2023 Menindee Mass Fish Kill: How it happened.

A desktop investigation unravelling the operational decisions that preceded the death of 20 million fish

by Megan Williams and Dan Schulz

Acknowledgments

The authors acknowledge that these events took place on Barkindji Country and that the land and waterways of Far Western NSW always was and always will be Aboriginal. We acknowledge the Barkindji struggle for land and water rights and the impact that mass fish kills have on this community, spiritually and culturally. We acknowledge Barkindji Elders, past and present.

The authors would like to acknowledge the broader Menindee community for their ongoing courage during the disastrous 2023 March fish kills, as well as the valuable conversations the authors had with community members during these events, and over many years.

In particular we would like to acknowledge Menindee resident Geoff Looney of Menindee NSW Outback Photography for the valuable contribution his on-the-ground photographs made to this report.

This investigation is the result of two volunteer community journalists seeking to verify public statements made by water agencies regarding the factors contributing to the Menindee mass fish kills of March 2023. This was done independently of any other paid or volunteer work the authors engage in. It was completed by reviewing publicly available satellite images, photographs posted to Facebook and community updates by WaterNSW and the Department of Planning and Environment.

For further information visit www.waterwatchradio.com

Summary:

This report challenges claims made by WaterNSW that “very limited management actions could have prevented [the mass fish kills]” about the March 2023 mass fish kill in Menindee. In a community update published on March 21st, 2023 WaterNSW states:

“The fish deaths are a natural event associated with record flooding in the area. There are very limited management actions that could have been taken to prevent it from happening.”

WaterNSW, Menindee Lakes Community Update March 21, 2023

In contrast to this claim, this report presents evidence that controlled releases of blackwater were made in the days leading up to the mass fish kill of March, 2023.

An unprecedented volume of blackwater had accumulated in Lake Wetherell at the top of the Menindee Lakes System following the flood of early 2023. Using publicly available satellite imagery, on-the-ground photography by Menindee resident Geoff Looney and published updates from WaterNSW and the Department of Planning and Environment (DPE), this report reconstructs a time line of controlled releases prior to the March mass fish kill. This is to better understand the role of management in discharging blackwater prior to and during the fish kill events that occurred in Menindee in February and March, 2023.

This timeline demonstrates that water authorities were acutely aware of the risk of releasing blackwater from Lake Wetherell by the end of February, 2023.

Between February 17th and 27th, the DPE had documented that efforts to dilute the blackwater in Lake Wetherell with better quality water in Lake Pamamaroo was impacting dissolved oxygen levels in the Darling-Baaka River, resulting in fish deaths.

In response to this observation, water authorities ceased releases of blackwater held in Lake Wetherell to allow dissolved oxygen in the river to recover. But by mid-March as Lake Wetherell approached capacity, public statements by WaterNSW and the DPE detail conflicting priorities:

1. Release water from Lake Wetherell as it approached capacity
2. Contain blackwater to mitigate risks to aquatic life

It can be seen on Satellite imagery presented in this report that from March 14th blackwater was being discharged from Lake Wetherell via two pathways:

1. Into Lake Pamamaroo via the Pamamaroo inlet and subsequently drawn through the Pamamaroo outlet, flows following the same pathway that was documented to cause fish kills in February, 2023.

2. Into the Pamamaroo creek via the Wetherell outlet which discharges directly into the Darling-Baaka River.

These controlled releases were made just two days before the onset of the mass fish kills on the evening of March 16th.

The role of these controlled releases in the mass fish kills has never been publicly addressed by water authorities, nor have they discussed what alternatives were considered.

Evidence presented in this report demonstrates that authorities were aware of the risk of releasing blackwater in the Darling-Baaka River and were monitoring the situation as risk factors intensified. The DPE reported on March 15th that dissolved oxygen was dropping and above average temperatures were forecasted, however no action was taken.

This report was conducted on volunteer time, and not in association with any other activities conducted by the authors. Its purpose is to provide recommendations to the NSW Inquiry into the 2023 Menindee mass fish kills, chaired by the NSW Chief Scientist & Engineer, Professor Hugh Durrant-Whyte.

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Definitions

Anoxic: Water with dissolved oxygen content that is nil; conditions that are unliveable for aquatic life.

Blackwater: Blackwater occurs when nutrients and debris washes off the floodplain during a flood and breaks down in the waterway. This chemical process consumes oxygen and when too much organic matter is present in the waterway it can deplete oxygen to the extent that large-bodied fish and other aquatic life cannot survive.

Darling-Baaka River: The Darling River originates at the confluence of the Barwon and Culgoa Rivers near Brewarrina and terminates at the junction with the Murray at Wentworth. Baaka is the local Barkindji word for the Darling River.

Emergency Operations Centre: The multi-agency government response committee established on March 19th 2023 to respond to the mass fish kill event that started on March 16th. It includes agencies such as WaterNSW, the NSW Department of Planning and Environment, NSW Department of Primary Industries – Fisheries, the NSW Environmental Protection Authority, the NSW Department of Health, Essential Water, the Central Darling Shire and was overseen by the NSW Police.

Hypoxic: Water with a dissolved oxygen content that is low or severely depleted, conditions that present a risk to the survival of aquatic life**.**

Main Weir: A very large regulator at Lake Wetherell that controls flows from the Barwon-Darling system into the regulated section of the Darling-Baaka River and the lower Darling-Baaka River.

Menindee Lakes System: A series of naturally occurring lakes along the Darling-Baaka River near Menindee in Far West NSW. The four largest lakes are Lake Wetherell, Lake Pamamaroo, Lake Menindee and Lake Cawndilla.

Mixing events: The mixing of blackwater held in Lake Wetherell with better quality water in Lake Pamamaroo. This mixing can take place either in Lake Pamamaroo with discharges from Lake Wetherell via the Lake Pamamaroo inlet regulator, or in Pamamaroo Creek where discharges from the Wetherell outlet regulator mixes with discharges from Pamamaroo outlet.

Outlets of interest in this report: Flows from these outlets are the subject of this report. These flows can originate from:
1. The Pamamaroo inlet regulator that connects Lake Wetherell with Lake Pamamaroo.
2. The Pamamaroo outlet regulator which discharges into Pamamaroo Creek.
3. The Wetherell outlet regulator which discharges into Pamamaroo Creek
4. Pamamaroo Creek which discharges into the top of the regulated section of the Darling-Baaka River.

Pamamaroo Creek: A short river channel that transports releases from the Lake Pamamaroo outlet regulator and Wetherell outlet regulator into the regulated section of the Darling River-Baaka River. This creek runs alongside the Burke and Wills Campsite.

Regulated section of the Darling-Baaka River: the section of river downstream of the Menindee Main Weir and above Weir 32. Flows into this section of the Darling Baaka River are controlled by releases from the Main Weir, the combined Pamamaroo/Wetherell outlets or Lake Menindee.

Weir 32: A small rock weir located approximately 18 km as the crow flies downstream of the Main Weir at Menindee. It is the site of the permanent field monitoring station that records water temperature and dissolved oxygen (among other parameters) and is considered the end of the 40 kilometre stretch of the regulated section of the Darling-Baaka River.

Background

The Unprecedented Accumulation of Blackwater

The floods of 2023 resulted in an enormous volume of blackwater entering the Menindee Lakes System from the Barwon-Darling (Figure 1). As floodwaters receded from the floodplains a large volume of floodplain nutrients, organic matter, and sediments accumulated in the river channel. This caused Lake Wetherell to become a storage of deoxygenated blackwater. These conditions presented challenges to river operators.

With this large volume of blackwater in the system, management decisions were critical to maintaining suitable water quality to support life. This report uses publicly available satellite imagery and photography on-the-ground to understand how this blackwater was managed.

The scope of this report does not extend to the reasons such large volumes of blackwater accumulated in the system.

Pamamaroo Creek and the Lake Wetherell and Lake Pamamaroo Outlets

The regulated section of the Darling-Baaka River begins below the Main Weir at Lake Wetherell. When the Main Weir is open water flows directly into the Darling-Baaka River. When flow is restricted by the Main Weir regulator, flows are diverted from the top lakes (Wetherell and Pamamaroo) which both have outlet regulators that discharge into Pamamaroo Creek. Flows into Pamamaroo Creek then discharge into the top of the regulated section of the Darling-Baaka river below the Main Weir (Figure 2).

Flows directly through Lake Wetherell and into the regulated section of the Darling-Baaka River were ceased when the Main Weir was closed on February 17th.

When this occured discharge from Pamamaroo Creek became the main source of flow into the regulated section of the Darling-Baaka River from the top lakes, and the regulators that controlled this flow became the primary tools for water authorities to manage blackwater through the Menindee Lakes System.

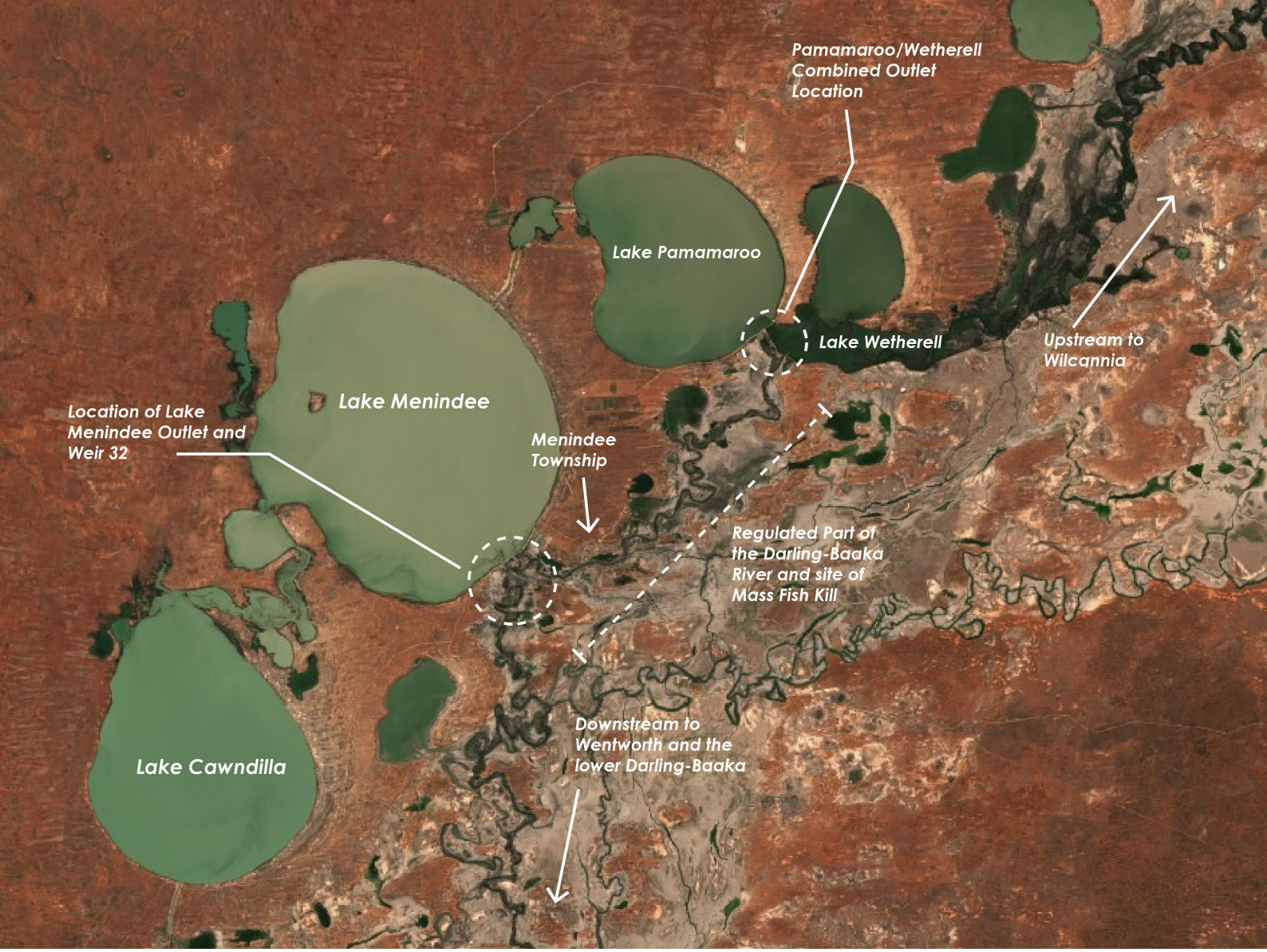


Figure 1 - Satellite image of Menindee Lakes showing outlet locations

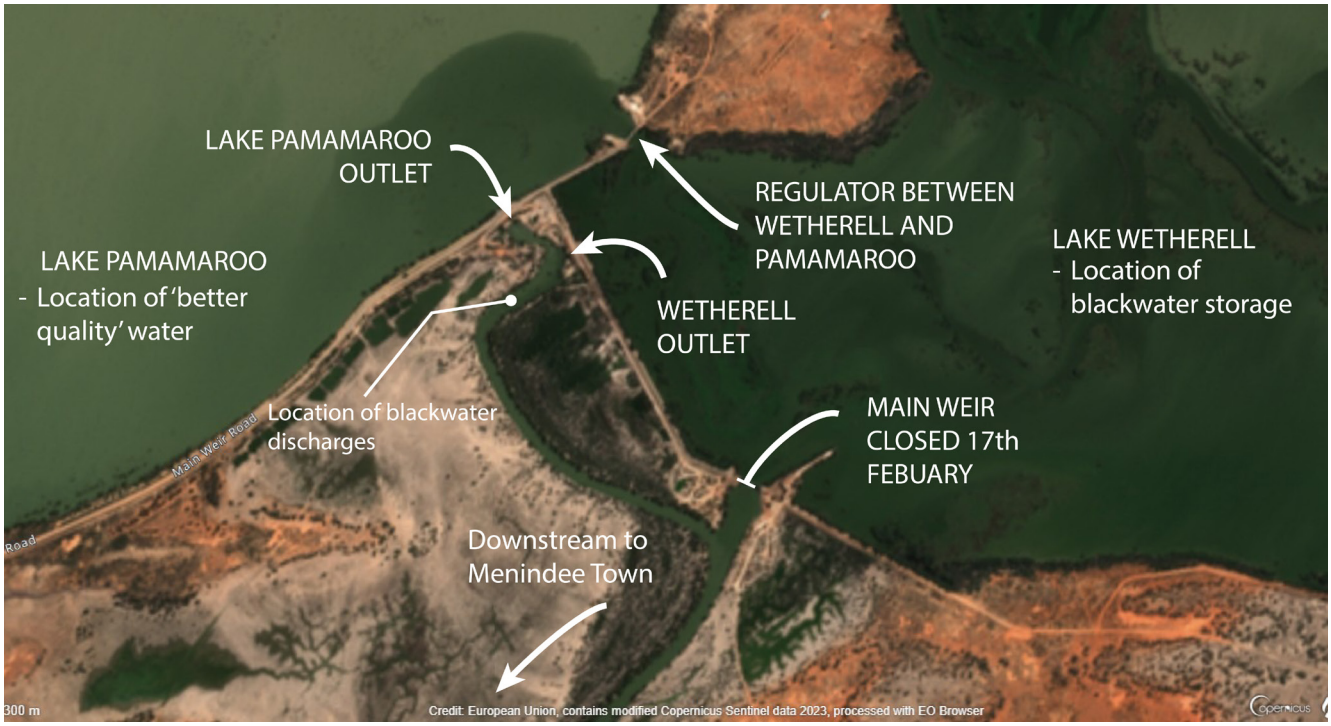


Figure 2 - Outlets of interest in this report, Pamamaroo & Wetherell combined outlet location

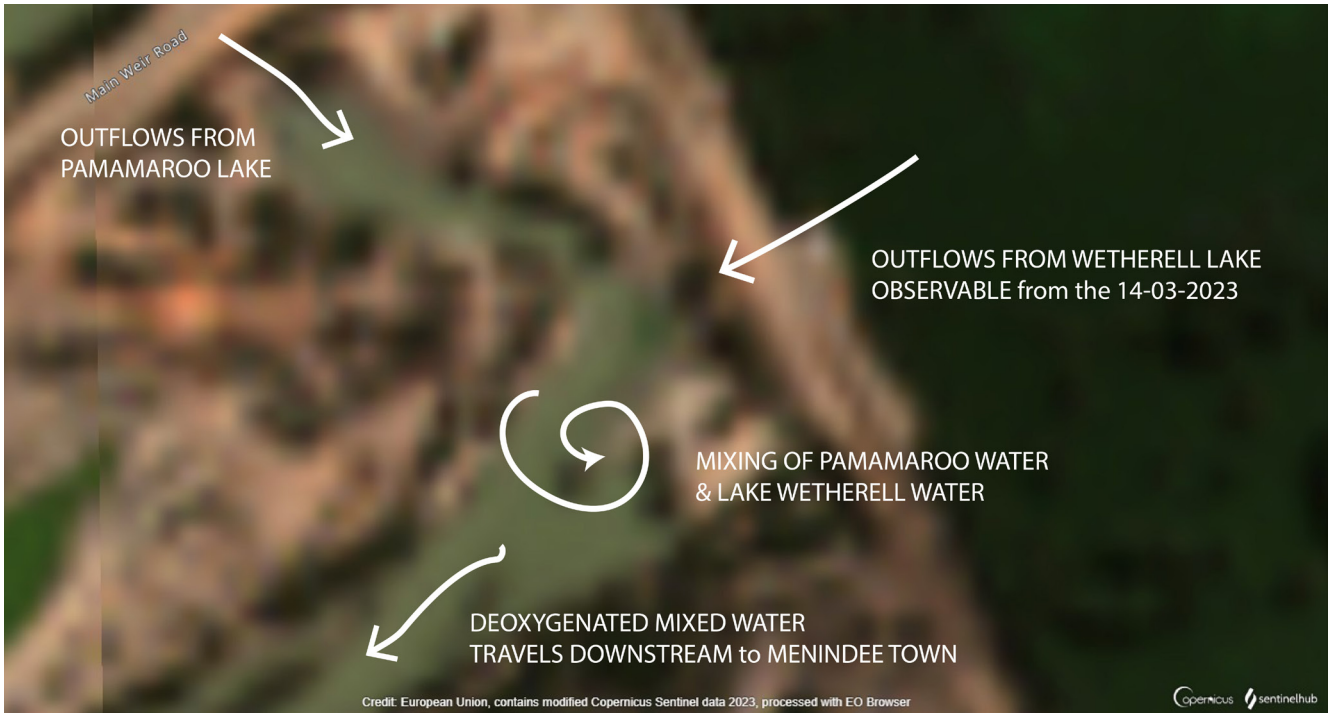


Figure 3 - Diagram of the outlets that mixed blackwater with 'better quality' water in Pamamaroo Creek

The main regulators used to manage the flow of blackwater through the top lakes at Menindee are:

- The Pamamaroo inlet which discharges water held in Lake Wetherell into Lake Pamamaroo
- The Pamamaroo outlet which discharges water held in Lake Pamamaroo into Pamamaroo Creek and is located about 600m from the Pamamaroo inlet
- The Wetherell outlet which discharges water held in Lake Wetherell into Pamamaroo Creek

The discharges from these regulators are the subject of this investigation (Figure 3).

Method

This report compares satellite imagery accessed via Sentinel-2 with time stamped photos accessed via Facebook Page *Menindee NSW Outback Photography by Geoff Looney* and supplied by Geoff Looney.

Satellite images for dates of March 4th, 14th, 19th, 24th have been adjusted by increasing saturation and contrast to enhance the delineation between blackwater and 'better quality' water. Where an enhancement as been applied, figures are captioned with the method of adjustment. No other changes have been made to these images, and these images can be independently accessed via https://apps.sentinel-hub.com

The combination of satellite data and on-the-ground observations provides information of controlled releases made from the Pamamaroo and Wetherell regulators.

These observations were compared with public statements published by the Department of Planning and Environment (DPE) and WaterNSW and data accessible via WaterNSW real-time monitoring data.

Chronology of Events

Blackwater Discharge Documented in February 2023

With a serious hypoxic blackwater situation unfolding in Lake Wetherell, the NSW Department of Planning and Environment (DPE) stated on February 24th, that an operational plan to "divert a portion of the low oxygen flood flows into the shallow lakes was achieved successfully during last year's flood event" (DPE March 24, 2023).

It appears the strategy in early 2023 was to dilute blackwater held in Lake Wetherell with 'better quality' water held in Lake Pamamaroo. The DPE stated that their aim was to "transfer water between the Menindee Lakes to mix the low dissolved oxygen water in Lake Wetherell with the better quality water in the other Lakes." (DPE March 24, 2023)

The satellite imagery of Pamamaroo inlet at this time confirms this strategy was employed to manage floodwaters during February 2023 (Figure 4). It appears this continued until it was discovered that discharges of blackwater held in Lake Wetherell was having an adverse impact on water quality downstream in the regulated section of the Darling-Baaka River.

