WaterNSW operated within its scope directed by the State Flood Plan which restricted WaterNSW communications largely to inflows to the lakes and likely releases, as it does elsewhere throughout the state.

The Bureau of Meteorology is responsible for providing flood forecasts, issuing flood alerts and flood warnings. The BoM worked closely with WaterNSW to forecast the flows in the system and provided timely and regular updates on its website throughout the floods. These changing roles were not well understood by the community at large, who in some instances believed, incorrectly, that WaterNSW was responsible for all flood communications.

- Some locals gave feedback that they do not feel adequately listened to by government agencies. Some themes include:
    - An impression that agencies involved in water management do not provide a coordinated response or communication with locals. Some felt that each agency, such as WaterNSW, NSW SES or MDBA would meet with locals separately but not together as a group to solve issues or discuss matters with locals.
    - Many locals with a long history and experience being connected to the river, including First Nations communities, believe their views are not being heard or incorporated into operational decision making.
    - There is a general lack of trust in government following multiple visits by public officials and politicians over a long period. Locals expressed that they have spoken to many officials and politicians following fish deaths, drought and now floods, with promises made but to date there is a belief that nothing has changed.
- Another theme is that while there is a move towards greater online communication some in the community do not have access to the internet via computers or smartphones.
    - During the floods, some community members needed to be told to evacuate from their houses face to face.

Appendix A - Historic Events

Past Flood Events

The Barwon and Darling Rivers experience infrequent large flood events. A record of peak flood heights at Bourke and Louth was presented in respective Floodplain Risk Management Studies (Bourke Shire Council). Tables 11 and 12 present the peak water levels at Bourke and Louth from these studies. At both locations, floods in 1890, 1976 and 1974 were in the top four events.

Peak water levels in the recent event were 13.43m at Louth and 13.95m at Bourke. These levels were higher than 2012 at Bourke and less than the 5% Annual Exceedance Probability (AEP)[6]; and at Louth around the 5% AEP event.

High flow periods over the last 50 years at Bourke, Louth and Wilcannia are presented in Figures 45, 46 and 47. High flow periods are taken as continuous days when flow exceeds 50,000 ML/d, 40,000 ML/d and 30,000 ML/d at Bourke, Louth and Wilcannia, respectively.

At Bourke, there have been nine periods where flow exceeded 100,000 ML/d and four periods where flow exceeded 200,000 ML/d. At all three locations, the 1974, 1976, 1983, 1998, 2012 and 2022 events were consistently large when considering peak flow, volume and duration.

Table 11 presents duration, peak flow and volume of water for these events from these stream gauges.

Table 11. Flood history and design flood levels - Bourke Stream Gauge

[6] Annual Exceedance Probability (AEP) for an event refers to the chance of an event occurring. For example, a 1% AEP event has a 1% chance of being equalled or exceeded in any one year.

Flood Event	Gauge Height (m)	Elevation[7] (m AHD)	Peak Flow (ML/d)
Extreme	15.96	107.81	1,684,800
0.2% AEP	14.7	106.55	924,480
March 1864	14.52	106.37	
0.5% AEP	14.5	106.35	699,840
April 1890	14.39	106.24	572,746
1% AEP	14.38	106.23	561,600
2% AEP	14.26	106.11	432,000
March 1976	14.18	106.03	504,662
January 1974	14.1	105.95	449,107
5% AEP	14.04	105.89	263,520
August 1950	13.93	105.78	375,494
March 2012	13.83	105.68	180,749
September 1998	13.78	105.63	233,366
March 1956	13.75	105.6	298,858
July 1893	13.68	105.53	278,208
March 1971	13.64	105.49	221,443

[7] Gauge zero on the Bourke stream gauge = RL 91.85m AHD

10% AEP	13.51	105.36	146,880
Major	12.7	104.55	
Moderate	11.4	103.25	
Minor	9.5	92.35	