On March 2nd, the DPE noted

> *"It was identified that the poorer quality water entering Lake Pamamaroo was being drawn through the Pamamaroo outlet and being discharged into the Darling River. To address this issue, the inlet structure between Lake Wetherell and Pamamaroo was closed."*
>
> DPE Water Quality Update March 2, 2023

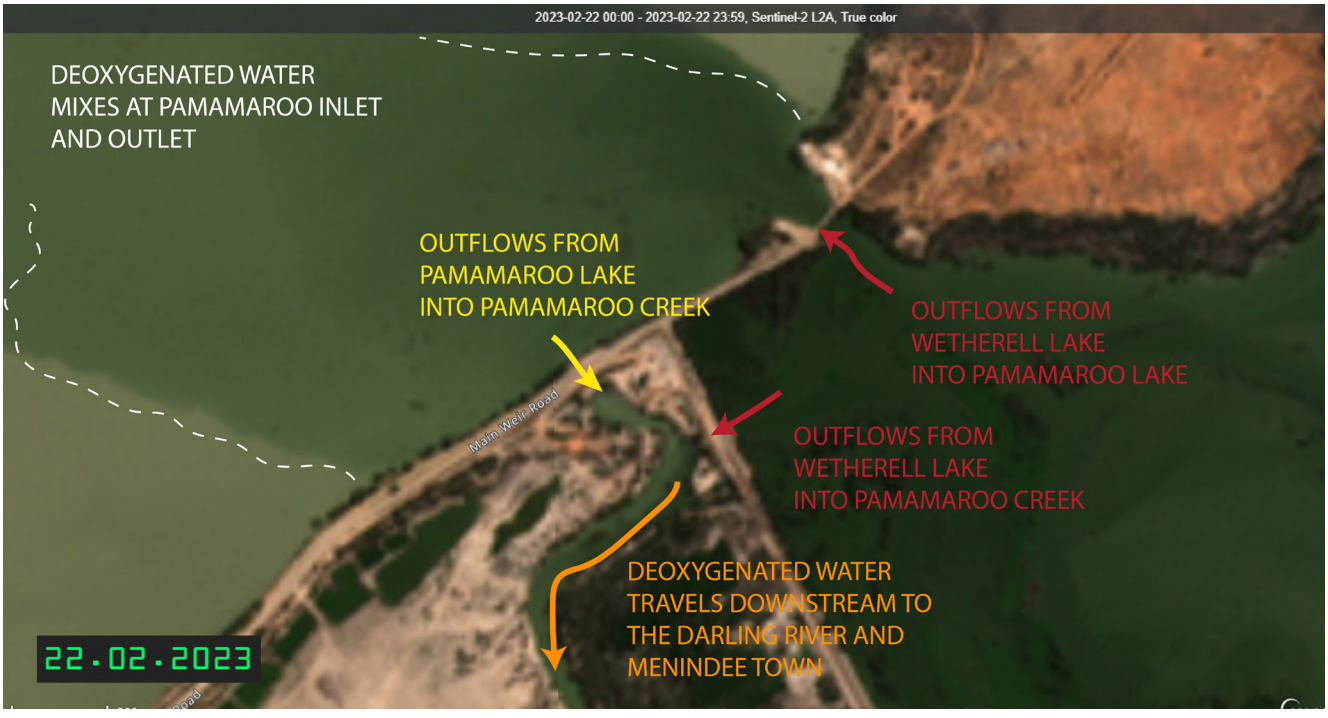


Figure 4 - Diagram of blackwater travelling into the regulated section of the Darling-Baaka River on February 22nd

While blackwater was travelling via the Lake Pamamaroo outlet, fish were found dead in the regulated section of the Darling-Baaka River, first in small numbers at the Main Weir on February 18th (Figure 5).

Then, on February 27th, many thousands of dead fish were documented by local photographer Geoff Looney at the Menindee Boat Ramp (Figure 6).

In relation to this event, Geoff Looney was quoted in the Guardian on March 3rd, saying: *"The dead fish now are in the town everywhere… As you stand on the bridge, with the current coming from Lake Pamamaroo, the dead fish are floating past you."* (Connick Fri 3 March, 2023)

In response to these events, the discharge of blackwater into Lake Pamamaroo was ceased.

> *"To address this issue, the inlet structure between Lake Wetherell and Pamamaroo was closed."*
>
> DPE Water Quality Update March 2, 2023

Satellite imagery confirms that the Pamamaroo inlet was closed by February 27th, 2023 (Figure 7).

Figure 5- Menindee NSW Outback Photography by Geoff Looney - Facebook Post - Photo taken February 18, 2023

Figure 6 - Menindee NSW Outback Photography by Geoff Looney - Boat Ramp in Menindee Town - Photos taken February 27, 2023

It appears that reducing releases from Lake Wetherell outlets was an effective strategy. The DPE acknowledged that water quality had improved in the regulated section of the Darling-Baaka River in its Water Quality Updates in early March. The DPE Water Quality Update of March 2nd states:

> *"Once the Pamamaroo inlet structure was closed, the darker, lower oxygen water is no longer flowing into the more turbid water in lakes Pamamaroo and Menindee."*
>
> DPE Water Quality Update March 2, 2023

The strategy communicated was:

> *"To maintain an oxygenated flow in the Darling River through Menindee Township and reduce the risk of further fish deaths, releases from Lake Wetherell outlet have been reduced, while releases from the Pamamaroo outlet have been increased."*
>
> DPE Water Quality Update March 2, 2023

By March 8th, the DPE were publicly reinforcing this strategy, stating:

> *"Monitoring is showing the water quality now being released from Lake Pamamaroo into the Darling River at Menindee is of more suitable quality and is providing some relief for fish."*
>
> DPE Water Quality Update March 8, 2023

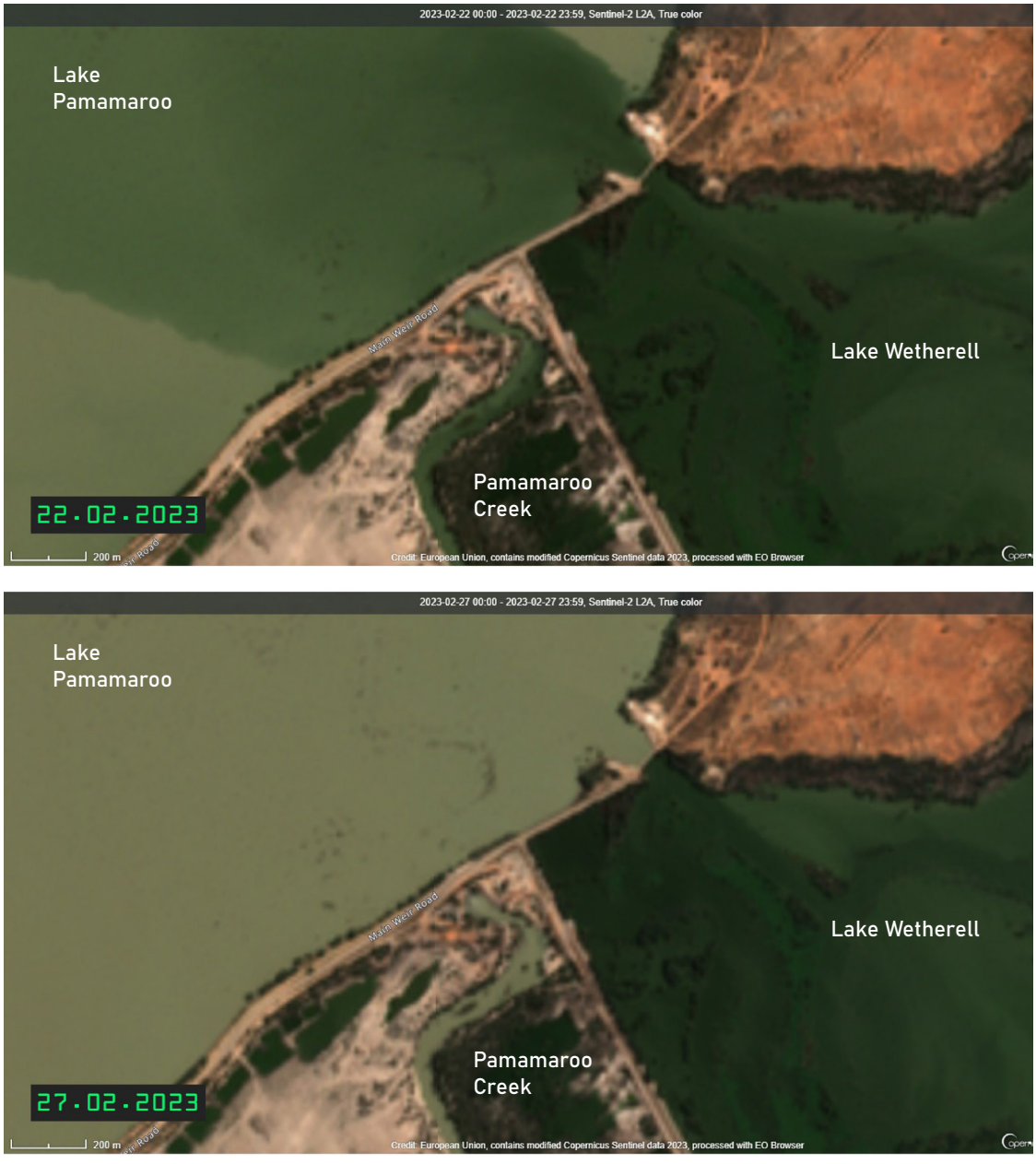


Figure 7 - Satellite images of Pamamaroo inlet on February 22nd and 27th, showing the dramatic reduction of releases from Lake Wetherell, improving the dissolved oxygen levels in the regulated section of the Darling-Baaka River

And

> *"Dissolved oxygen in the Darling River downstream of Menindee at Weir 32 had been low, decreasing to less than 2 mg/L on 25 February. These levels have now improved above 2 mg/L in response to the operational measures implemented and are continuing to increase toward the safer level for fish health of 4 mg/L"*

DPE Water Quality Update
March 8, 2023

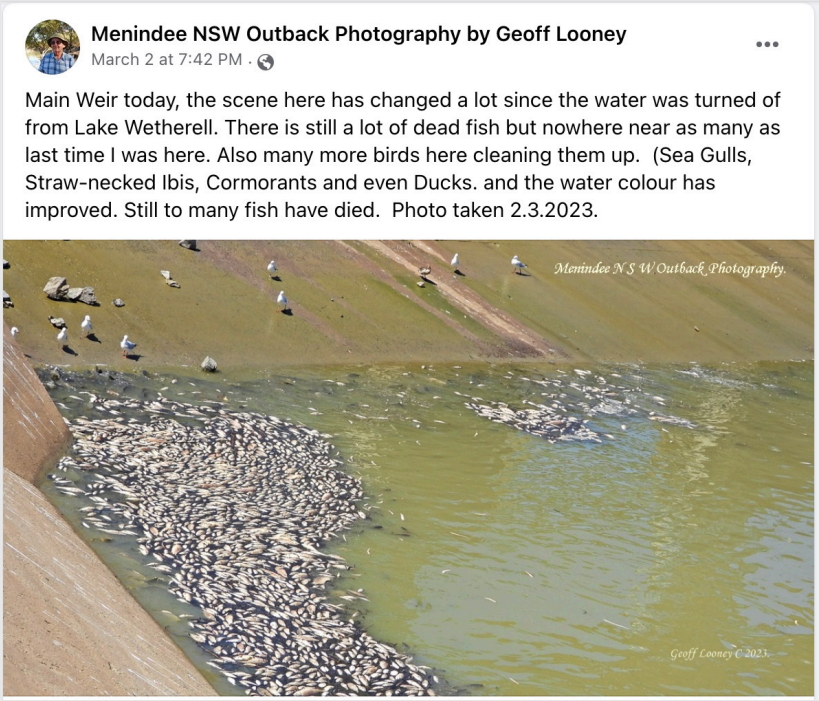


Figure 8 - Menindee NSW Outback Photography by Geoff Looney - Main Weir - Photo taken March 2nd 2023 - Mr. Looney observes the improvement of water quality, fish health and bird life since the the Wetherell outlets had been closed.

Observations Supporting DPE Communications

On the ground, local photographer Geoff Looney noted on March 2nd that the numbers of dead fish at the Main Weir, downstream of Pamamaroo Creek had been reduced and that the water colour had improved (Figure 8).

Geoff Looney wrote:

> *"The scene here has changed a lot since the water was turned off from Lake Wetherell. There is still a lot of dead fish but nowhere near as many as last time I was here."*

All evidence analysed in this report supports the claims made by the DPE that the efforts to limit releases from Lake Wetherell had improved oxygen levels in the regulated section of the Darling-Baaka River and potentially avoided further fish deaths (Figures 7 & 8).

However, with the Lake Wetherell outlet regulators closed, the top lake was reaching capacity, forcing this operational strategy to be discontinued.

Blackwater Discharge in March 2023

The successful strategy to improve dissolved oxygen levels in the regulated section of the Darling-Baaka River was short-lived.

By mid-March Lake Wetherell was approaching full capacity and the storage of blackwater would have to be released somewhere. It appears water authorities were faced with two emerging priorities:

1. Release water from Lake Wetherell as it approached capacity
2. Mitigate risks to aquatic life

To manage these priorities, the stated plans from WaterNSW and the DPE during this period appear to be contradictory:

> *"...in an attempt to maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Lake Pamamaroo outlet are being maintained."*
>
> DPE Water Quality Update March 15, 2023

And

> *"Pamamaroo outlet regulator gates to continue to close as soon as practical. Pamamaroo inlet regulator to be opened progressively as the outlet closes."*
>
> WaterNSW Operational Update March 13, 2023

What can be observed in the satellite imagery and on-the-ground photographs are further releases of blackwater in regulated section of the Darling-Baaka River.

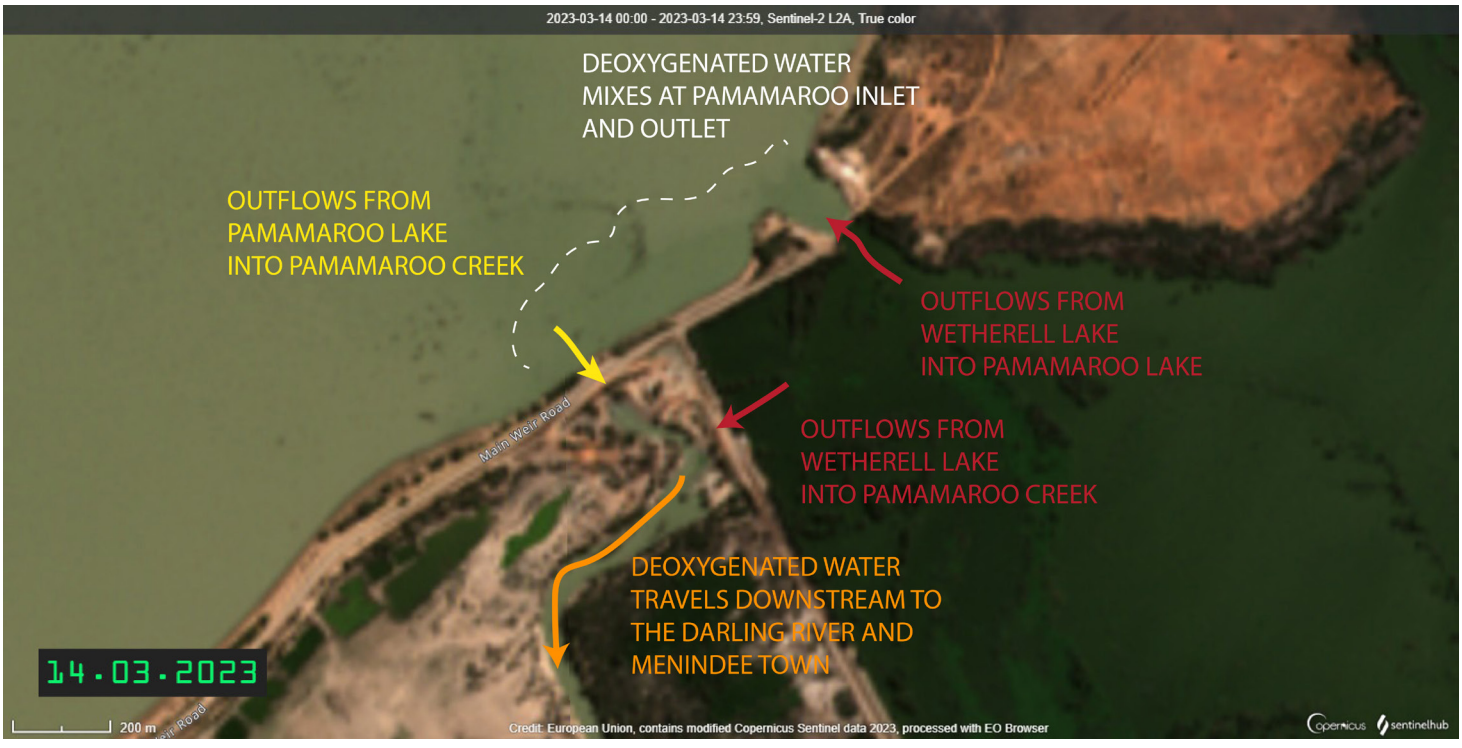


Figure 9 - Diagram of blackwater being discharged into the regulated section of the Darling-Baaka River on March 14th

Satellite imagery on March 14th, confirms the regulator between Lake Wetherell and Lake Pamamaroo had been opened (Figures 10 & 11). A comparison of satellite imagery from March 4th and March 14th shows a plume of blackwater entering Lake Pamamaroo from Lake Wetherell, and travelling to the Pamamaroo outlet where it was discharged into Pamamaroo Creek (Figure 9).

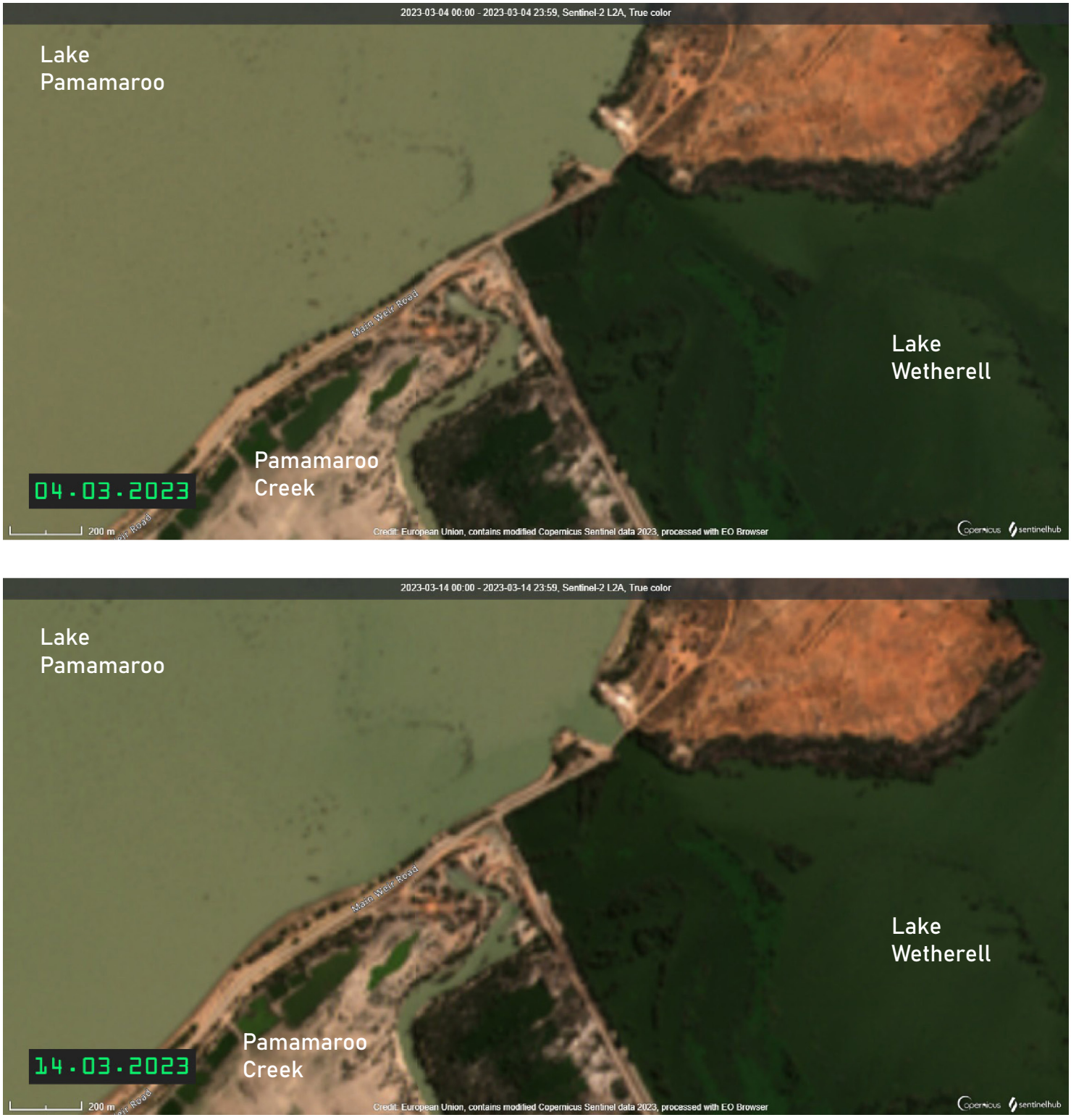


Figure 10 - A comparison of satellite imagery from March 4th and March 14th shows a discolouration around the Pamamaroo Inlet

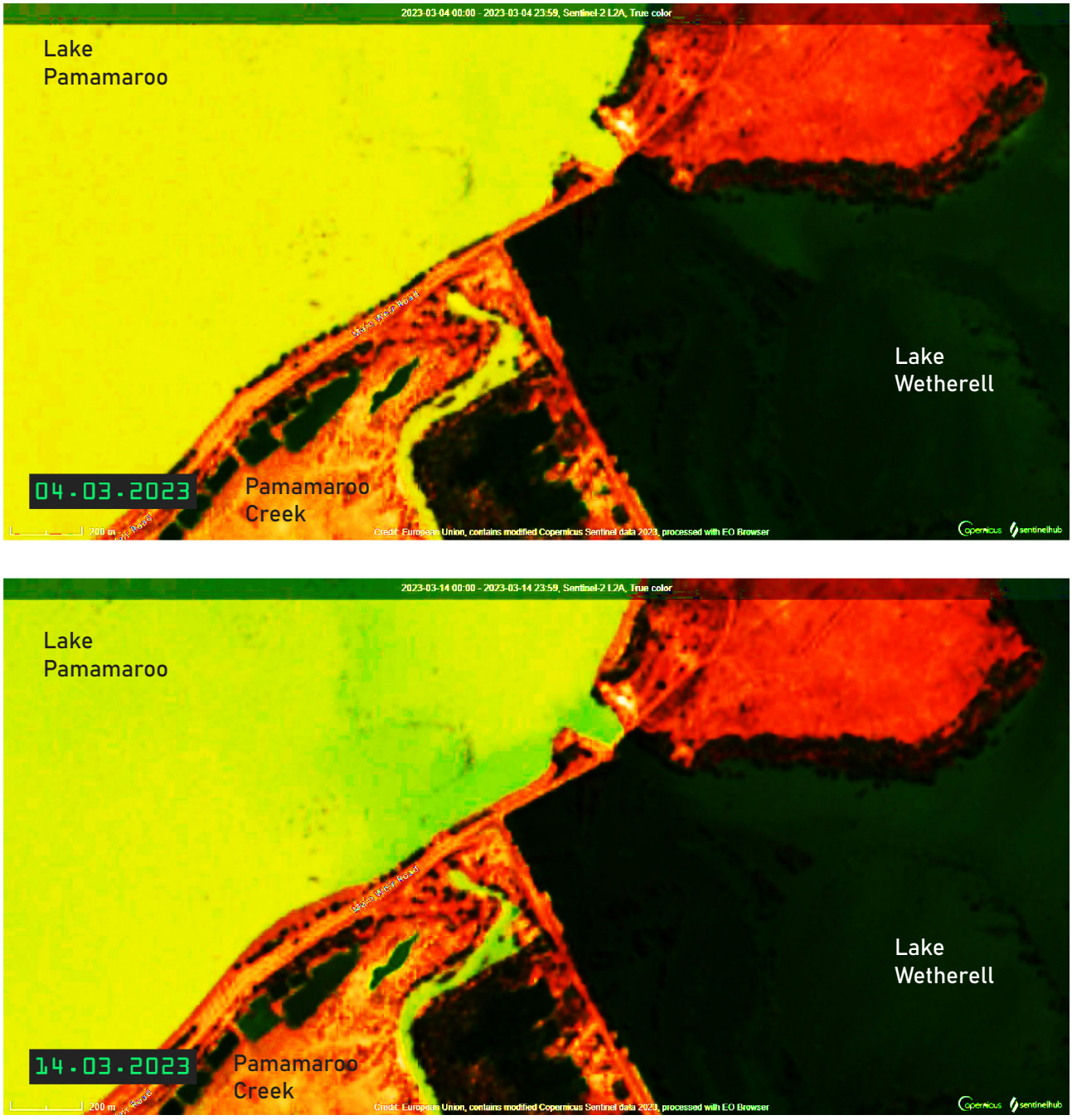


Figure 11 (Above) - The Pamamaroo/Wetherell outlets on March 4th and 14th with photoshop adjustments of +100 Saturation and +200 contrast to exaggerate the delineation of blackwater mixing with Pamamaroo water and travelling into the regulated section of the Darling-baaka River.

A photoshop enhancement of +100 saturation and +200 contrast exaggerates the delineation between blackwater and better quality water to enhance the clarity of the plume front.

These images show a repeat of the events of February which were found to have resulted in fish deaths. The images clearly show blackwater held in Lake Wetherell being drawn through

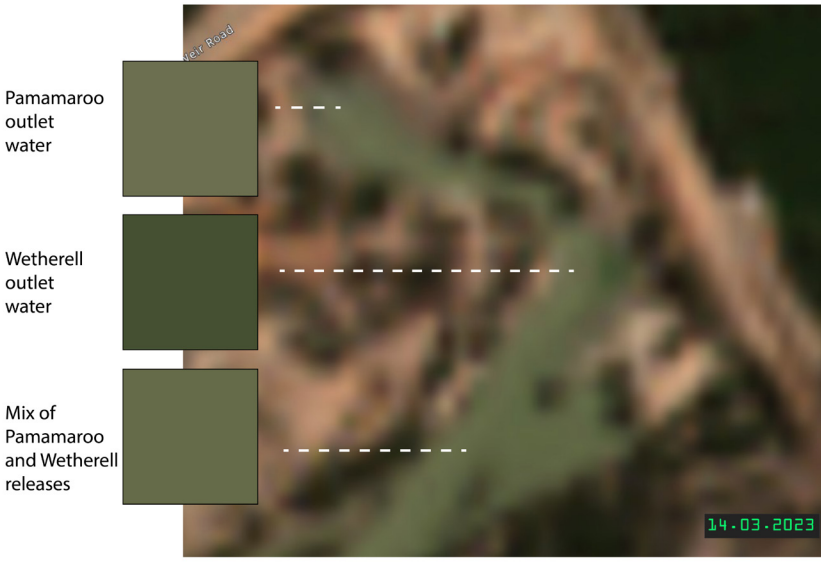


Figure 12 (Right) - Colour swatches of waters shows discharge of blackwater occurring in Pamamaroo Creek

the Pamamaroo outlet and discharged into the Darling-Baaka River via Pamamaroo Creek (Figure 9). From there it discharged into the regulated section of the Darling-Baaka River via Pamamaroo Creek.

The photoshop adjusted enhancements of satellite images highlight another potentially more dangerous pathway for blackwater. A closer inspection of the March 14th satellite imagery shows a second discharge from the Lake Wetherell outlet directly into Pamamaroo Creek (Figure 12).

This indicates that by March 14th, blackwater held in Lake Wetherell was discharging directly in Pamamaroo Creek via the Wetherell outlet (Figure 14).

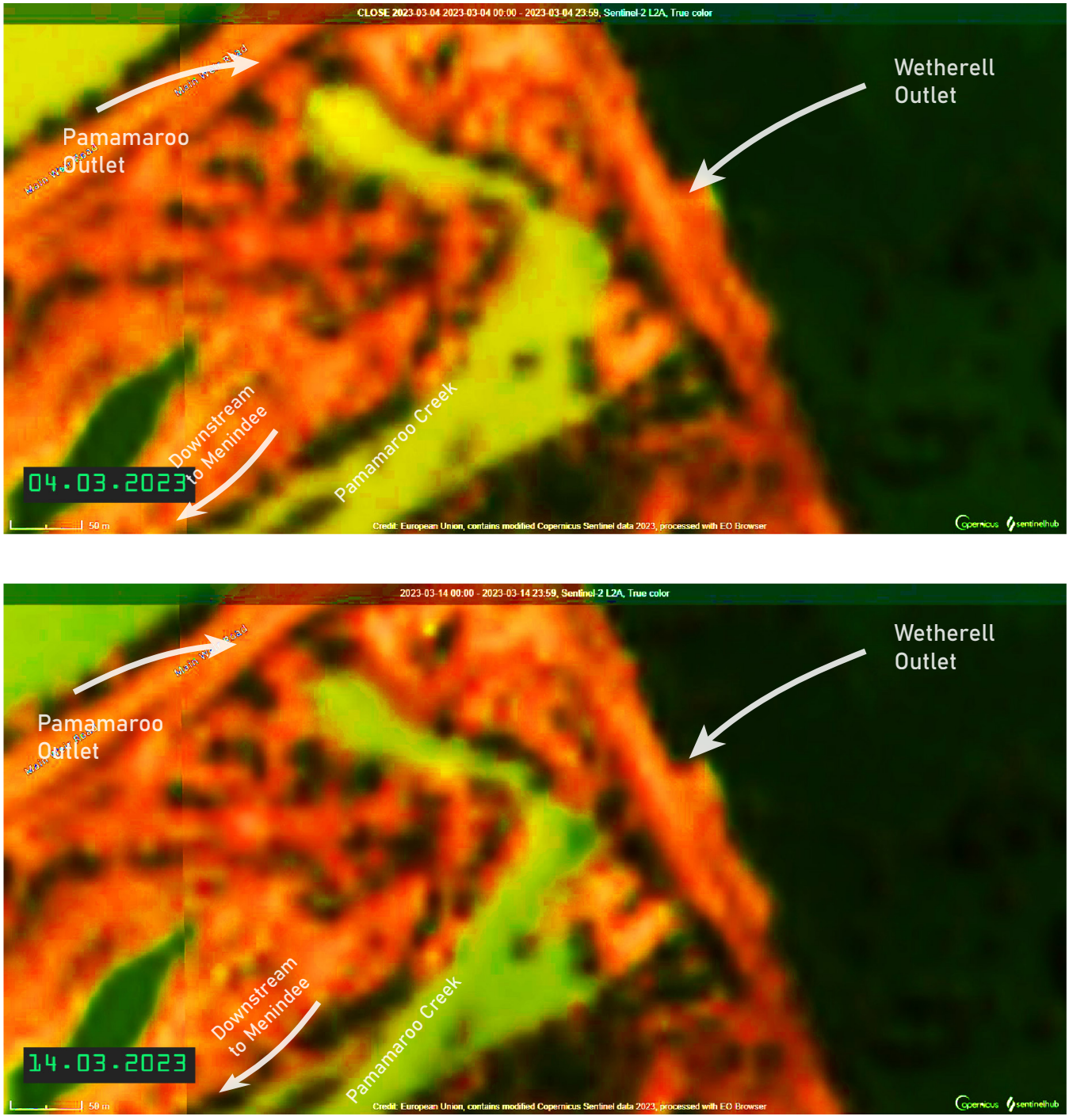


Figure 13 - Pamamaroo and Wetherell outlets at Pamamaroo Creek. A photoshop adjustment of +100 Saturation and +100 exaggerates the delineation of blackwater being released from the Wetherell outlet.

On March 18th, local photographer Geoff Looney confirms this release when he documented the mixing of blackwater being discharged from the Wetherell outlet with discharge from the Pamamaroo outlet, in Pamamaroo Creek (Figure 14 & 16).

He noted at that time:

> *"Lake Wetherell Outlet, Good to see that this outlet has been closed today where they were blending it with the water from Lake Pamamaroo. (You can see the different colours of the two waters)"*

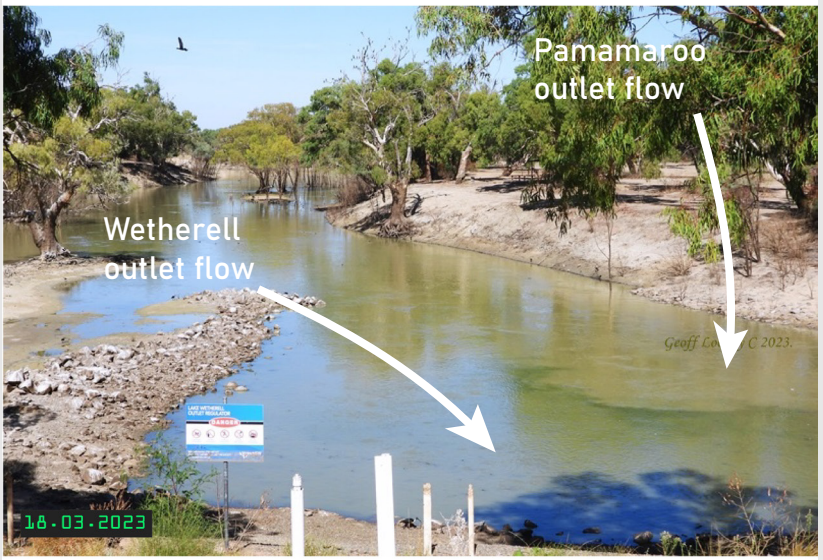
And

> *"This should help enormously as the water from Lake Pamamaroo looks quite good and the flow from this should re oxygenate the water (hopefully)."*

As observed by Geoff Looney, controlled releases into Pamamaroo Creek via the Wetherell outlet are of much poorer quality than the releases from Lake Pamamaroo. The discharge via the Wetherell outlet is taken from the lowest strata of Lake Wetherell, as the offtake structure is located on the lakebed (Figure 15).

LAKE WETHERELL OUTLET CLOSED

LAKE WETHERELL OUTLET OPEN



PHOTOGRAPHIC CONFIRMATION OF LAKE WETHERELL OPEN

Figure 14 - Lake Wetherell outlet shown on satellite imagery on March 4th and 14th and on the ground photography by Geoff Looney on March 18th shows discharges of blackwater from the Lake Wetherell outlet.

Figure 15 - Lake Wetherell pictured March 2020. Offtake structure draws water from the bottom of the lake bed. Photo by Dan Schulz on March 11, 2020

The bottom most water layer is where anoxic water is most likely to occur in reservoirs with high levels of nutrient (Steichen, Garton and Rice 1979) (Boys, Baldwin et al. 2021). Because of this, the Wetherell outlet was the worst possible outlet to release water from Lake Wetherell and simultaneously manage dissolved oxygen to mitigate risk to aquatic life in the regulated section of the Darling-Baaka River (see Appendix A).

According to the satellite imagery and observations by Geoff Looney, it appears the Wetherell outlet was open from March 14th and closed by March 18th.

The March 2023 Mass fish kill began on the evening of March 16th.

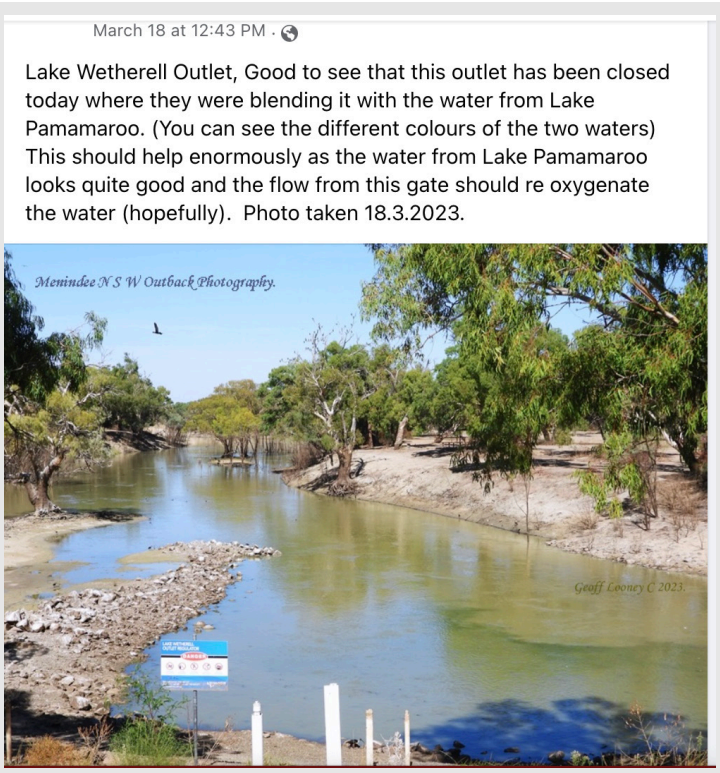


Figure 16 - Menindee NSW Outback Photography by Geoff Looney - This photo evidences that blackwater was being released from Lake Wetherell. Mr. Looney notes it was closed before midday on March 18th. According to the satellite imagery it was initiated by March 14th

“Well it’s happened again” – Fish Kills Following Blackwater Discharge in March 2023

On the evening of March 16th local photographer Geoff Looney documented the onset of the mass fish kills in Menindee. This observation was made just two days after satellite imagery reveals blackwater being discharged from Lake Wetherell (Figure 17).

In his Facebook post on March 16th Geoff Looney observed a death of “mostly native fish” and remarked, “well it’s happened again dead fish in their thousands at the Main Weir and in the river towards town.” (Figure 17)

By the morning of March 17th millions of native fish were reported dead in the regulated section of the Darling-Baaka River.

The mass fish kill event peaked during March 17th & 18th (Figure 18 & 19), and media reports typically state 20 million fish perished in this event, although exact numbers are unknown.

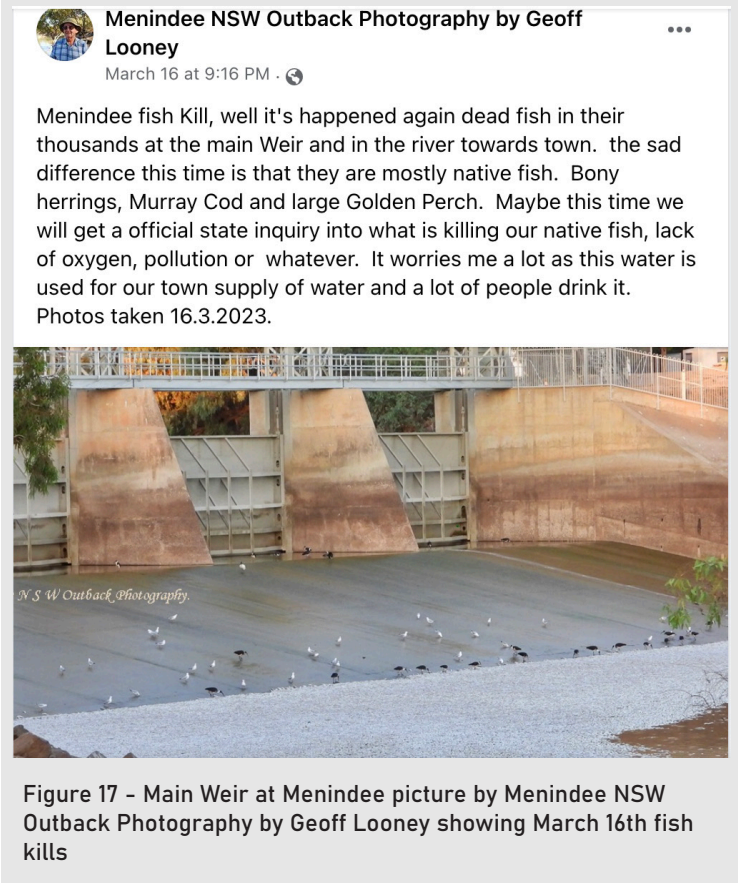


Figure 17 - Main Weir at Menindee picture by Menindee NSW Outback Photography by Geoff Looney showing March 16th fish kills

Blackwater releases continue throughout March 2023

Despite these catastrophic scenes of mass fish kills from March 16th, blackwater releases from Lake Wetherell into the regulated section of the Darling-Baaka River were sustained through March via the Pamamaroo inlet/outlet.

During the releases of blackwater from Lake Wetherell into the regulated section of the Darling-Baaka River the DPE stated in a Water Quality Update on March 15th:

> *“With forecast heatwave conditions this weekend, to maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Lake Pamamaroo outlet will continue.”*
>
> DPE, Water Quality Update March 15, 2023

This statement appears to mirror the strategy to reoxygenate the river that was implemented in late February and early March, but this time with one key difference. Satellite imagery through March shows that the Pamamaroo inlet that receives water

Figure 18 – Stream of dead fish observable from the road bridge in Menindee Town. Photo taken by Daniel Schulz on March 18th

Figure 19 – Stream of dead fish observable from the railway bridge in Menindee Town. Photo taken by Daniel Schulz on March 18th

from Lake Wetherell, remained open (Figure 21). These releases of blackwater into Lake Pamamaroo were subsequently increased as can be seen in the satellite image of March 24th which shows the plume of blackwater in Lake Pamamaroo being drawn through the Pamamaroo outlet (Figure 21).

This is the same regulation of blackwater held in Lake Wetherell and travelling into the Darling-Baaka river via the Lake Pamamaroo outlet, that was known to be resulting in fish deaths in February. Furthermore there is no mention by water authorities of plans to discharge blackwater directly into the regulated section of the Darling-Baaka River via the Wetherell outlet.

On the ground, local photographer Geoff Looney was observing the pattern of blackwater being discharged in the river via the Pamamaroo outlet. Photographs of the Pamamaroo inlet and outlet regulators on March 21st (Figure 20) show the flow of blackwater from Lake Wetherell into Lake Pamamaroo and Pamamaroo Creek and subsequently into the regulated section of the Darling-Baaka River.

On the ground Geoff Looney observed this in real time and documented it on March 21st.