Table 12. Flood history and design flood levels - Louth Stream Gauge

Flood Event	Gauge Height (m)	Elevation (m AHD)	Peak Flow ML/d
Extreme Flood	16.41	98.87	3,542,400
0.2% AEP	15.03	97.49	1,684,800
0.5% AEP	14.40	96.86	1,036,800
1% AEP	14.05	96.51	708,480
1890	13.94	96.40	661,651
2% AEP	13.77	96.23	475,200
1976	13.76	96.22	490,752
1974	13.65	96.11	413,251
1956	13.54	96.00	325,469
5% AEP	13.41	95.87	267,840
2012	13.36	95.82	218,506
1921	13.36	95.82	216,000
1971	13.28	95.74	197,338

1998	13.24	95.70	187,834
1920	13.10	95.56	159,581
1983	13.07	95.53	154,397
10% AEP	13.05	95.51	159,840
1893	12.95	95.41	133,834
1990	12.84	95.30	114,912
1988	12.43	94.89	86,918
1955	12.40	94.86	87,696
2011	12.35	94.81	83,635
1891	12.26	94.72	79,574

Table 13. Duration, peak flow and volume at Bourke, Louth and Wilcannia for Events[8] over last 50 years

	Darling River at Bourke (Gauge 425003)	**Darling River at Louth (Gauge 425004)**	**Darling River at Wilcannia (Gauge 425008)**
1976			
Duration (days)	60	70	87
Peak (GL/d)	500	360	68

[8] event defined as a continuous period when flow exceeded reference flow

Volume (GL)	12,500	12,200	4,500
1974			
Duration (days)	36	46	54
Peak (GL/d)	440	330	50
Volume (GL)	7,000	6,500	2,300
1998			
Duration (days)	74	Missing data	71
Peak (GL/d)	230	210	45
Volume (GL)	8,200	Missing data	2,800
2022 (Oct-Dec)			
Duration (days)	79	98	81
Peak (GL/d)	200	200	45
Volume (GL)	9,200	9,500	3,000
1983			
Duration (days)	64	72	73
Peak (GL/d)	160	165	42
Volume (GL)	6,100	6,500	2,900
2012 (Feb – Mar)			
Duration (days)	32	37	36
Peak (GL/d)	180	145	37

Volume (GL)	3,600	3,600	1,300

Darling River at Bourke

Table 14. Continuous Periods when flow at Bourke above 50,000ML/d (ranked by peak flow)

Date start	Date End	Peak flow (GL/d)	Total flow (GL)
15/02/1976	14/04/1976	501	12484
20/01/1974	24/02/1974	444	7026
17/08/1998	29/10/1998	231	8175
8/10/2022	25/12/2022	203	9186
23/02/2012	25/03/2012	180	3628
7/06/1983	9/08/1983	160	6055
28/04/1990	5/06/1990	137	3568
7/05/1988	5/06/1988	104	2462
27/08/1984	24/09/1984	101	2370
27/12/2010	4/03/2011	88	4776
17/02/1996	7/03/1996	80	1375
12/12/2000	1/01/2001	76	1381
3/01/2022	25/01/2022	74	1480
28/12/2011	22/01/2012	73	1676

4/09/1990	23/09/1990	70	1244
13/06/1977	30/06/1977	65	1076
31/03/1977	10/04/1977	58	604