> *"Looks like Lake Pamamaroo Outlet (above) is open again today although the water colour looks darker.*
>
> *And looks like Lake Pamamaroo inlet (below) has opened too letting the water from Lake Wetherell into Lake Pamamaroo."*

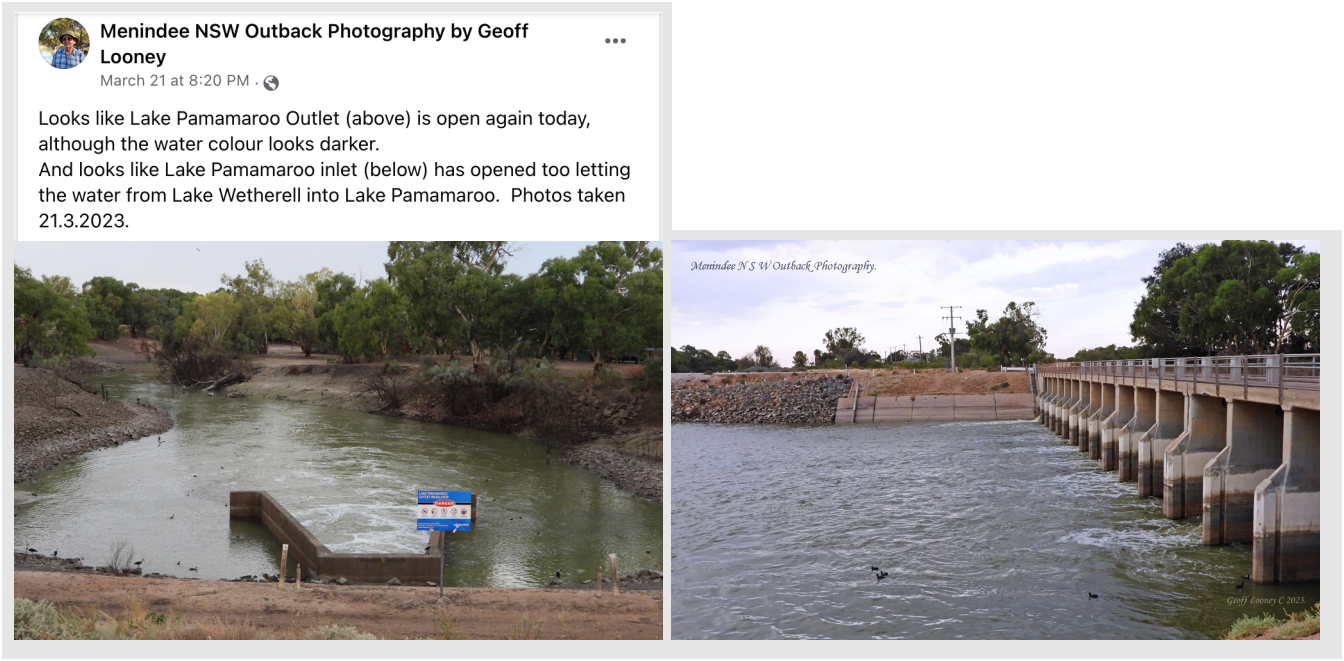
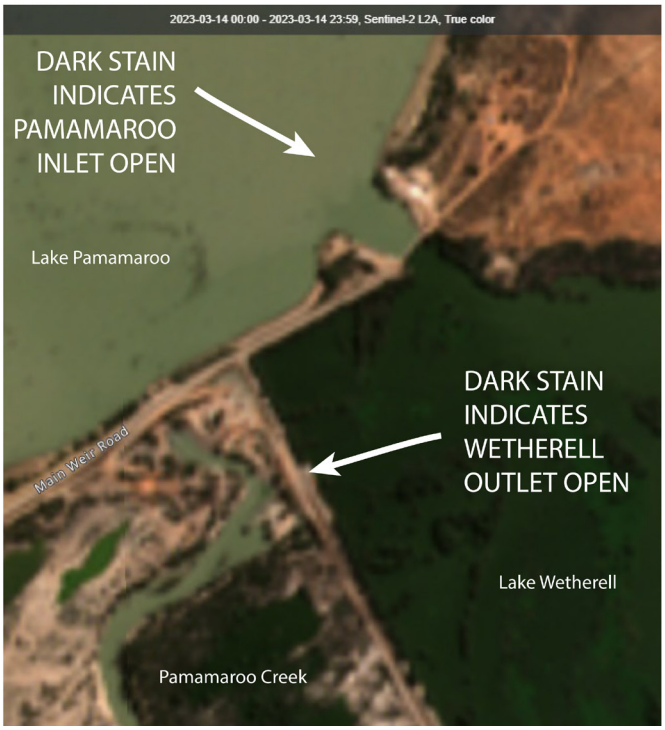


Figure 20 - Left: Pamamaroo outlet, Right: Pamamaroo Inlet, Pictures March 21st, 2023 by Geoff Looney

March 4th, 2023 - WETHERELL OUTLETS CLOSED - NO BLACKWATER DISCHARGE

March 14th, 2023 - WETHERELL OUTLETS OPENED - BLACKWATER DISCHARGES BEGIN



March 19th, 2023 - WETHERELL OUTLETS OPENED - BLACKWATER DISCHARGES CONTINUE

March 24th - WETHERELL OUTLETS OPENED FURTHER - BLACKWATER DISCHARGES INCREASED

Figure 21 - Sequence of satellite images from March 4th - March 24th, showing blackwater travelling into the regulated section of the Darling-baaka River

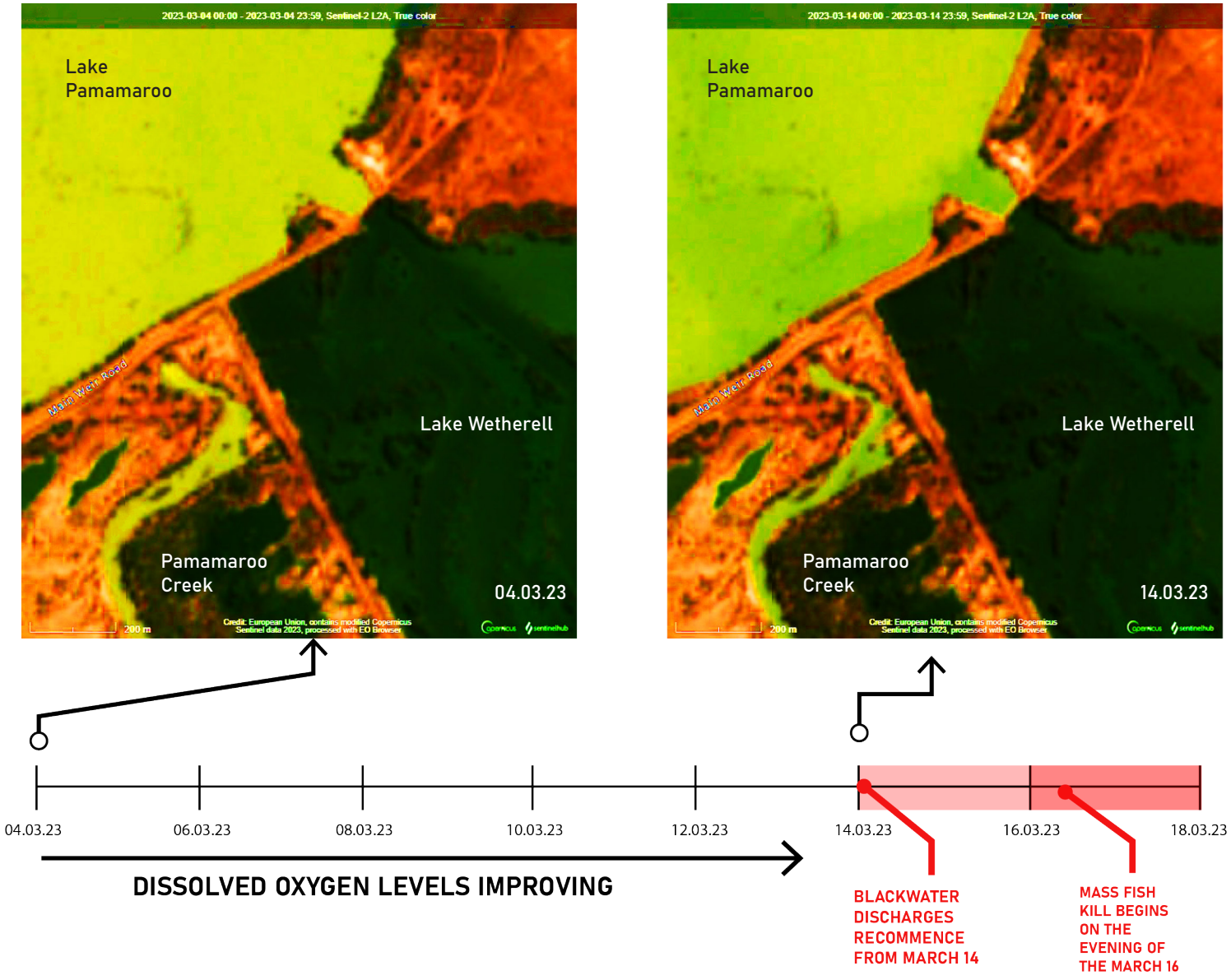


Figure 22

A photoshop adjustment of +100 saturation and +100 contrast to the sequence of satellite images exaggerates the delineation between blackwater and better quality water (Figure 22).

The timeline shows that fish deaths closely followed the release of blackwater into the regulated section of the Darling-Baaka River (Figure 22).

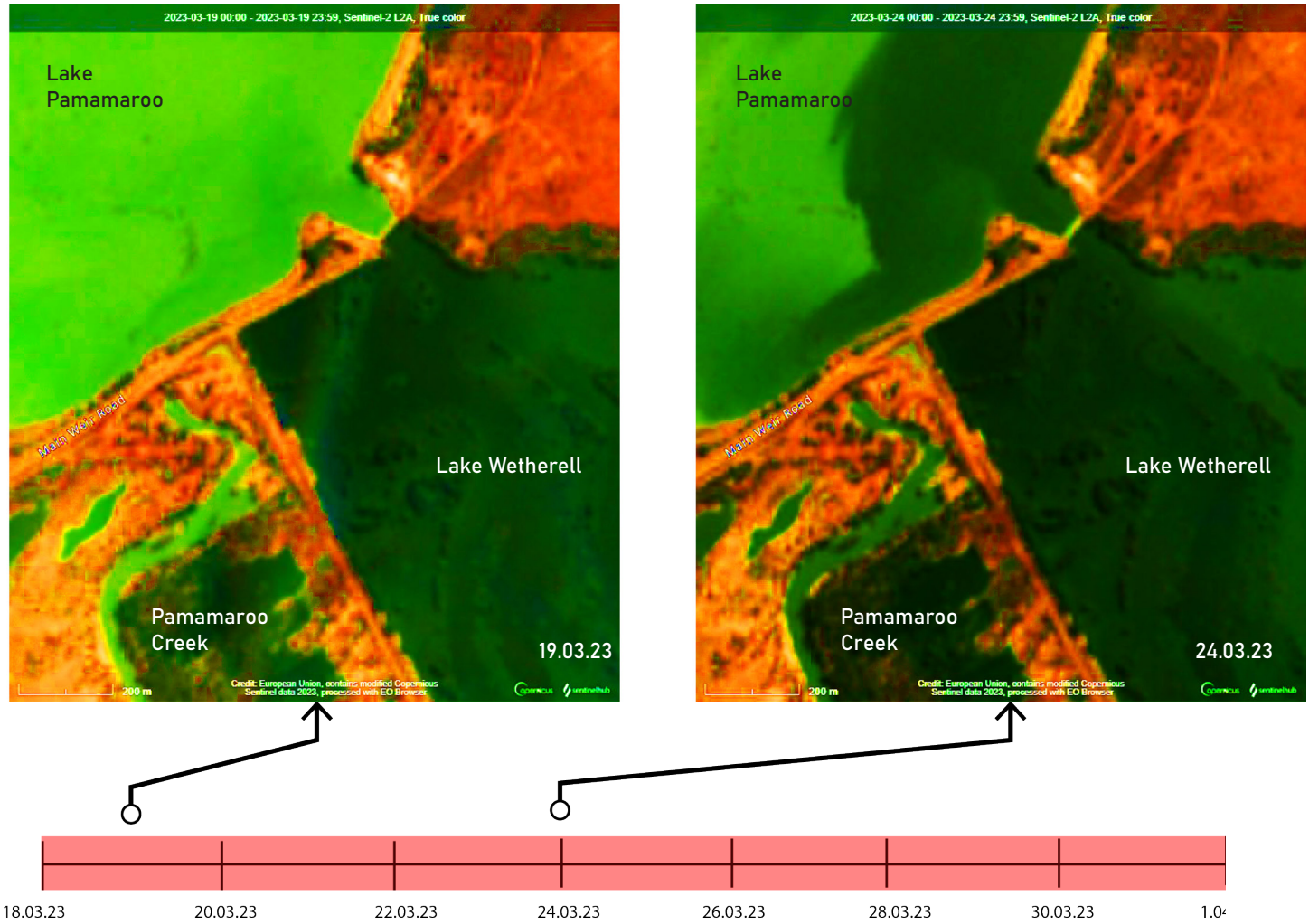


Figure 22 continued

Stream Height Data

Stream heights are recorded at three monitoring sites by WaterNSW (Figure 23):

1. Downstream of the Main Weir at Menindee
2. At the Menindee Lake outlet channel
3. Weir 32 downstream of the Menindee Lake outlet channel

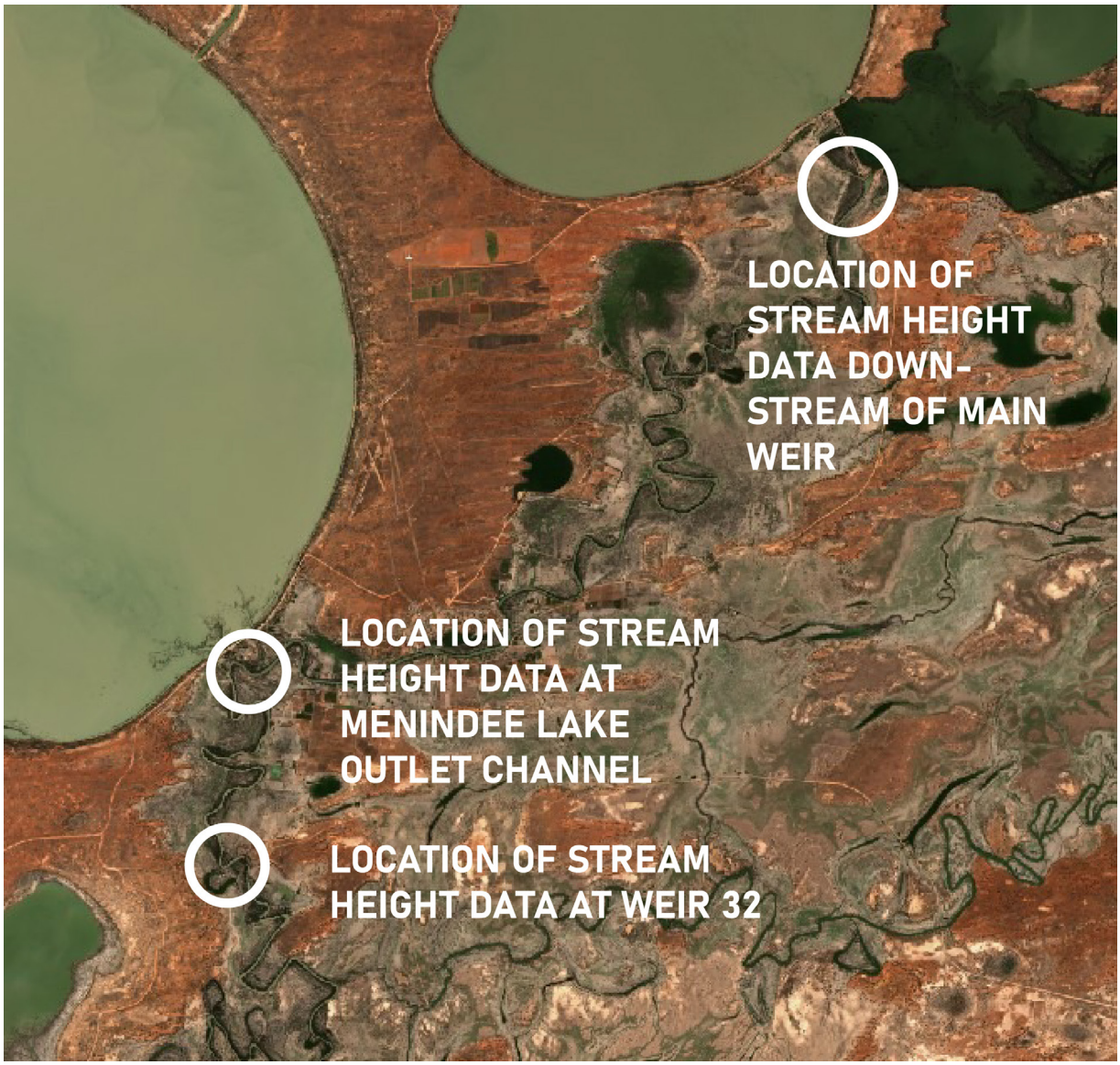


Figure 23 - Location of monitoring stations for stream height data

Data of all three monitoring stations shows stream heights steadily decreasing through early March until there is brief but fast rise in stream height from March 15th to March 16th (Figure 24). This correlates with satellite imagery showing the onset of blackwater discharges observable on March 14th, peaking at the date of the fish deaths which began on the evening of March 16th.

This rise in stream height is followed by a sharp decrease to March 19th, the day after local photographer Geoff Looney observed that the Wetherell Outlet was closed (March 18th). Satellite Imagery and on the ground observation showed that the Wetherell outlet had been open by March 14th .

As river operations returned to normal following the flood, this rise in stream heights is an anomaly.

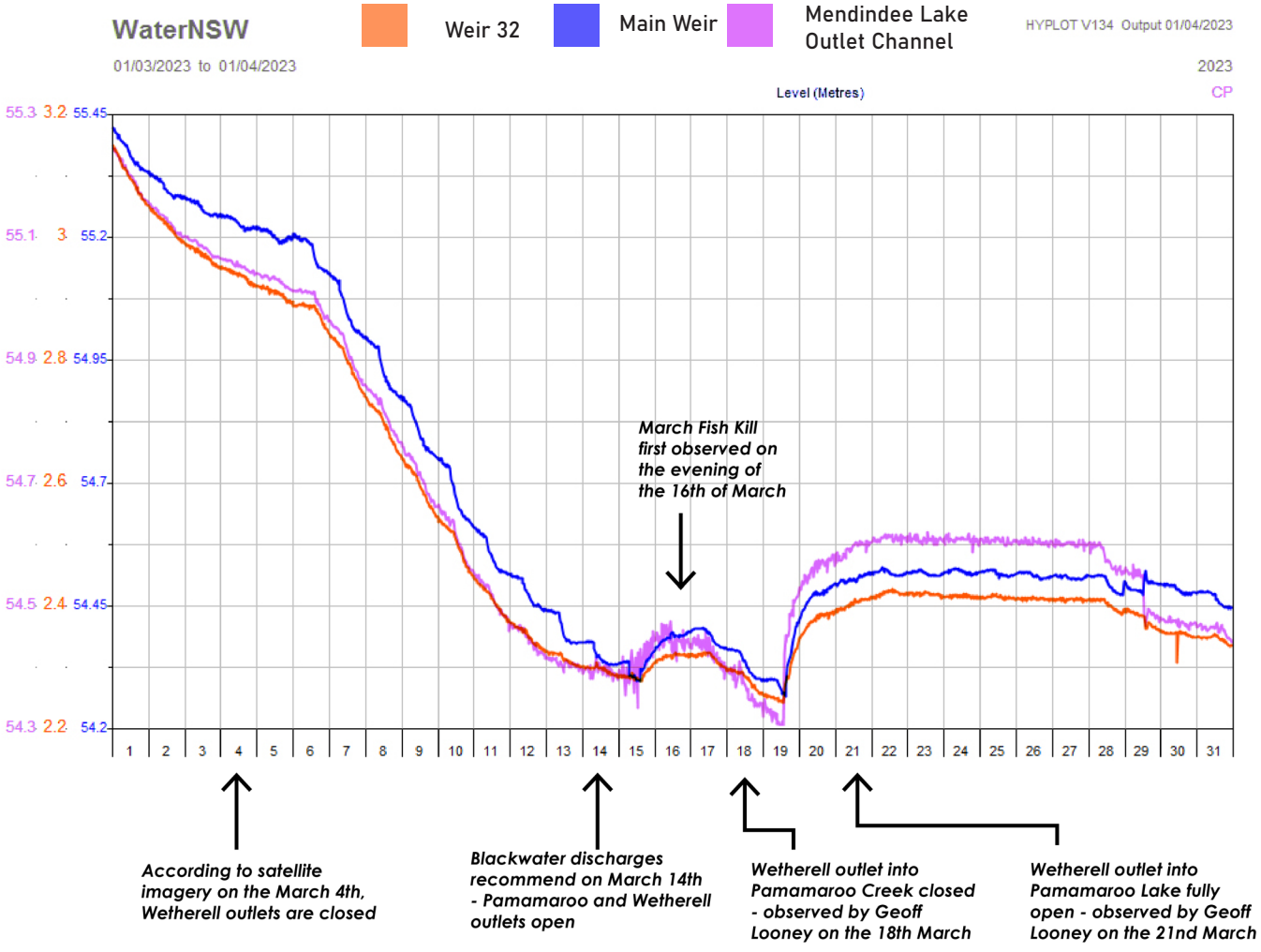


Figure 24 - Stream height data for all three monitoring stations along the length of regulated section of the Darling-Baaka River

Discussion & Analysis

NSW Government Rationale for the 2023 Fish Kill

Over a number of community meetings the Emergency Operations Centre (EOC) managing water quality for domestic use and the clean-up of fish carcasses in Menindee, presented their rationale for the immense scale of the mass fish kill. Their rationale is as follows (DPE, March 24 2023):

1. A very large blackwater event had moved downstream as floodwaters receded.

2. A heat wave coincided with this blackwater further decreasing the dissolved oxygen in the river.

3. The floods and higher than average rainfall over previous two years had created ideal breeding conditions for fish which were now trapped below the Main Weir at Menindee.

It appears the relevant agencies developed this rationale within 72 hours of the fish kill, despite insistence from the Menindee community that policy/management must have contributed to a fish kill of this scale.

When the Emergency Operations Centre was established on March 19, the NSW Police media release stated:

> *"The deaths are believed to be attributed to hypoxic blackwater, a naturally occurring phenomenon which causes extremely low dissolved oxygen levels. The scale of this event has been exacerbated by recent hot weather and significantly increased numbers of fish in the system as floodwaters recede. NSW Government agencies are continuing targeted releases of higher quality water where possible to boost dissolved oxygen levels in this area."*
>
> NSW Police March 19, 2023

The role of operational decisions to release blackwater prior to the mass fish kills were not publicly addressed by the Emergency Operations Centre. This is despite knowledge within the agencies represented in the EOC that releases of blackwater from Lake Wetherell into the regulated section of the Darling-Baaka River carried a risk of fish kills.