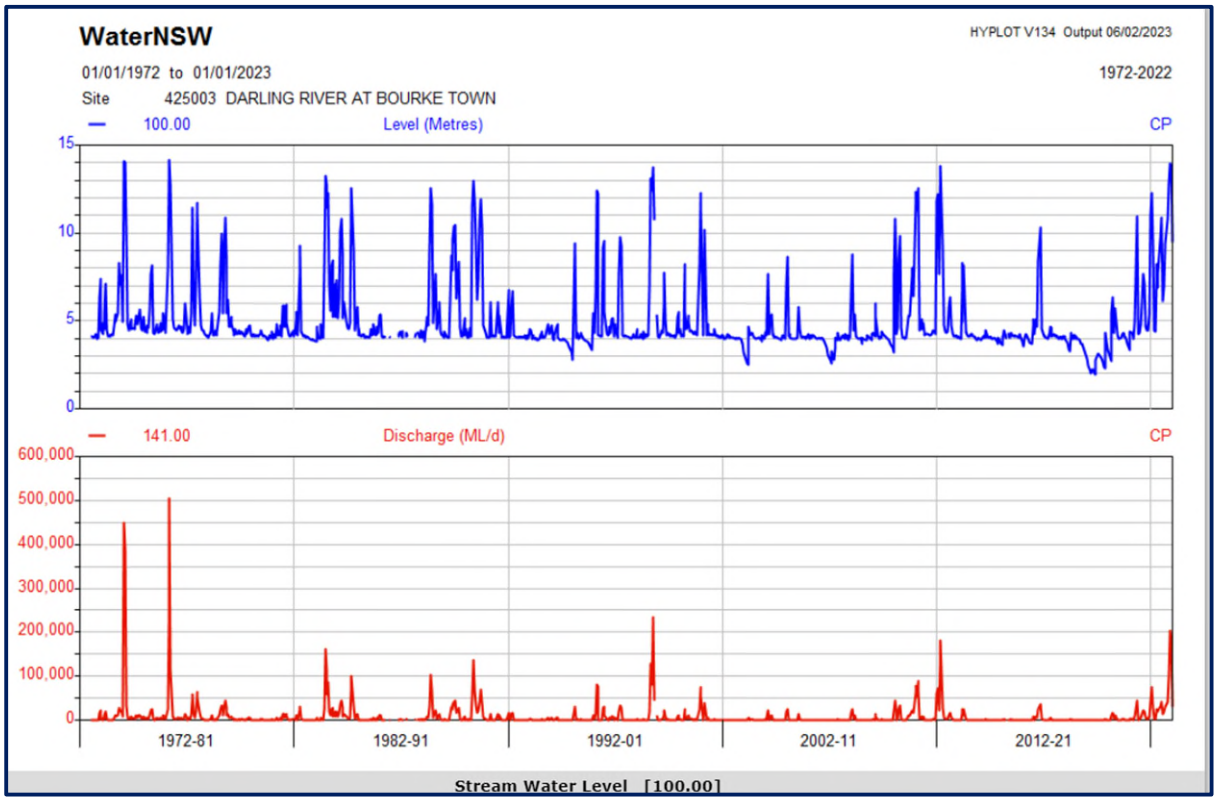


Figure 45. Time series of river level and discharge for the Bourke gauge (425003) over the past 50 years.

Darling River at Louth

Table 15. Continuous Periods when flow at Louth above 40,000ML/d since 1972 (ranked by peak flow)

Date Start	Date End	Peak flow (GL/d)	Total flow (GL)
18/02/1976	27/04/1976	360	12172
26/01/1974	12/03/1974	327	6526
1998		Missing data	
1/10/2022	6/01/2023	195	9530
13/06/1983	23/08/1983	165	6528
1/03/2012	6/04/2012	145	3559
4/01/2011	14/03/2011	83	4751
6/01/2012	3/02/2012	70	1703
16/06/1977	15/07/1977	68	1730
10/01/2022	5/02/2022	67	1560
26/02/1996	16/03/1996	63	1098
2/04/1977	24/04/1977	63	1191

21/12/2000	10/01/2001	62	1148
15/10/1978	4/11/1978	52	993
24/06/2022	10/07/2022	44	722

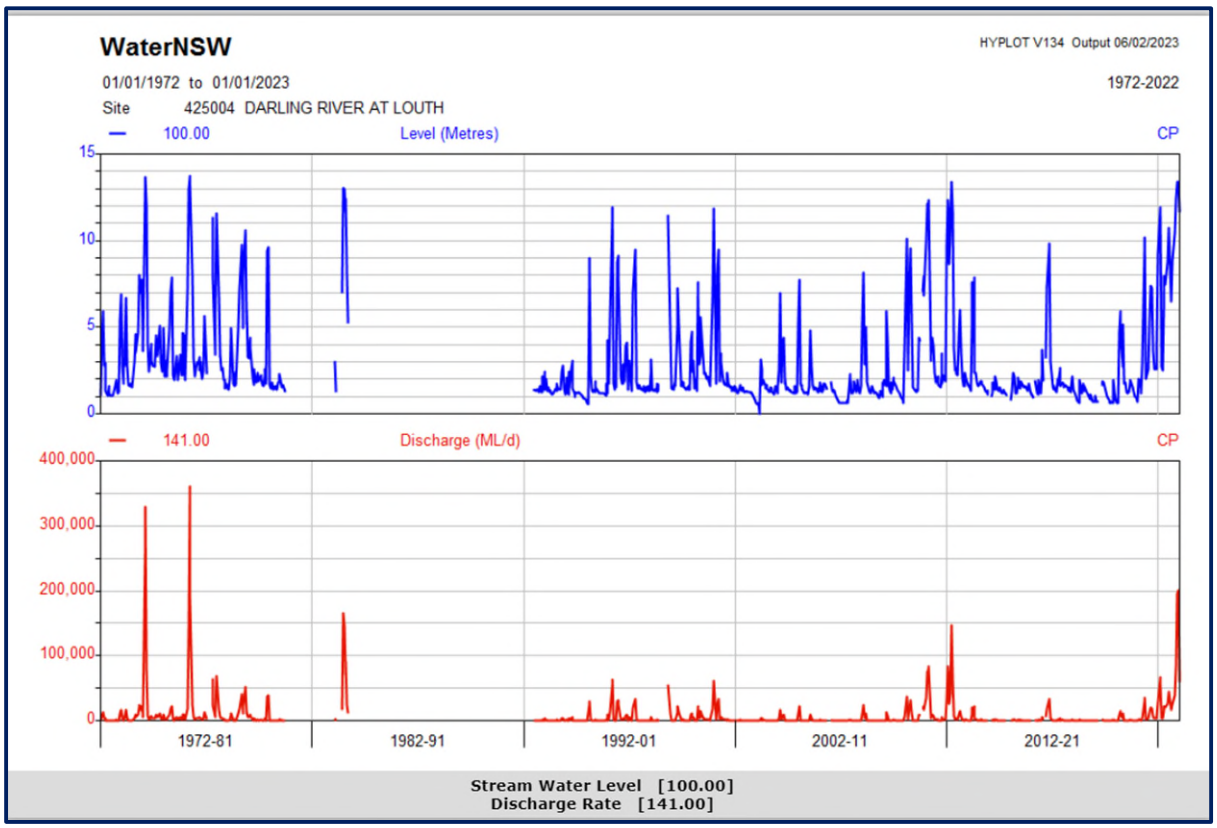


Figure 46. Time series of river level and discharge for the Louth gauge (425004) over the past 50 years.

Darling River at Wilcannia

*Table 16. Continuous Periods when flow at Wilcannia above 30,*000 ML/d (ranked by volume)

Date Start	Date End	Peak flow (GL/d)	Total flow (GL)
22/02/1976	18/05/1976	68	4462
16/05/1990	9/08/1990	48	3410
1/11/2022	20/01/2023	45	3063
26/06/1983	6/09/1983	42	2879
14/09/1998	23/11/1998	43	2783
5/02/1974	30/03/1974	51	2302
3/02/2011	27/03/2011	35	1804
4/09/1990	24/10/1990	34	1722
19/06/1989	4/08/1989	34	1606
10/09/1984	21/10/1984	38	1508
25/05/1988	29/06/1988	37	1312
18/03/2012	22/04/2012	37	1298
30/06/1977	28/07/1977	33	993
20/03/1984	14/04/1984	33	897
21/04/1977	4/05/1977	31	492
31/10/1978	13/11/1978	31	490
18/03/1996	24/03/1996	31	276