A ‘Naturally occurring phenomenon’

While blackwater events are a naturally occurring phenomenon, the scale of the blackwater that had flowed down the Darling-Barwon river system in early 2023 was on an unprecedented level. This presented a challenge for water authorities whose role it is to safely manage the hypoxic blackwater stored in Lake Wetherell.

According to operational and water quality updates from WaterNSW and the DPE, the strategy to manage the 2023 floods and resulting blackwater event included:

1. Closing the Main Weir on February 17th, 2023
2. Diluting blackwater with better quality water in Lake Pamamaroo in February, 2023
3. Ceasing releases from Lake Wetherell by February 27th due to fish deaths in the main river channel
4. Recommencing discharges from Lake Wetherell into Lake Pamamaroo to maintain the structural integrity of Lake Wetherell as it reached capacity
5. Progressively reduce outflows from Lake Pamamaroo and increase inflows of blackwater held in Lake Wetherell into Lake Pamamaroo

It is unclear what alternatives were considered or whether the strategy outlined above was implemented effectively to manage the blackwater held in Lake Wetherell while mitigating risks to aquatic life.

Active Monitoring of Dissolved Oxygen in High Risk Areas

The top part of the regulated section of the Darling-Baaka River is a known barrier to fish passage where large numbers of native fish become trapped below the Main Weir while they attempt to travel upstream. This is known to water authorities:

> *“After successive years of high flows and successful fish breeding events, a large biomass of fish is congregating in the reach of the Darling River between Lake Wetherell main weir and Menindee town.”*
>
> DPE Water Quality Update March 15, 2023

This barrier leaves fish vulnerable to sudden changes in water quality. The regulated section of the Darling-Baaka River is a known high risk site for fish deaths. (Vertessy, Barma et al. 2019) (Australian Academy of Science 2019)

After the mass fish kills of 2018 and 2019 it was found that the accumulation of fish biomass in the weir pool in Menindee contributed to the scale of the fish deaths. The *Independent assessment of the 2018–19 fish deaths in the lower Darling* states, “Ultimately, it was the rapid transition from very favourable conditions to very adverse ones that resulted in such high numbers of fish deaths.” (Vertessy, Barma et al. 2019, pp 8)

Dissolved oxygen is an important indicator for a river system to sustain aquatic life. This is well known to water authorities.

> *"As a general guide, native fish and other large aquatic organisms require at least 2 mg/L of dissolved oxygen to survive, but may begin to suffer if levels are below 4 to 5 mg/L for prolonged periods."*
>
> DPE Water Quality Update March 8, 2023

The only permanent monitoring site in the regulated section of the Darling-Baaka River for dissolved oxygen is at Weir 32.

The DPE were monitoring dissolved oxygen levels throughout March with the goal to implement the "best operational measures" available to river operators to "mitigate risks to aquatic life as much as possible" (DPE, March 15, 2023).

On March 14th the dissolved oxygen levels below the Main Weir were recorded at 2.35mg/L and 1.39mg/L in Menindee town (DPE March 15, 2023). The DPE reported a significant drop in dissolved oxygen levels below the Main Weir and in the main river channel (Figure 25). In the same report that they acknowledged the forecasted heatwave:

> *"NSW and Commonwealth agencies will continue to work together and monitor dissolved oxygen levels in this area and advise the best operational measures to mitigate risks to aquatic life as much as possible.*
>
> *With forecast heatwave conditions this weekend, to maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Lake Pamamaroo outlet will continue."*
>
> *DPE Water Quality Update March 15*

The DPE stated they aimed to maintain oxygenated flows down the regulated section of the Darling-Baaka River, however it is reasonable that discharges of low oxygen water from Lake Wetherell (1.49mg/L) directly via the Wetherell outlet and indirectly via the Pamamaroo outlet into this section of the river at this time, contributed to the drop in dissolved oxygen.

It is not known what information was communicated between departments, however the ingredients for a mass fish kill in the regulated section of the Darling-Baaka River were observed on March 15th (DPE March 15). Further investigation is needed to understand what advice was being provided to water authorities and why no adequate preventative measures were taken as these factors converged.

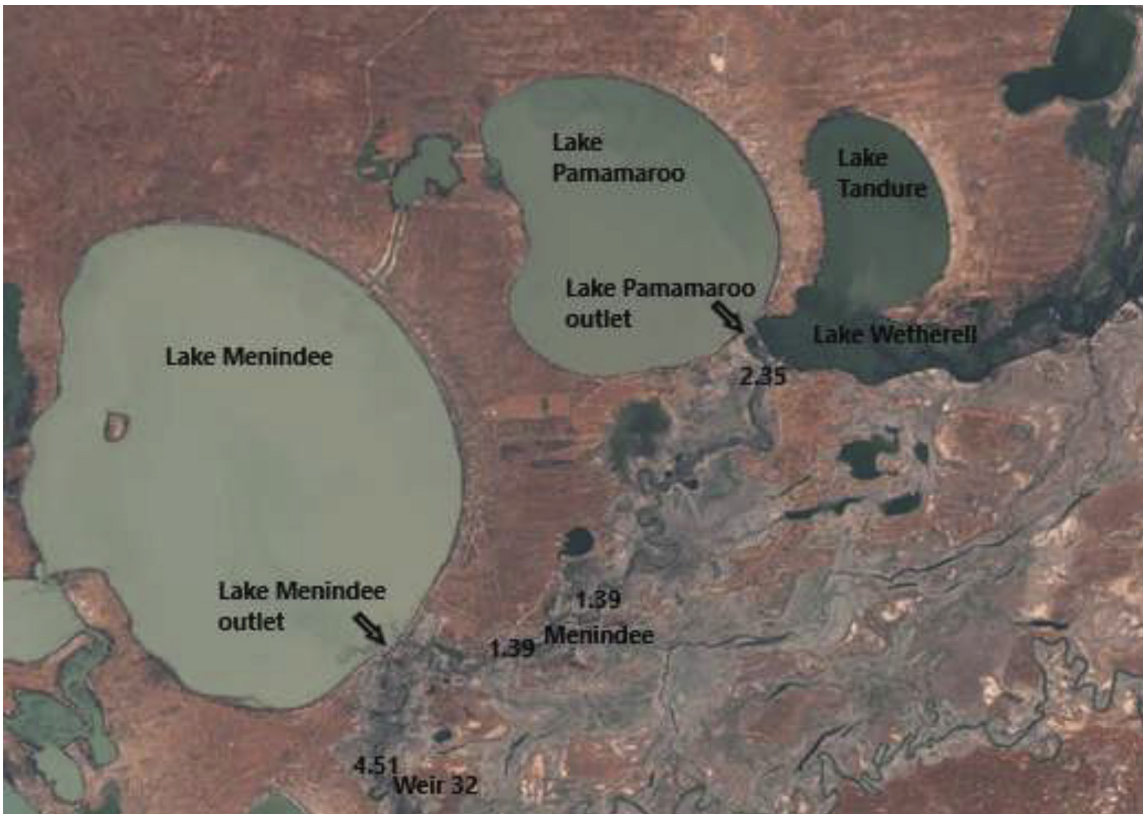


Figure 25 - Data collected 14 March (mg/L) by the DPE (DPE Water Quality Update March 15, 2023)

WaterNSW Communications Prior to Blackwater Discharge

The WaterNSW Operational Update of March 13th prior to the March mass fish kills states:

> *"The current Operational plan is for:*
>
> • *Pamamaroo outlet regulator gates to continue to close as soon as practical.*
> • *Pamamaroo inlet regulator to be opened progressively as the outlet closes.*
> • *Menindee Outlet regulator to continue to meet the majority of system targets at Weir-32*
> • *Flows below Weir-32 will continue to reduce until late-March 2023 where base flow and environmental delivery will continue.*
> • *Lake Cawndilla outlet regulator to maintain a flow of around 750 ML/d to meet environmental orders to Great Darling Anabranch throughout March."*
>
> WaterNSW, Operational Update March 13, 2023

The exact operational strategies to avoid blackwater being released into the regulated section of the Darling-Baaka River are unclear. However, according to the WaterNSW operational update of March 13th, it appears the operational plan was to reduce outflows from Lake Pamamaroo and increase inflows to Lake Pamamaroo to manage blackwater held in Lake Wetherell through the Menindee Lakes System.

By mid-March the capacity of Lake Wetherell had been reached and river operators chose to follow the sequence of releases trialled in February, as well as discharge blackwater directly into Pamamaroo Creek via the Wetherell outlet on/by March 14th.

A photograph by Geoff Looney on March 16th, the day the March mass fish deaths were first observed, shows the Pamamaroo outlet was open (Figure 26). Satellite imagery of blackwater entering Pamamaroo Lake can be observed on March 14th.

A close comparison of March 4th and March 14th satellite images shows the water level in Pamamaroo Creek does appear to reduce by March 14th as stated in the plan. As discharge from Lake Pamamaroo decreased, the role of potentially anoxic discharge from the Wetherell outlet may have been exacerbated.

Whether it was blackwater being discharged directly into Pamamaroo Creek via the Lake Wetherell outlet, or indirectly via the Pamamaroo outlet, the stated plan to mitigate risks to aquatic life in the regulated section of the Darling-Baaka River was unsuccessful. Further investigation is needed to understand how this operational plan was intended to mitigate risks to aquatic life in the regulated section of the Darling-Baaka River, and whether it was followed effectively.

Figure 26 - Menindee NSW Outback Photography by Geoff Looney - Documentation of releases from Lake Pamamaroo into Pamamaroo Creek - Photo taken 16.03.23

The Role of Above Average Temperatures in the March Mass Fish Kills

Communications from the EOC and water agencies cited a heat wave as one factor increasing the intensity of the fish kills from March 16th.

> *"The fish deaths are believed to be attributed to hypoxic blackwater, a naturally occurring phenomenon which causes extremely low dissolved oxygen levels. The scale of this event has been exacerbated by recent hot weather and significantly increased numbers of fish in the system as floodwaters recede."*
>
> WaterNSW, Menindee Lakes Community Update March 21, 2023

Maximum air temperature at the Menindee Post Office was above average for the period March 16 -19 (Table 1), however the onset of the fish kill began on March 16th and it was abundantly clear on the morning of March 17th that fish deaths numbered in the millions.

In the weeks leading up to the fish kill, daily maximum temperatures were only 0.2C above the 30-year average for March.

Table 1 - Mean Daily Max Temperatures for March 1991-2020, March 01-16,2023 and March 16-19,2023

Period	Mean Daily Max (C)	Notes
March 1991-2020	31.1	
March 01 -16, 2023	31.3	March fish kills observed March 16
March 16 -19, 2023	38.15	March Fish Kills continued

For comparison, above average temperatures were also recorded on March 4th and March 5th, with a two day average hotter than March 15th and 16th.
No fish kills were observed on March 4th and 5th (Table 2).

Table 2 - Two Day Averages for 04 March - 05 March and 15 March - 16 March

Date	Daily Max (C)	Two Day Average	Fish Kills
04-Mar-23	35.2	37	No Fish Kills Observed
05-Mar-23	38.8		
15-Mar-23	36.2	36.6	Fish Kills Observed starting on March 16
16-Mar-23	37		

During the temperature rise of March 4th and 5th there was an ongoing strategy to reoxygenate the river through better quality water releases from Lake Pamamaroo. At this time there were no blackwater releases making their way into the regulated section of the Darling-Baaka River via the Pamamaroo inlet/outlet or the Wetherell outlet and no fish kills were observed.

Communications from the EOC and water agencies correlate the March fish kills with above average temperatures. However, all documented fish kills correlate with controlled releases of blackwater into the regulated section of the Darling-Baaka River.

Water authorities were aware of a forecasted heatwave and stated that "*to maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Lake Pamamaroo outlet will continue."*

Further investigation needs to be conducted to know whether the strategy to reoxygenate the river, observable from February 27th and ceasing on March 14th, could have prevented the mass fish deaths during the temperature rise of mid-March.

Conclusion

A chronology of events constructed through a review of publicly available satellite imagery, and on ground photography shows controlled releases of blackwater from Lake Wetherell in March should be considered a contributing factor that led to the March 2023 Menindee mass fish kills.

This report demonstrates that water authorities discharged blackwater into the regulated section of the Darling-Baaka River via the Lake Pamamaroo outlet and directly via the Wetherell outlet on/by March 14th. This appears to be done knowing that similar releases in February resulted in fish deaths.

It remains unclear what management options were available to water authorities after it was found that February blackwater releases resulted in fish deaths, and whether any alternatives were considered. However, the trial and error release strategy to dilute blackwater held in Lake Wetherell with water from Lake Pamamaroo after the Main Weir was closed on February 17th, demonstrated that simply discharging a 'shandy' of these waters presented risk to aquatic life in the regulated section of the Darling-Baaka River.

This report only reviews the management decisions that immediately preceded the 2023 mass fish kills in Menindee. We recognize that the blackwater event in Lake Wetherell was on an unprecedented scale and managing this volume of blackwater in the system has never been done before.

However, the knowledge that blackwater releases were impacting fish health in February should have warranted a consideration of the risk of further blackwater releases; including:

- the timing of these releases in relation to forecasted temperatures
- preparedness for fish deaths
- a review of all management options available to river operators to limit risk to water quality in the regulated section of the Darling-Baaka River

Public statements made by WaterNSW and the NSW Department of Planning and Environment have not communicated disaster preparedness before releases of blackwater were made on/by March 14th.

Furthermore, the decision to discharge blackwater into the regulated section of the Darling-Baaka River was not communicated by water authorities to the Menindee community prior to the releases, or during the community meetings held by the Emergency Operations Centre at Menindee after the mass fish kill had occurred.

The DPE stated prior to and after the fish kills that releases of “oxygenated flows” from Lake Pamamaroo were being maintained, however this report highlights the inconsistency between the stated plan and reality of what happened. This report challenges the statement by WaterNSW that “very limited management actions could have prevented [the mass fish kills].” (WaterNSW, March 21, 2023)

This investigation was completed without flow rate data from any Menindee Lake System outlet or comprehensive field monitoring data of dissolved oxygen. It relies on data available only in the public domain and some additional photographs provided by Menindee resident Geoff Looney from his personal archive.

The purpose of this report is to provide sufficient evidence for further investigation into the role of controlled releases of blackwater in the 2023 Menindee Fish Kills, and the reasoning behind these releases.

This analysis of publicly available data has shown that operational decisions to discharge blackwater into the regulated section of the Darling-Baaka River are at least in part responsible, and that it is reasonable that water authorities were aware of the risks of these discharges. However, further investigation at the highest levels is required to determine the responsibility of water agencies in the 2023 Menindee mass fish kills.

Recommendations to the NSW Government’s 2023 Menindee Fish Kill Inquiry

On Wednesday the 29th of March the incoming NSW Government visited Menindee to announce an inquiry into the causes of the 2023 Menindee mass fish kills. According to the information laid out in this report, this inquiry must include:

- A detailed analysis of releases from all regulators at Menindee Lakes, in particular all regulators at Lake Pamamaroo and Lake Wetherell where blackwater discharges occurred, including:

1. A review of the timing of discharges from Pamamaroo inlet while there was still releases from the Pamamaroo outlet regulator around March 14th, 2023. Was this managed sufficiently to avoid blackwater being drawn into the regulated section of the Darling-Baaka River, as was documented in February, 2023?
2. A review into why blackwater held in Lake Wetherell was discharging directly into Pamamaroo Creek on/by March 14th, 2023.

- A review of why no action was taken on March 14th, 2023 when dissolved oxygen readings were below 2 mg/L in Menindee town and there was a forecasted temperature rise.

- A review of the research and rationale for the blackwater discharges made on/by March 14th. What (if any) scientific evidence was used to justify this management decision?

- A review of what engineering and/or management solutions were available to water authorities to manage blackwater held in Lake Wetherell and whether any alternatives were considered as viable options.

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WaterNSW, Operations Update, March 3, 2023

WaterNSW, Operations Update, March 13, 2023

WaterNSW, Operations Update, March 29, 2023

Author Information and Contact

Megan Williams has an undergraduate degree in Environmental Science and Social Science (environment) from RMIT University. They are the Station Manager at 2DRY FM in Broken Hill, creator and co-host of *Water Watch Radio*. They previously worked for water research consultancy *Slattery & Johnson* and as the *River Country Coordinator at Friends of the Earth Melbourne*. Prior to that they work as a field technician monitoring contaminated groundwater.

Dan Schulz is currently a PhD student at the Crawford School of Public Policy at the Australian National University. Their research looks at the previous 30 years of water policy and management in relation to the Darling-Baaka River and Menindee Lakes. Dan is a visual artist, filmmaker, and co-creator of *Water Watch Radio* at Broken Hill's community radio station, 2DRY FM. The research in this report was conducted independently of any institutional support and is not affiliated with Dan's research activities at the Australian National University. For more information on the research practice of Dan Schulz visit www.fluidfronts.com

The authors live and work on Barkindji & Wilyakali Country, in Broken Hill, Menindee & Wilcannia, NSW, and pay their deepest respects to the Traditional Owners of the land and waterways on which they live and work.

To contact the authors of this report please email waterwatchradio@gmail.com with the subject heading *2023 Menindee Mass Fish Kill Report*.

Appendix A - Wetherell outlet - Location of offtake structure

Stratification in reservoirs and lakes can cause a variety of water quality issues. In lakes where there is a high concentration of biological material, the bottom most layer of the water column can become anoxic as the biological oxygen demand at the sediment-water interface is highest (water layers shown below).

The bottom most layer is where anoxic waters are most likely occur, especially in nutrient rich environments. Anoxic water depleted of oxygen is a known cause of fish kills. (Steichen, Garton and Rice 1979) (Boys, Baldwin et al. 2021)

The Wetherell outlet that releases flows into Pamamaroo Creek receives its water intake from the lowest strata of Lake Wetherell, as the offtake structure is located on the lake bed. In a severe blackwater event such as what had occurred in Lake Wetherell in 2023, anoxic blackwater had likely accumulated at the bottom most layer of the reservoir (Figure 15). In this case, the Wetherell outlet is the worst possible choice of releases for dissolved oxygen outcomes in the regulated section of the Darling-Baaka River.

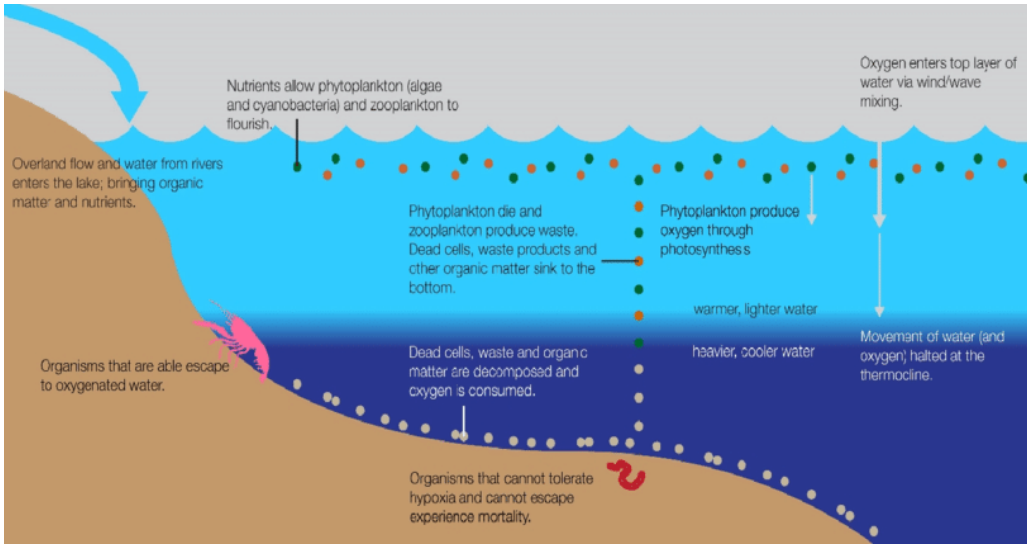


Diagram of stratification with lowest oxygen layer on the lake bed (Wackler, Babb-Brott et al. 2017)

Lake Wetherell pictured 11 March 2020. Offtake structure draws water from the bottom of the lake bed. Photo by Dan Schulz

Appendix B - Temperature Table

Date	Day	Min Temp (C)	Max Temp (C)	Water Temp (C)
17-Feb-23	Friday	26.2	43.2	25.19
18-Feb-23	Saturday	21.8	35	25.75
19-Feb-23	Sunday	17	35.7	25.54
20-Feb-23	Monday	18	39	25.12
21-Feb-23	Tuesday	17.8	39.1	24.83
22-Feb-23	Wednesday	17.2	37.2	24.69
23-Feb-23	Thursday	16.5	35.7	25.16
24-Feb-23	Friday	22.3	36.9	25.5
25-Feb-23	Saturday	21.6	37.4	26.1
26-Feb-23	Sunday	19.6	30.8	25.8
27-Feb-23	Monday	17.5	32	25.1
28-Feb-23	Tuesday	17	34.2	24.6
01-Mar-23	Wednesday	16.3	27.5	24
02-Mar-23	Thursday	15.5	30.2	23.5
03-Mar-23	Friday	15.7	31.3	22.9
04-Mar-23	Saturday	16	35.2	22.8
05-Mar-23	Sunday	18.6	38.8	23.6
06-Mar-23	Monday	17.6	30.5	23.8
07-Mar-23	Tuesday	17.3	29	24.3
08-Mar-23	Wednesday	15	28	23.8
09-Mar-23	Thursday	12.7	25	23
10-Mar-23	Friday	11.2	29.2	22.4
11-Mar-23	Saturday	14.4	32.9	22.6

12-Mar-23	Sunday	18.2	28.1	23.3
13-Mar-23	Monday	14.5	29.5	22.6
14-Mar-23	Tuesday	14.2	33	22.4
15-Mar-23	Wednesday	16	36.2	23.7
16-Mar-23	Thursday	19	37	23.4
17-Mar-23	Friday	16	33.8	22.9
18-Mar-23	Saturday	19.2	42.6	23.7
19-Mar-23	Sunday	20.6	39.2	24.9
20-Mar-23	Monday	19.2	31.2	24.2
21-Mar-23	Tuesday	19.4	28.5	23.2
22-Mar-23	Wednesday	18	34.2	22.1
23-Mar-23	Thursday	17.6	36	23.6
24-Mar-23	Friday	18.2	31.4	23.6
25-Mar-23	Saturday	16.2	27.8	22.5
26-Mar-23	Sunday	12.9	28.2	21.9
27-Mar-23	Monday	14	29.7	22.2
28-Mar-23	Tuesday	18.4	29	22.2
29-Mar-23	Wednesday	17.1	25	22.3
30-Mar-23	Thursday	12	23.2	21.8

Source: Bureau of Meterology

OPERATIONS UPDATE

Increase to releases expected in the coming days

28th December 2022

This is a WaterNSW customer and community update on the Menindee Lakes flood release plan.