16/01/2001	19/01/2001	30	181

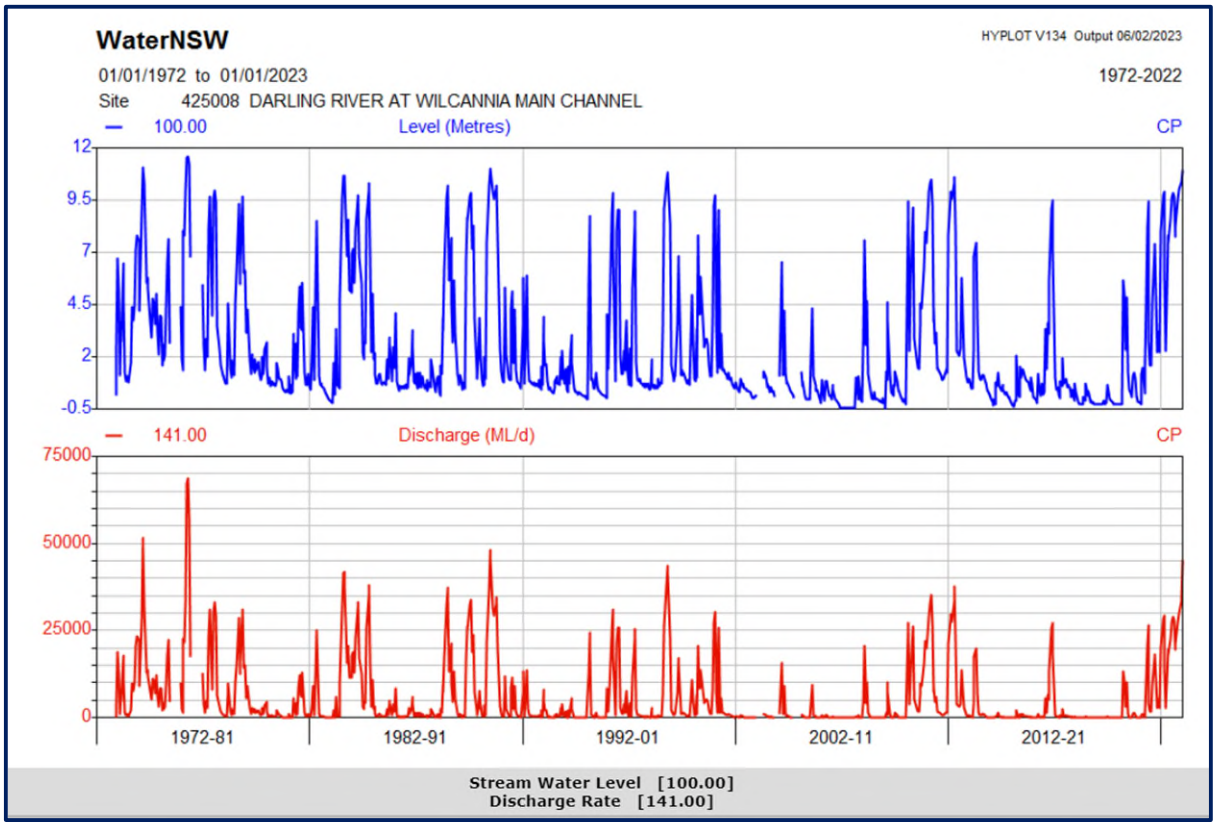


Figure 47. Time series of river level and discharge for the Wilcannia gauge (425008) over the past 50 years.

Appendix B - Water Monitoring Activities

Water Monitoring during the event

The river level monitoring network was useful for understanding water movement though the Northern Basin and assisted operational decisions to be made based on real-time developments.

Over the course of the evolving flood operations, the WaterNSW Water Monitoring team increased their servicing of the existing network, as well as identifying additional locations that could assist operational management with increased data collection.