Observations over the past 7 days are indicating the trend of higher volumes of unaccounted water entering the Menindee Lake system is continuing. 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, these additional flows are filling the available airspace within the Lake system at a rate far greater than previously forecast.

Inflows to the Menindee lakes system are currently being observed at a rate greater than 70GL/d. These flows are continuing to see gains, indicating insufficient airspace is available in the lakes to absorb the flood peak. Adjustments to the operating arrangement will result in increased releases from the storages to pass inflows once storages are full. This will inherently result in a rise to the levels observed at the Menindee town gauge and community members should consult the BOM for the most up to date information on expected levels.

WaterNSW are continually monitoring this situation and are continually reassessing the situation throughout the event. Monitoring teams are on ground to ascertain the extent of these additional inflows and how they are impacting operational arrangements. WaterNSW are working closely with the SES as to the timing of the increased release with the current strategy bring to maintain releases to target the **9.6m** at the town gauge for as long as possible. This is utilising all available airspace in the storages and pushing the lakes to surcharge before increasing release. WaterNSW is notifying effected landholders and resident to prepare for further increases to the town gauge in the **coming days**.

WaterNSW encourages effected landholders and resident to prepare for this increase to releases. We remain committed to providing ongoing updates throughout the event and will be issuing changes to the public as they occur. WaterNSW are continuing regular consultation with LEMC, SES and the BOM in release decisions throughout the event.

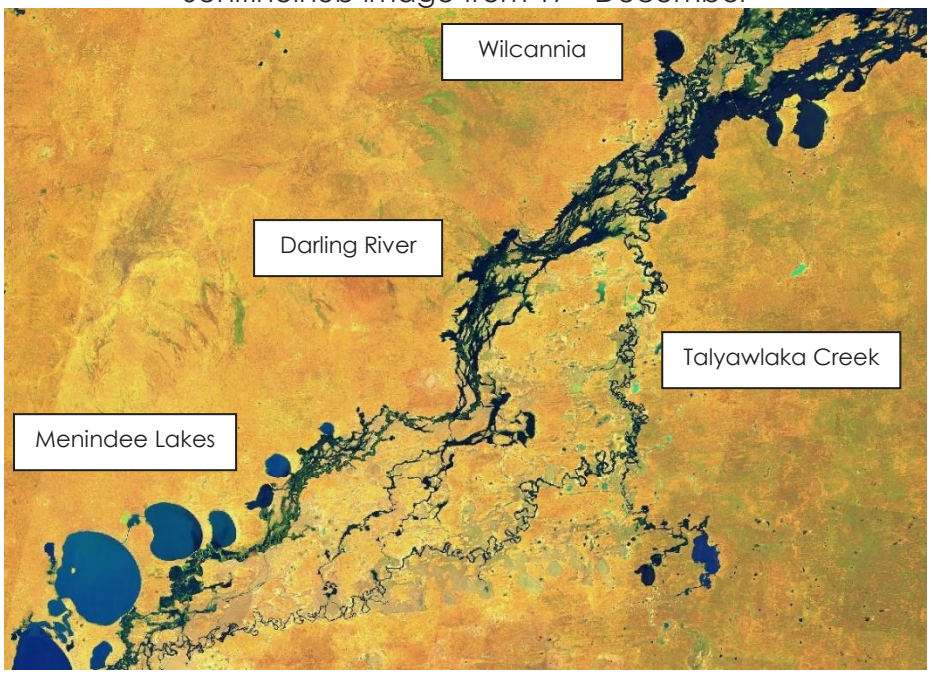
As the water levels continue to rise, under the State Flood Plan, the Bureau of Meteorology is responsible for providing information of river heights and flood warnings, while the State Emergency Service is the lead combat agency. You can find the latest and most up to date forecast for the area on the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

Current System Status as of the 28th of December 2022

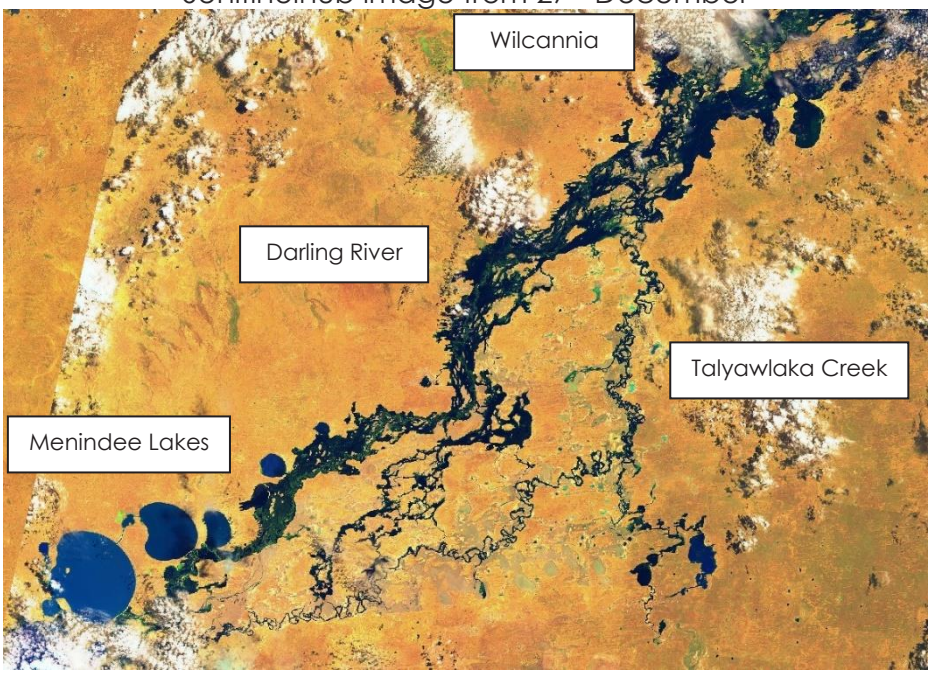
	Storage Level (mAHD)	Storage Volume (GL)	Capacity
Lake Wetherell + Tandure	61.87	213	110%
Lake Pamamaroo + Copi Hollow	60.21	332	120%
Lake Menindee	60.38	718	114%
Lake Cawndilla	60.39	698	111%
TOTAL		**1,960 GL**	**113%**

WaterNSW ABN 21 147 934 787
169 Macquarie Street Parramatta NSW 2150
PO Box 398, Parramatta NSW 2124
T 1300 662 077 E Customer.Helpdesk@waternsw.com.au **waternsw.com.au**

Senitinelhub image from 17th December



Senitinelhub image from 27th December



Credit: Sentinelhub Playground apps.sentinel-hub.com/sentinel-playground (27 –12 –22)
https://apps.sentinel-hub.com/sentinel-playground/?source=S2&lat=-31.992353668990656&lng=142.62176513671875&zoom=10&preset=4_AGRICULTURE&layers=B01,B02,B03&maxcc=100&gain=1.0&gamma=1.0&time=2022-06-01%7C2022-12-27&atmFilter=&showDates=false&showImage

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WaterNSW ABN 21 147 934 787
169 Macquarie Street Parramatta NSW 2150
PO Box 398, Parramatta NSW 2124
T 1300 662 077 E Customer.Helpdesk@waternsw.com.au
waternsw.com.au

OPERATIONS UPDATE

Transition from Flood Operations to Standard Operations
Update on Lower Darling Release Plan

17 February 2023

WaterNSW is advising customers and community on updates to the Menindee release plan following recent flood operations at the Lake system.

The high inflows to the Menindee Lake system experienced throughout recent months resulting from the widespread rainfall events in 2022 across the Barwon-Darling catchment, are continuing to decrease as seen throughout January and February 2023.

The major flood event experienced around the Menindee township reached peak level in January and has since been receding where the community has and will continue to see gradual decreases from the current observed level at Menindee Town gauge. Throughout the flood operations, we have been making gradual reductions to releases to control the rate of fall.

As we transition from over 9 months of flood operations to Business As Usual (BAU), the operations plan is to continue recession of river flows by continued reduction in lake releases. Future demand targets have been identified fin consultation with stakeholders including Murray Darling Basin authority Environment Water Managers, and Fisheries to address environmental and water quality requirements.

Operationally, when the flow at Weir-32 is less than 10,000 ML/day the rate of fall will be a maximum of 500 ML/d . This strategy aims to maintain bank stability and prolong the recession hydrograph if the inflows are higher than forecast. When the flow at Weir-32 is less tha 5,000 ML/day then the reduction would be at a maximum rate of 250 ML/day until the flows reach the base flow targets. The adopted rate of fall is aper the Work Approval conditions.

Darling River below the Weir-32 is still experiencing flooding from water re-entering the main channel from the floodplain and continued inflows from the Talyawalka Creek. Our water monitoring team are undertaking regular inspections and flow gauging activities with the aim

of reinstating rating tables at those station where they were turned off due to backwater impacts as per standard procedures.

Operational plans for the coming weeks are 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.

The Menindee storages still remain above full supply level (FSL) and are expected to reduce to near full supply level (FSL) in early March 2023 as per operating rules.

Current System Status as of the 17th of February of 2023

	Storage Level (mAHD)	Storage Volume (GL)	Capacity
Lake Wetherell + Tandure	61.30	158	82%
Lake Pamamaroo + Copi Hollow	61.22	333	120%
Lake Menindee	60.17	683	109%
Lake Cawndilla	60.16	670	106%
TOTAL		**1,844 GL**	**107%**

Issued by: Water System Operations – South

OPERATIONS UPDATE

Operations Update on Lower Darling Release Plan

3 March 2023

WaterNSW is advising customers and the wider community of update to the Menindee release plan following recent water quality issues and amended operations at the Lake System.

The operations plan is to continue recession of lake releases over coming weeks to target flows at Weir-32 as per the Water Sharing Plan.

As a result of the poor water quality issues being experienced downstream of the Menindee Lake system, the operations and release strategy is being guided by advice from Department of Planning and Environment (DPE) and other NSW and Commonwealth water agencies.

DPE is providing regular updates and information sheets advising of current water quality monitoring and remediation actions undertaken by multiple agencies. Links to these sources of information are provide below:

DPE - Water Quality Update 24 February 2023
DPE – Water Quality Update 3 March 2023
DPE – Hypoxic Blackwater information

Water releases into the Darling River from water quality allowances are being targeted to ensure the best chance of achieving better dissolved oxygen levels, to reduce the chance of further fish deaths.

WaterNSW ABN 21 147 934 787
169 Macquarie Street Parramatta NSW 2150
PO Box 398, Parramatta NSW 2124
T 1300 662 077 E Customer.Helpdesk@waternsw.com.au
waternsw.com.au

Operationally, when the flow at Weir-32 is less than 10,000 ML/day, the rate of fall will be a maximum of 500 ML/d. When the flow at Weir-32 is less than 5,000 ML/day then the reduction would be at a maximum rate of 250 ML/day until the flows reach the base flow targets. Operational plans for the coming weeks are as follows:

- Pamamaroo outlet regulator gates to be kept open to release flows into the Lower Darling River ensuring better quality water into the system.
- Menindee Outlet regulator will continue to meet the majority of system targets at Weir-32
- Flows below Weir-32 will continue to reduce until mid-March 2023 for base flow and environmental delivery.
- Lake Cawndilla outlet regulator to maintain a flow of 750 ML/d to meet environmental orders to Great Darling Anabranch throughout March into April.

The Menindee storages are currently at full supply level (FSL) and are expected to reduce to 90% by the end of March 2023 as per the current demands and operations plan.

Current System Status as of the 3 March 2023

	Storage Level (mAHD)	Storage Volume (GL)	Capacity
Lake Wetherell + Tandure	61.25	156	81%
Lake Pamamaroo + Copi Hollow	60.67	293	106%
Lake Menindee	59.88	636	101%
Lake Cawndilla	59.85	632	100%
TOTAL		**1,718 GL**	**99%**

Issued by: Water System Operations – South

OPERATIONS UPDATE

Operations Update on Lower Darling Release Plan

13th March 2023

WaterNSW is advising customers and the wider community of updates to the Menindee release plan following recent water quality issues and amended operations at the Lake System.

Since our previous update the recession was postponed for a period as a result of poor water quality issues being experienced downstream of the Menindee Lake system. The operations and release strategy is currently being guided by advice from Department of Planning and Environment (DPE) and other NSW and Commonwealth water agencies with the use of the Environmental Water Allowance (EWA) and eWater contributing to the management of the current event. The recession was continued after a period, at a slower rate of 250ML/d. This is expected to continue at this rate until the end of the month where demand is required or base flows are realised, see attached Menindee Lakes release forecast.

Flows at the combined outlets are around 5,500ML/d today with flows at the Weir 32 gauge still being affected by backwater from the Talyawalka Creek. Monitoring teams are continuing to assess when the Weir 32 gauge can accurately report flows with data being available via our Real Time Data and Water Insights portals once established.

DPE is providing regular updates and information sheets advising of current water quality monitoring and remediation actions undertaken by multiple agencies. Links to these sources of information are provide below:

DPE - Water Quality Update 24 February 2023

DPE – Water Quality Update 2 March 2023

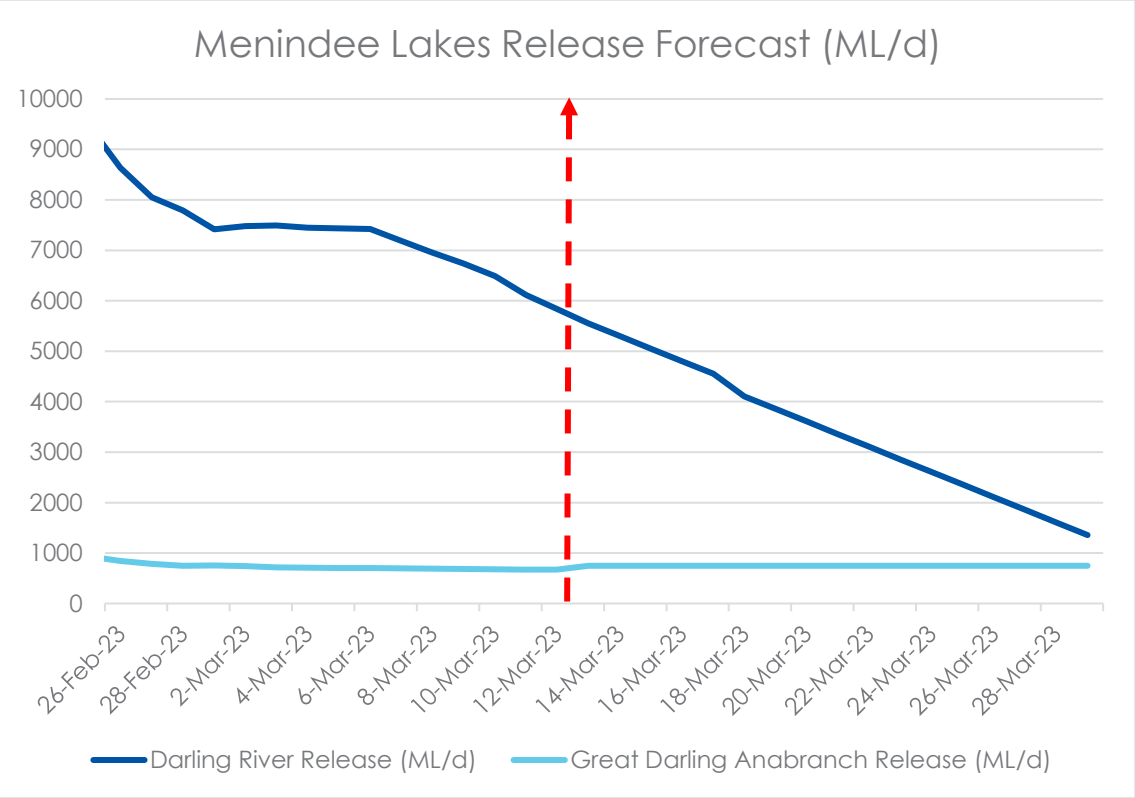
DPE – Water Quality Update 8 March 2023

DPE – Hypoxic Blackwater information

Water releases into the Darling River from water quality allowances are being targeted to ensure the best chance of achieving better dissolved oxygen levels, to reduce the chance of further fish deaths.

The current Operational plan is for:

- Pamamaroo outlet regulator gates to continue to close as soon as practical.
- Pamamaroo inlet regulator to be opened progressively as the outlet closes.
- Menindee Outlet regulator to continue to meet the majority of system targets at Weir-32
- Flows below Weir-32 will continue to reduce until late-March 2023 where base flow and environmental delivery will continue.
- Lake Cawndilla outlet regulator to maintain a flow of around 750 ML/d to meet environmental orders to Great Darling Anabranch throughout March.



Current System Status as of the 13 March 2023

	Storage Level (mAHD)	Storage Volume (GL)	Capacity
Lake Wetherell + Tandure	61.41	196	88%
Lake Pamamaroo + Copi Hollow	60.17	258	93%
Lake Menindee	59.70	607	96%
Lake Cawndilla	59.67	611	97%
TOTAL		**1,645 GL**	**95%**

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WaterNSW ABN 21 147 934 787
169 Macquarie Street Parramatta NSW 2150
PO Box 398, Parramatta NSW 2124
T 1300 662 077 E Customer.Helpdesk@waternsw.com.au
waternsw.com.au

OPERATIONS UPDATE

Operations Update on Lower Darling Release Plan

29th March 2023

WaterNSW is advising customers and the wider community of updates to the Menindee release plan following recent water quality issues and amended operations at the Lake System.

The operations and release of water are currently being guided by advice from the Department of Planning and Environment (DPE) and other NSW and Commonwealth partner agencies. The use of the Environmental Water Allowance (EWA) and eWater are contributing to the active management and monitoring response being undertaken. Water releases into the Darling-Baaka River are being targeted to ensure the best chance of achieving better dissolved oxygen levels, to reduce the chance of further fish deaths.

As part of this strategy, recommendations have been made to increase releases from Lake Pamamaroo in an effort to assist the situation within the Menindee town weir pool. Flows at Weir 32 are currently around 5,000ML/day and are expected to experience minor fluctuations as system changes are made to releases over the next 24 hours, these changes are a result of balancing water delivery between the Pamamaroo and Menindee outlets.

Downstream users are being advised that flows may fluctuate over coming days based on decisions made in managing the current event. WaterNSW advises customers and landholders to monitor warnings and river levels closely to make necessary arrangements and ensure infrastructure and livestock are not impacted by the potential for changes to release.

WaterNSW will be issuing changes made to releases via the Early Warning Network (EWN) which can be subscribed to HERE. Coupled with this the Weir 32 and Menindee Town gauge data is available via our Real Time Data and Water Insights portals.

DPE is providing regular updates and information sheets advising of current water quality monitoring and remediation actions undertaken by multiple agencies. Links to these sources of information can be found here: DPE – Hypoxic Blackwater information

WaterNSW ABN 21 147 934 787
169 Macquarie Street Parramatta NSW 2150
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T 1300 662 077 E Customer.Helpdesk@waternsw.com.au
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Current System Status as of the 29 March 2023

	Storage Level (mAHD)	Storage Volume (GL)	Capacity
Lake Wetherell + Tandure	61.41	169	88%
Lake Pamamaroo + Copi Hollow	60.10	253	91%
Lake Menindee	59.39	546	87%
Lake Cawndilla	59.39	577	82%
TOTAL		**1546 GL**	**89%**

Issued by: Water System Operations – South

Department of Planning and Environment

Water Quality Update – 24 February 2023

Murray Darling Basin – water quality and dissolved oxygen results

Multiple agencies are undertaking water quality monitoring to review dissolved oxygen conditions across NSW and identify potential risks to ecological communities. This update provides a summary of information collected up to 24 February 2023.

The main focus of activities is on Menindee Lakes and the lower Darling River. Dissolved oxygen in these areas is at levels that could be detrimental to fish health. There have been reports of fish deaths (predominantly Carp and Bony Herring) in the upper reaches of Lake Wetherell and in the Darling River downstream of Lake Wetherell and downstream of Weir 32. NSW and Commonwealth agencies will continue to assess the risks in this area as low oxygen water makes its way into Menindee Lakes and the lower Darling River and to monitor dissolved oxygen levels while air temperatures remain high. Ongoing monitoring will inform the best operational measures to mitigate risks to aquatic life as much as possible.

River levels in the lower Darling River have receded to a minor flood warning alert for Pooncarie and Burtundy. As the river level drops, floodwaters are draining off the floodplain and back into the main river channel upstream of Pooncarie. This can bring low oxygen water into the Darling River.

The Bureau of Meteorology has forecast maximum air temperatures in far western New South Wales will increase up towards 40°C this week before returning to cooler temperatures again next week. As air temperature increases, so does the water temperature. The amount of dissolved oxygen water can hold decreases with increasing water temperature which can add additional stress to fish that may already be struggling in areas of concern.

As flows recede, fish may become stranded in disconnected waterbodies on the floodplain where they may suffer from exposure to declining water quality and dissolved oxygen, higher air and water temperatures and predators as water depth decreases and these waterbodies eventually dry out.

To report dead fish, fish struggling or starting to gasp at the water surface, or crayfish exiting the water please call the New South Wales Department of Primary Industries Fisheries, Fishers Watch Phoneline 1800 043 536 or fill in a fish kill protocol and report form at: https://www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

Dissolved oxygen levels – Menindee Lakes

WaterNSW are transitioning from flood operations to normal operations at Menindee Lakes as inflows from the Darling River decline. Figure 1 is a satellite-derived Sentinel colour infrared image showing the Darling River and Menindee Lakes at Menindee on 22 February. The image highlights the floodwater upstream of Lake Wetherell has returned to the main river channel. Similarly, floodwater has receded downstream of Menindee township.

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The image also highlights the darker-coloured flood water from Lake Wetherell pushing into lakes Pamamaroo and Tandure where it is mixing with the turbid water (blue colour) held in the lakes. As well as the mixing of floodwater with the more oxygenated water in the lakes, these large shallow lakes allow the water to be more quickly aerated and provide refuge areas for smaller fish and crustaceans to move into if dissolved oxygen conditions deteriorate in Lake Wetherell. As flooding continues to decrease, there will be some ability to manipulate or divert a portion of the low oxygen flood flows into the shallow lakes, as was achieved successfully during last year's flood event.

To assess the impact the low dissolved oxygen floodwater is having on Menindee Lakes and the Darling River, and to guide flow management decisions, dissolved oxygen monitoring was undertaken on 20 to 22 February. The dissolved oxygen results (in mg/L) are shown in Figure 1. These samples were taken close to the water surface during the day with all results from the lakes above 2 mg/L. The lowest readings were in the upper reaches of Lake Wetherell. There were lower readings in the Darling River at Menindee town (1.58 mg/L) and upstream of the town (1.65 mg/L). As a general guide, native fish and other large aquatic organisms require at least 2 mg/L of dissolved oxygen to survive but may begin to suffer if levels are below 4 to 5 mg/L for prolonged periods.

Lower dissolved oxygen results are being observed overnight and early in the morning in some areas. Dissolved oxygen levels drop overnight when respiration (microbes and animals breathing oxygen) outpaces oxygen replenishment (photosynthesis from aquatic plants and algae) that occurs during the day.

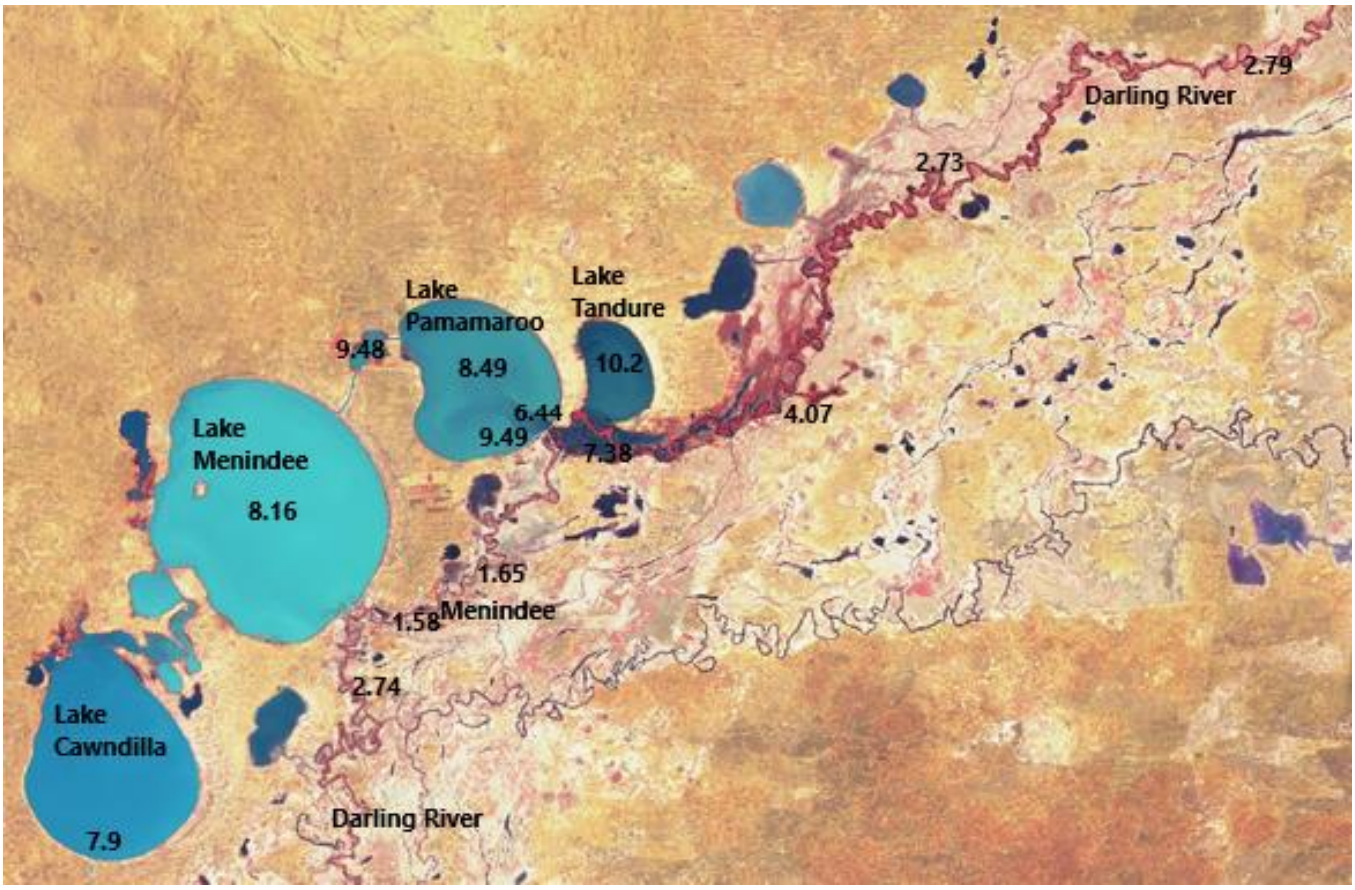

Figure 1: Satellite derived Sentinel colour infrared image of the Darling River and Menindee Lakes, 22 February 2023. Dissolved oxygen results are in mg/L

Dissolved oxygen levels in the Darling River at Wilcannia have been steadily improving as river levels fall and the last of the water returns to the main channel from the floodplain (Figure 2). This indicates that oxygenated water is making its way toward Lake Wetherell. Dissolved oxygen levels in the upper reaches of Lake Wetherell at Nellia Gaari are less than 2 mg/L as the low dissolved oxygen water that was at Wilcannia in late January makes its way through Lake Wetherell.

High concentrations of nutrients such as nitrogen and phosphorus have been flushed into the rivers during flooding. These nutrient-rich inflows combined with warm, still water provide ideal conditions for the growth of potentially toxic blue-green algae and increases the risk that dissolved oxygen levels could deteriorate in this area.

NSW and Commonwealth agencies will continue to work together to assess the risks as floodwaters make their way through Menindee Lakes and into the lower Darling River. The agencies will monitor dissolved oxygen levels throughout the river system and advise the best operational measures to mitigate risks to aquatic life as much as possible. This can involve:

- transferring water between the Menindee Lakes to mix the low dissolved oxygen water in Lake Wetherell with the better quality water in the other Lakes
- adjusting the timing, size and location of releases from the Lakes into the lower Darling River to maintain the water quality in the main river.

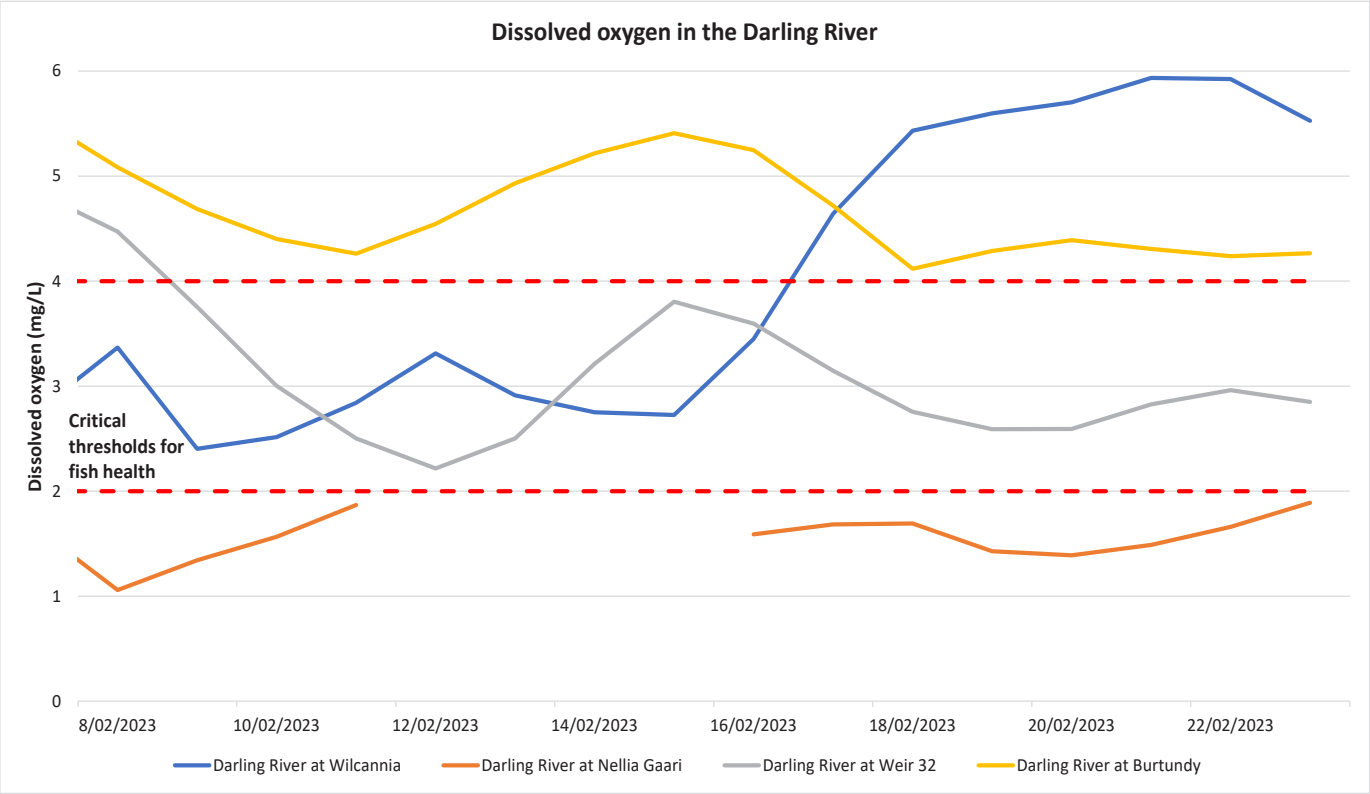

Figure 2: Mean daily dissolved oxygen (mg/L) in the Darling River at Wilcannia, Nellia Gaari, Weir 32 and Burtundy – 8 to 23 February 2023

Dissolved oxygen levels – lower Darling River

Flooding in the lower Darling River has decreased to the minor flood warning level at Pooncarie and Burtundy. Dissolved oxygen in the Darling River downstream of Menindee at Weir 32 had been decreasing toward 2 mg/L but has stabilised at around 3 mg/L in recent days.

The flooding of higher areas of the lower Darling River floodplain that have not been inundated since 2012 will flush organic material such as sticks, leaves, bark and grass into the river system. The breakdown of this organic material by bacteria uses up the oxygen in the water which can impact fish health. Despite this water returning off the floodplain, dissolved oxygen in the Darling River at Burtundy has remained above 4 mg/L (Figure 2).

Hypoxic blackwater fish death summary

In recent months NSW DPI Fisheries has received reports of fish deaths, fish struggling and crustaceans leaving the water across a broad area in the Murray-Darling Basin, including in the Murray, Kolety/Edward, Wakool, Murrumbidgee, Lachlan, Gwydir, Darling, Barwon, Namoi and Macquarie rivers and Yanco-Billabong Creek system. High air temperatures increase the risk of further reductions in dissolved oxygen in some areas and the potential for further fish death events.

There have been three confirmed fish death events in the Darling River near Menindee related to poor water quality: in the upper reaches of Lake Wetherell, the Darling River downstream of Lake Wetherell and the Darling River between Menindee and Pooncarie. In all three cases predominantly Common Carp and Bony Herring were affected, with a small number of Murray Cod and yabbies also impacted.

NSW agencies are working together to investigate and determine if any other native fish have been affected. There may be fish death incidents that have not yet been reported directly to NSW Department of Primary Industries Fisheries.

Programs to benefit native fish such as improving fish passage and habitat restoration to provide conditions conducive to fish breeding and population growth are ongoing. These works are vital and provide an environment where fish populations can bounce back from low oxygen events.

What is being done?

Releases into the lower Darling River are being made from Lake Wetherell, Lake Pamamaroo and Lake Menindee. The location of these outlets is shown in Figure 3.

Monitoring is showing the quality of the water in Lake Pamamaroo is better than in Lake Wetherell. To maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of fish deaths, the Lake Wetherell outlet will be reduced while the Pamamaroo outlet will remain open. Flows out of Pamamaroo will be maintained at higher levels, rather than returning to normal operations, over the next few days while heat wave conditions prevail. This will provide a flow of more oxygenated water into the Darling River upstream of Menindee town. The flow will also be of sufficient velocity that research has shown provides conditions that are less favourable for harmful algal growth. Ongoing monitoring will identify if the operations are achieving the desired results.

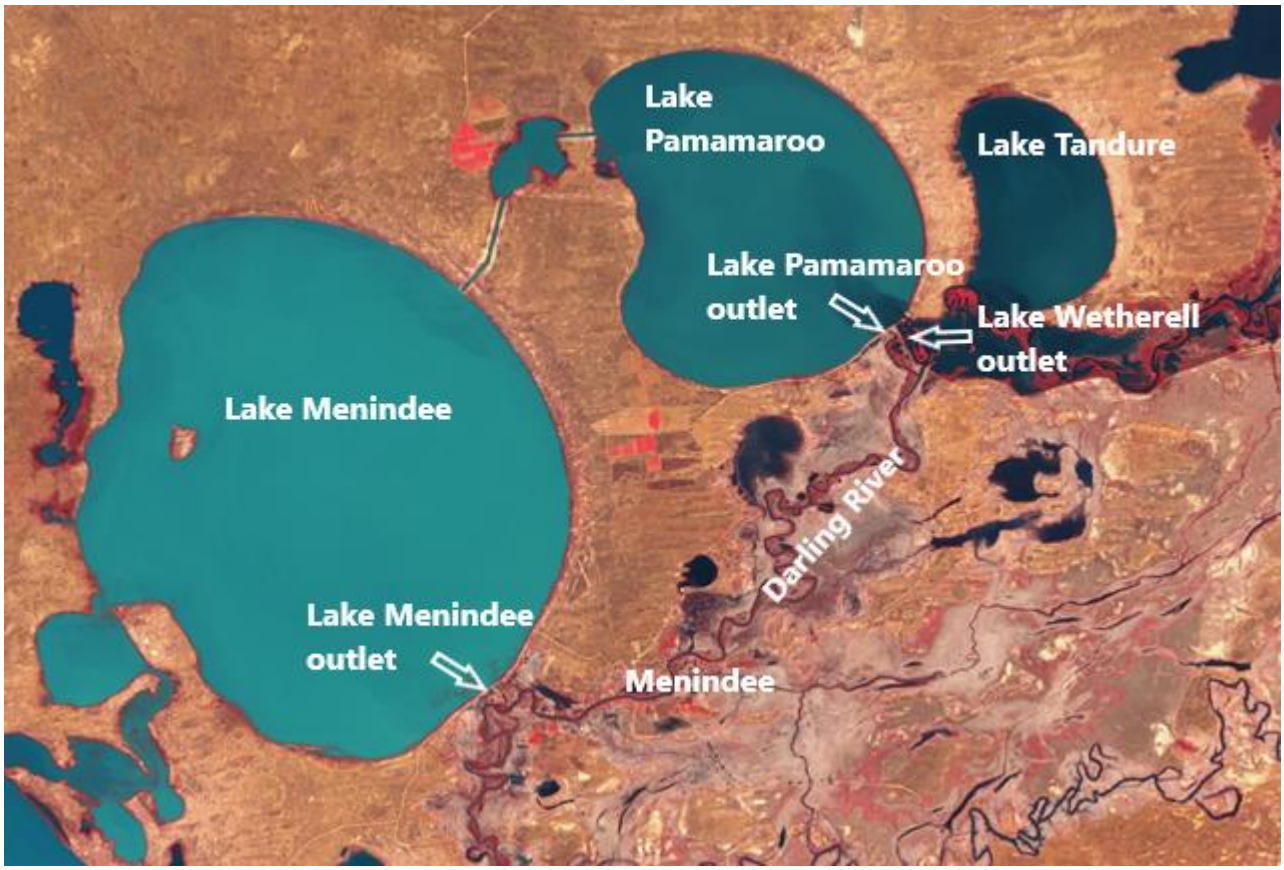

Figure 3: Satellite derived Sentinel colour infrared image of Menindee Lakes showing the location of discharge outlets

Weather outlook

The Bureau of Meteorology has forecast median maximum air temperatures will remain close to average to slightly lower for March with a higher chance of exceeding the median maximum temperature for March to May across most of New South Wales. The forecast is that rainfall figures for March through to May will be similar or slightly lower than historic averages for the majority of New South Wales. Refer to the Bureau of Meteorology website for the latest forecasts.

Additional information

To notify the NSW Department of Planning and Environment – Water of potential blackwater events email: waterqualitydata@dpie.nsw.gov.au

To report dead fish, fish struggling or gasping at the water surface, or crayfish leaving the water please call the NSW DPI Fisheries Phoneline 1800 043 536 or fill in a fish kill protocol and report form at: https://www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

Information on recent fish deaths is available at: Fish kills in NSW. When reporting, please include the name of the river/waterbody, location and date of your observation. If possible, please also record what species are affected and an estimate of number of each species observed.

Further information on blackwater events can be found at the DPE Water website at: https://www.industry.nsw.gov.au/water/allocations-availability/droughts-floods/drought-update/managing-drought-recovery/blackwater

Additional information is also available on the Murray-Darling Basin Authority website at: https://www.mdba.gov.au/publications/mdba-reports/water-management-101-factsheets

Operational updates are available at: WaterInsights - WaterNSW

Flood updates can be found on the Environment Protection Authority web page at: https://www.epa.nsw.gov.au/news/news/2022/nsw-storm-and-flood-updates-2022

To report suspected algal blooms see the WaterNSW website.

Murray Darling Basin – water quality and dissolved oxygen results

Multiple agencies are undertaking water quality monitoring to review dissolved oxygen conditions across NSW, identify potential risks to ecological communities, and implement mitigating measures. This update provides a summary of information collected up to 2 March 2023.

The focus of monitoring activities is on Menindee Lakes and the lower Darling River. Dissolved oxygen in these areas is at levels that could be detrimental to fish health. There have been fish deaths in the Darling River in Lake Wetherell, downstream of Lake Wetherell (between Menindee Main Weir and Weir 32) and in stretches between Menindee and Pooncarie. In each case predominantly Common Carp and Bony Herring have been affected, along with some Murray Cod, Golden Perch and yabbies.

River levels in the lower Darling River are continuing to recede. As the river level drops, the last of the floodwaters upstream of Pooncarie are draining off the floodplain and back into the main river channel. This can bring low oxygen and nutrient-rich return water into the Darling River which contributes to the depletion of dissolved oxygen. This is exacerbated overnight when, in the absence of sunlight, water plants and algae cease producing dissolved oxygen via photosynthesis.

The Bureau of Meteorology has forecast maximum air temperatures at Menindee will increase towards 40°C again this weekend, before returning to cooler temperatures again next week. As air temperature increases, so does the water temperature. The amount of dissolved oxygen water can hold decreases with increasing water temperature, further contributing to oxygen stress for organisms that need dissolved oxygen to survive, including fish.

NSW and Commonwealth agencies will continue to assess the risks in this area as low oxygen water makes its way down the lower Darling River and to monitor dissolved oxygen levels while air temperatures remain high. Ongoing monitoring will inform the best operational flow measures to mitigate risks to aquatic life as much as possible.

As flows recede, fish can become stranded in disconnected waterbodies on the floodplain where they may suffer from exposure to declining water quality and dissolved oxygen, higher air and water temperatures and predators as water depth decreases and these waterbodies eventually dry out. Some fish deaths have been reported in the lower Darling, as a result of this process occurring. Given the size of recession flows, there is little management action that can be taken to prevent this from happening.

To report dead fish, fish struggling or starting to gasp at the water surface, or crayfish exiting the water please call the New South Wales Department of Primary Industries Fisheries, Fishers Watch

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Phoneline 1800 043 536 or fill in a fish kill protocol and report form at:
www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

Dissolved oxygen levels – Menindee Lakes

WaterNSW are transitioning to normal operations at Menindee Lakes as inflows from the Darling River decline. To guide flow management decisions and to assess the impact low dissolved oxygen floodwater is having on Menindee Lakes and the Darling River, water quality monitoring is continuing.