During the period November 2022 until mid-January 2023, the team were highly responsive and adaptive in their approach to the emerging events, increasing the amount of information coming from the area to support decision making through:

- An additional 155 site visits and activities undertaken in addition to routine work including:
    - Data collected from sites, as access allowed with widespread road closures:
        - Additional flow gaugings for instantaneous discharge checks in a variety of locations for on ground understanding of the dynamics of the event
        - Installation and maintenance of a temporary site between Wilcannia and Lake Wetherell – Nelia Gaarie (425060)
        - Installation of stand-alone level monitoring instruments (Rugged Trolls) to capture flood information for post-analysis.
    - Additional visits across the regular network
        - Flow gaugings at a higher frequency and on demand from the Incident Management Team, targeting flows not previously measured to increase confidence in the information
    - Additional tasks:
        - Installation of gauge posts at new sites
        - Surveying gauge ranges to confirm accuracy
        - Cross sectional profiling to estimate relative channel capacity and predict flows.

- Instrument management
    - Repairs - Cawndilla Outlet. This site suffered a complete failure and required a full refit
    - Upgrades of sensors and loggers
    - Orifice extensions for high water
- Data recording
    - Increasing level logger call-in frequencies to 15 minutes for key sites
    - Alerts applied to threshold levels
- Rating Table management – updating the water level to flow relationship tables based on observed measurements affected by:
    - Record high flows, meaning flow rating tables required extension
    - New flow measurements triggering flow rating table adjustments to ensure flow data published was accurate as quickly as possible.
    - Active data management to minimise incorrect data being presented to the public
    - Creation of a new theoretical rating table for Three Mile Offtake at sheet pile
    - Managing the effects of vegetation growth changes to the level/flow relationship from previous events. This is dynamic and continues to change as vegetation holds water back, catches debris, collapses and then breaks down. This changes the relationship between level and flow, and drives a need for increased check measurements and flow rating table changes
- Quality Assurance and Quality Control QA/QC)
    - Water monitoring in WaterNSW is externally certified under ISO9001:2015
    - All site visits and activities are undertaken in accordance with AS and ISO standards, WaterNSW Quality Assurance procedures and the Bureau of Meteorology National Industry Guidelines for Hydrometric Monitoring
    - Recommendations for changes to rating table relationships were peer reviewed according to the Quality Management System standards

See Tables 17 & 18 and Figure 48 for details of the frequency and location of these activities.

Table 17. Breakdown of activities undertaken between November 2022 - mid-January 2023

Activity	Sites/locations
155 x discreet flood related data collection activities	33 x locations - 26 established sites - 7 new ad-hoc locations
58 x gaugings	26 x locations - 19 established sites - 7 new ad-hoc locations
35 x surveys of water level and gauge posts	15 x locations
41 x maintenance site visits	19 x sites
21 x ad hoc instrument and gauge installation, repairs and reactive maintenance activities	14 x locations
multiple rating table adjustments, including STOP ratings	6 x sites

Table 18. Number of visits and activities undertaken at each site between November 2022 and mid-January 2023

Site	No. Visits / Tasks Undertaken
Talyawalka Creek @ Barrier Highway	12
Darling River @ Wilcannia	11
Darling River @ Menindee Town	9
Darling River DS Main Weir	9
Darling River US Main Weir	9
Three Mile Ck @ Regulator	8
Darling River @ Lakes Wetherell + Tandure Total Storage	7
GDA @ Wycot	7
Redbank Creek @ Packers Crossing	7
Darling River @ Nelia Gaari/Weinteriga/Viewmont	7
Cawndilla Outlet	6
Darling River @ Lake Pamamaroo Storage Gauge	6
Darling River @ Moorabin	6
Murray River @ Wentworth	5
Darling River @ Burtundy	4
Darling River @ Lake Menindee Storage Gauge	4
Lake Cawndilla Storage Gauge	4

Site	No. Visits / Tasks Undertaken
Darling River @ GDA Offtake	3
GDA @ Bulpunga	3
GDA @ Bunnerungee Bridge	3
GDA DS Dam 183	3
Lake Menindee Outlet Regulator	3
Talyawalka Creek @ Ivanhoe Rd	3
Brewers Creek	2
Darling River @ Pooncarie	2
GDA @ Offtake	2
GDA @ Tara Downs	2
Inlet channel at Lake Menindee	2
GDA US Dam 183	1
Inlet channel at Lake Pamamaroo	1
Murray River @ Wentworth	1
Talyawalka Creek @ Kangaroo Waterholes/ Billilla Station	1
Talyawalka Creek @ Windalle	1
Two Mile Creek	1
Grand Total	**155**

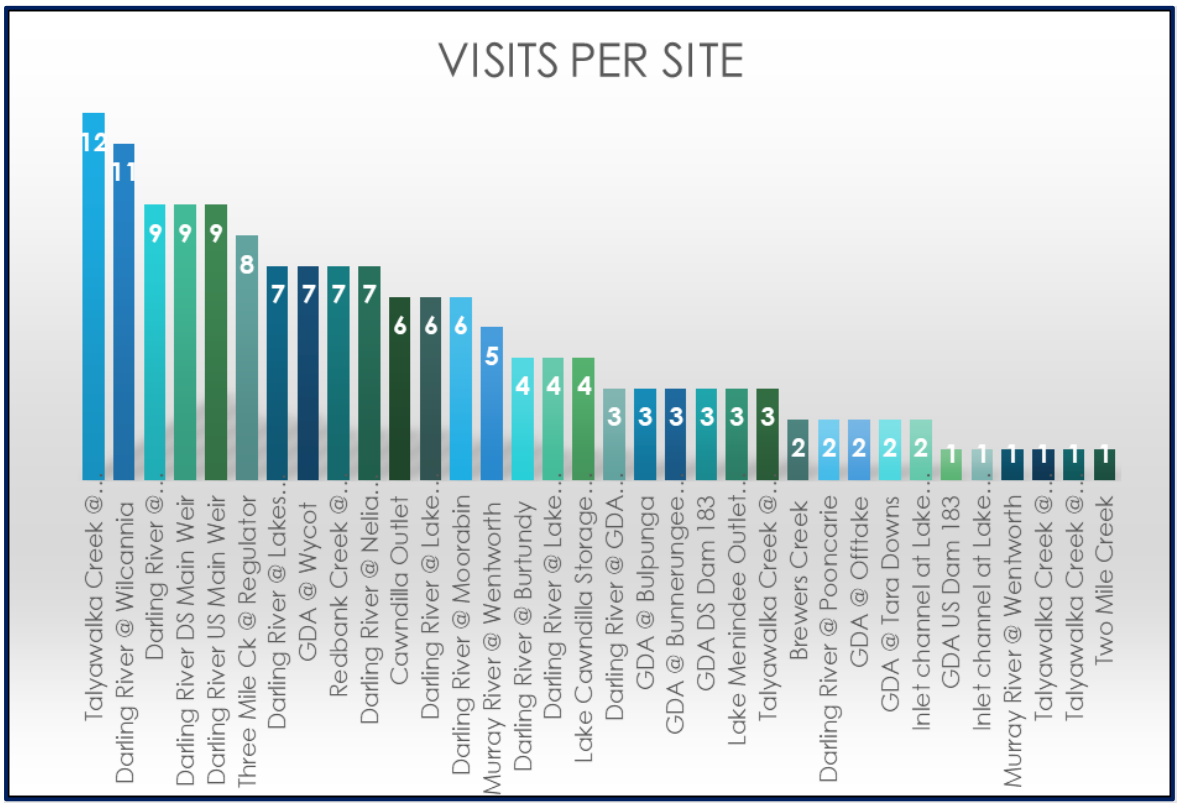


Figure 48. Number of visits and activities undertaken at each site between November 2022 and mid-January 2023

Appendix C – Floodplain satellite images