Figure 1 is a satellite-derived Sentinel colour infrared image of Lakes Wetherell, Tandure and Pamamaroo at Menindee on 25 February. It highlights the darker coloured, low oxygen floodwater from Lake Wetherell was pushing into lakes Tandure and Pamamaroo. This approach has been used during previous flooding events. As well as the mixing of floodwater with the more oxygenated water in the lakes, these large shallow lakes allow the water to be more quickly aerated and provide refuge areas for smaller fish and crustaceans to move into if dissolved oxygen conditions deteriorate in Lake Wetherell.

It was identified that the poorer quality water entering Lake Pamamroo was being drawn through the Pamamaroo outlet and being discharged into the Darling River. To address this issue, the inlet structure between Lake Wetherell and Pamamaroo was closed.

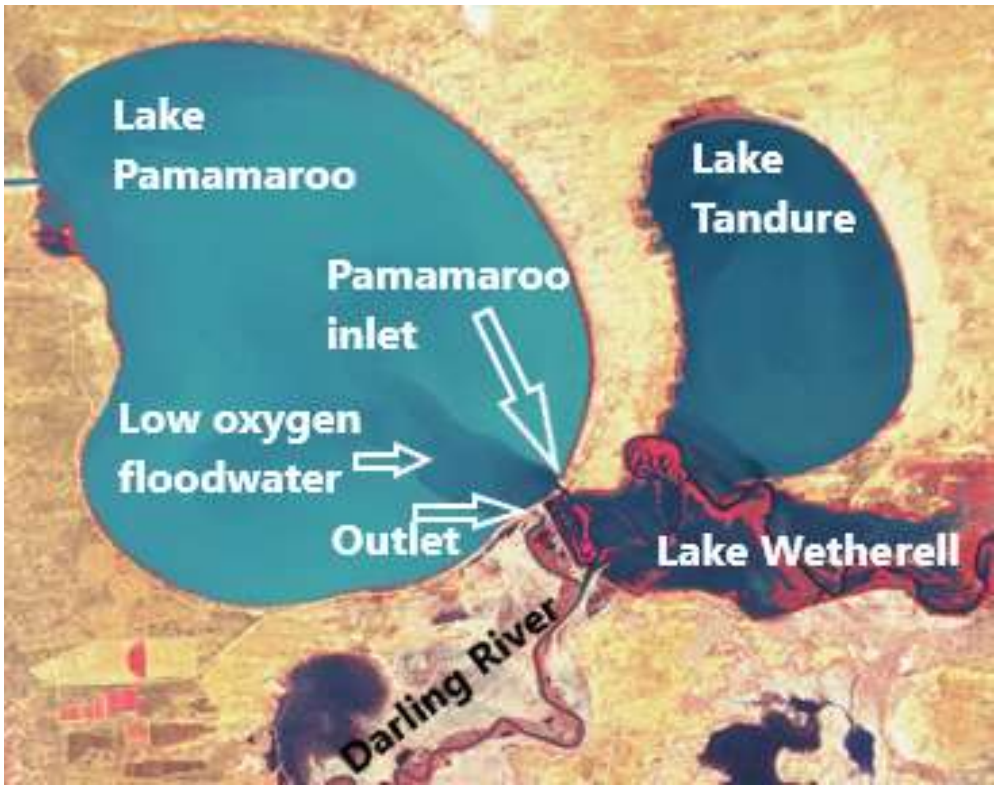

Figure 1: Satellite derived Sentinel colour infrared image of Lakes Wetherell, Tandure and Pamamaroo, 25 February 2023

Figure 2 is a Sentinel colour infrared image from the 27 February. This image highlights the darker-coloured low oxygen flood water from the upper Darling River is being held in Lake Wetherell. Once the Pamamaroo inlet structure was closed, the darker, lower oxygen water is no longer flowing into the more turbid water (blue colour) in lakes Pamamaroo and Menindee. Monitoring is showing the

water in Lake Pamamaroo is of better quality than in Lake Wetherell, making it the preferred option of the two higher lakes for releasing water into the lower Darling River. Water is also being released from Lake Menindee.

Figure 2 also shows dissolved oxygen results (in mg/L) collected 1 March. The samples were taken close to the water surface during the day with all four dissolved oxygen results from the Darling River less than 2 mg/L. As a general guide, native fish and other large aquatic organisms require at least 2 mg/L of dissolved oxygen to survive but may begin to suffer if levels are below 4 to 5 mg/L for prolonged periods.

Lower dissolved oxygen results are being recorded overnight and early in the morning in some areas. Dissolved oxygen levels drop overnight when respiration (microbes and animals breathing oxygen) outpaces oxygen replenishment (photosynthesis from aquatic plants and algae) that occurs during the day.

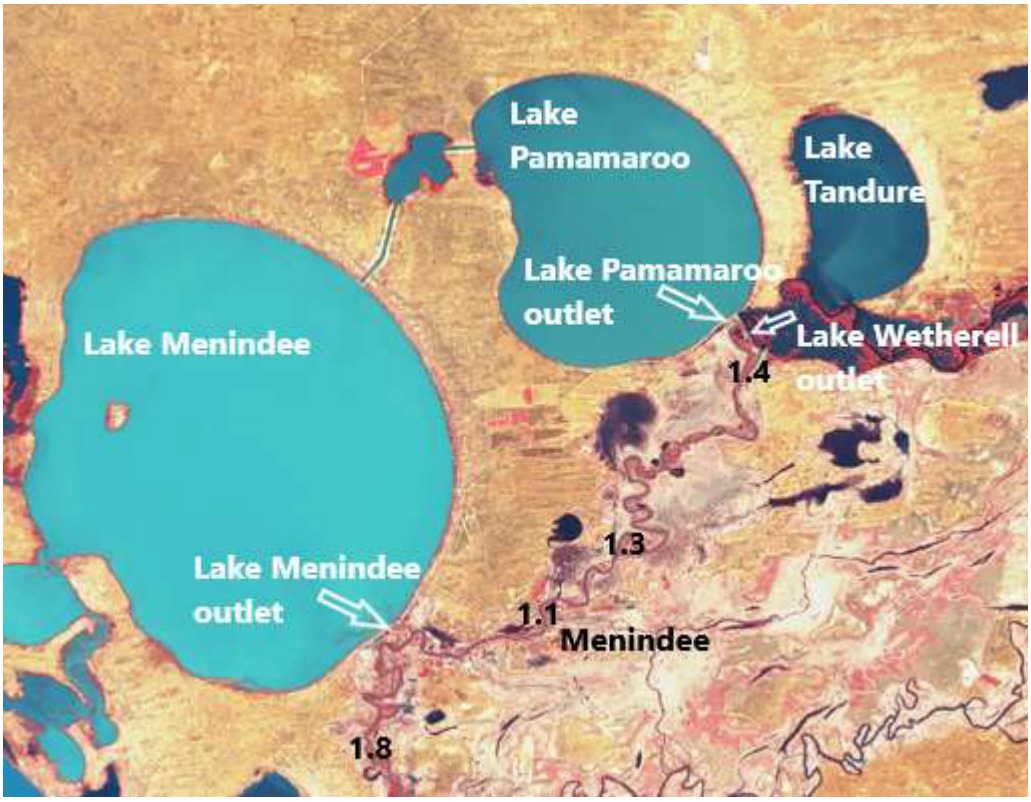

Figure 2: Satellite derived Sentinel colour infrared image of the Darling River and Menindee Lakes, 27 February 2023. Dissolved oxygen results collected 1 March are in mg/L

Dissolved oxygen levels in the Darling River at Wilcannia have been steadily improving as river levels fall (Figure 3). This indicates that oxygenated water is making its way toward Lake Wetherell. Dissolved oxygen levels in the upper reaches of Lake Wetherell at Nelia Gaari have been dropping to less than 1 mg/L overnight but increasing to safe levels during the day. Dissolved oxygen in the Darling River downstream of Menindee at Weir 32 had also been low, but has improved above 2 mg/L over the last two days in response to the operational measures implemented.

High concentrations of nutrients such as nitrogen and phosphorus have been flushed into the rivers during flooding. These nutrient-rich inflows combined with warm, still water provide ideal conditions

for the growth of potentially toxic blue-green algae and increases the risk that dissolved oxygen levels could deteriorate in this area.

NSW and Commonwealth agencies will continue to work together to assess the risks as floodwaters make their way through Menindee Lakes and into the lower Darling River. The agencies will monitor dissolved oxygen levels throughout the river system and advise the best operational measures to mitigate risks to aquatic life as much as possible. This can involve adjusting the timing, size and location of releases from the Lakes into the lower Darling River to maintain the quality of the water in the river.

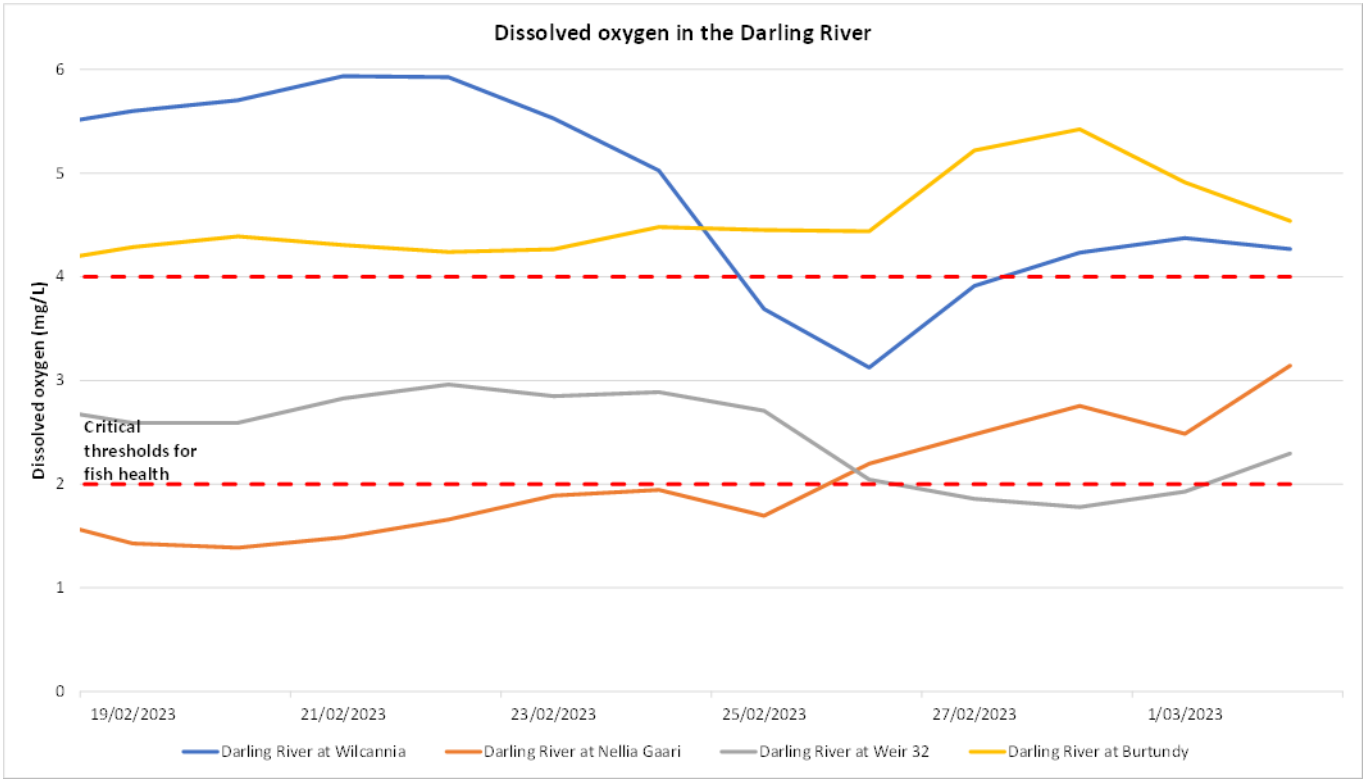

Figure 3: Mean daily dissolved oxygen (mg/L) in the Darling River at Wilcannia, Nelia Gaari, Weir 32 and Burtundy – 17 to 28 February 2023

Dissolved oxygen levels – lower Darling River

Flooding in the lower Darling River has decreased to the minor flood warning level at Burtundy. The flooding of higher areas of the lower Darling River floodplain that have not been inundated since 2012 will flush organic material such as sticks, leaves, bark and grass into the river system. The breakdown of this organic material by bacteria uses up the oxygen in the water which can impact fish health.

Figure 4 is a series of satellite derived Sentinel colour infrared images. The image on the left was taken on 8 January during major flooding at Menindee. The centre image (11 February) shows, as river levels drop, floodwater is returning back into the main channel. By 27 February (right) the last of the floodwaters are returning to the channel. The most recent fish deaths (mostly Carp and Bony Herring) in this area downstream of Menindee have been attributed to the last of the return water coming back into the channel.

Despite this floodwater water returning off the floodplain, dissolved oxygen in the Darling River downstream of Pooncarie at Burtundy is remaining above 4 mg/L (Figure 3).

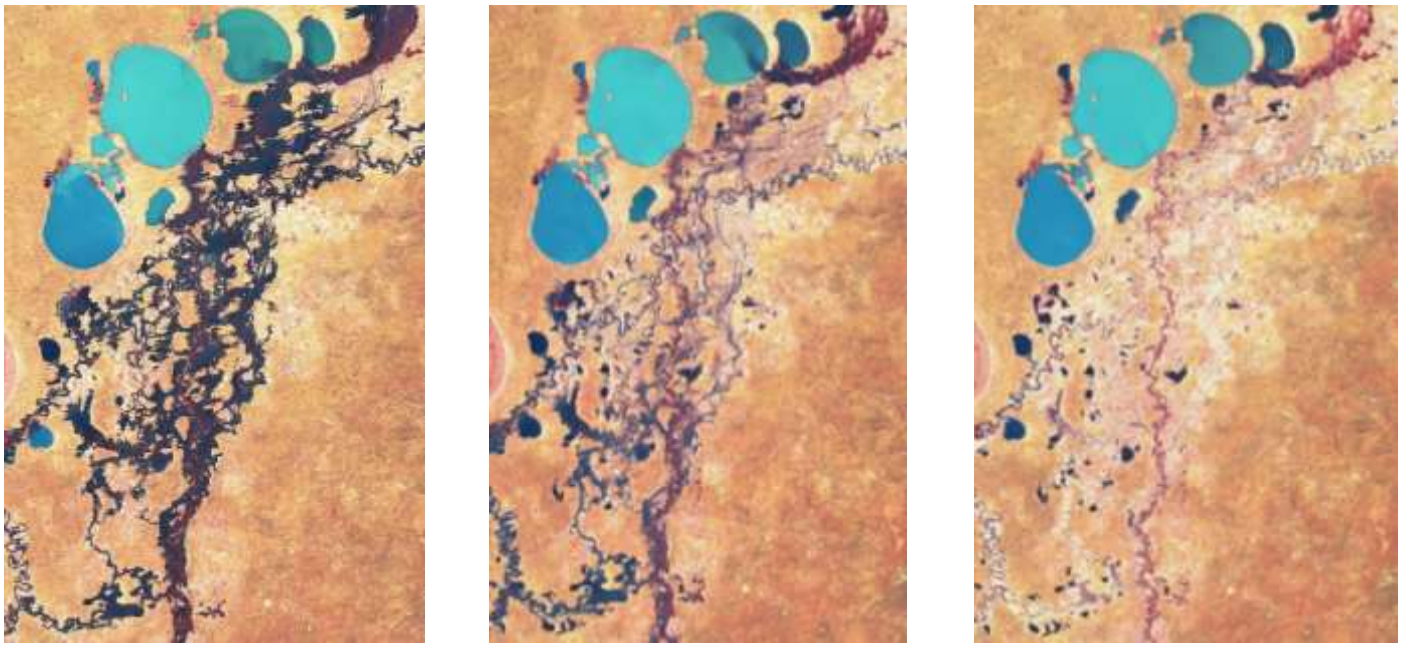

Figure 4: Series of satellite derived Sentinel colour infrared image of the Darling River between Menindee and Pooncarie. 8 January (left), 11 February (middle) and 27 February (right)

Hypoxic blackwater fish death summary

In recent months NSW DPI Fisheries has received reports of fish deaths, fish struggling and crustaceans leaving the water across a broad area in the Murray-Darling Basin, including in the Murray, Kolety/Edward, Wakool, Murrumbidgee, Lachlan, Gwydir, Darling, Barwon, Namoi and Macquarie rivers and Yanco-Billabong Creek system. High air temperatures increase the risk of further reductions in dissolved oxygen in some areas and the potential for further fish death events.

There have been confirmed fish death events in the Darling River near Menindee related to poor water quality: in Lake Wetherell, the Darling River downstream of Lake Wetherell to Weir 32 and in stretches of the Darling River between Menindee and Pooncarie. In each case predominantly Common Carp and Bony Herring are affected, along with Murray Cod, Golden Perch and yabbies.

NSW agencies are working together to investigate and determine if any other native fish have been affected. There may be other fish death incidents that have not yet been reported directly to NSW Department of Primary Industries Fisheries.

Programs to benefit native fish such as improving fish passage and habitat restoration to provide conditions conducive to fish breeding and population growth are ongoing. These works are vital and provide an environment where fish populations can bounce back from low oxygen events.

What is being done?

Releases into the lower Darling River can be made from Lake Wetherell, Lake Pamamaroo and Lake Menindee. Monitoring is showing the quality of the water in Lake Pamamaroo is better than in Lake Wetherell. To maintain an oxygenated flow in the Darling River through Menindee township and

reduce the risk of further fish deaths, releases from the Lake Wetherell outlet have been reduced, while releases from the Pamamaroo outlet have been increased. Releases from Lake Menindee have also been reduced (currently at 3 GL/day) to assist in the flow of water from Lake Pamamaroo, past Menindee town and through to the lower Darling River. Discharge from Pamamaroo will be maintained at higher levels over the next few days, utilising the lower Darling water quality allowance to provide a flushing flow of oxygenated water to the Darling River through Menindee town. The discharge will also maintain sufficient flow velocity that research has shown provides conditions that are less favourable for harmful algal blooms. Ongoing monitoring will identify if the operations are achieving the desired results. Water recessions are expected commence on Monday 6 March at a slower rate than normal operational requirements.

Weather outlook

The Bureau of Meteorology has forecast median maximum air temperatures will remain close to average to slightly higher for March with a higher chance of exceeding the median maximum temperature for March to May across most of New South Wales. The forecast is that rainfall figures for March through to May will be slightly lower than historic averages for the majority of New South Wales. Refer to the Bureau of Meteorology website for the latest forecasts.

Additional information

To notify the NSW Department of Planning and Environment – Water of potential blackwater events email: waterqualitydata@dpie.nsw.gov.au

To report dead fish, fish struggling or gasping at the water surface, or crayfish leaving the water please call the NSW DPI Fisheries Phoneline 1800 043 536 or fill in a fish kill protocol and report form at: www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

Information on recent fish deaths is available at: Fish kills in NSW. When reporting, please include the name of the river/waterbody, location and date of your observation. If possible, please also record what species are affected and an estimate of number of each species observed.

Further information on blackwater events can be found at the DPE Water website at: www.industry.nsw.gov.au/water/allocations-availability/droughts-floods/drought-update/managing-drought-recovery/blackwater

Additional information is also available on the Murray-Darling Basin Authority website at: www.mdba.gov.au/publications/mdba-reports/water-management-101-factsheets

Operational updates are available at: WaterInsights - WaterNSW

Flood updates can be found on the Environment Protection Authority web page at: www.epa.nsw.gov.au/news/news/2022/nsw-storm-and-flood-updates-2022

To report suspected algal blooms see the WaterNSW website.

Murray Darling Basin – water quality and dissolved oxygen results

Multiple agencies are undertaking water quality monitoring to review dissolved oxygen conditions across NSW, identify potential risks to ecological communities, and implement mitigating measures. This update provides a summary of information collected up to 8 March 2023.

River levels in the lower Darling River are continuing to recede. As the river level drops, the last of the floodwaters upstream of Pooncarie are draining off the floodplain and back into the main river channel. This results in concentration of large volumes of floodplain nutrients, organic matter, sediment, algae and fish into the river channel. As flows recede, fish can also become stranded in disconnected waterbodies and billabongs on the floodplain where they may suffer from declining water depth, dissolved oxygen depletion (particularly overnight when photosynthetic production of oxygen ceases), higher air and water temperatures and exposure to predators as these waterbodies dry out.

Since mid-February fish deaths have been recorded upstream of Pooncarie, both in the main channel of the river and in off-channel wetlands and depressions, where fish became stranded as water levels dropped. Most of the dead fish are native Bony herring and non-native Carp, although increasing numbers of large-bodied native fish such as Murray cod and Golden perch are being documented. The stranding of substantial numbers of Murray cod and Golden perch during flood recession in this manner is unusual, suggesting fish were avoiding the particularly poor water quality in the river channel during the recession of this flood event. Typically, we expect Murray cod and Golden perch to exit off channel habitats before disconnection. Recent hot weather in the region is also exacerbating the risk of low dissolved oxygen levels in both the river and disconnected floodplain wetlands because warmer water holds less oxygen.

The Bureau of Meteorology has forecast maximum air temperatures at Menindee will increase towards 30°C later this week, which is cooler than the high temperatures experienced last week. Cooler water temperatures assist dissolved oxygen levels to improve which may bring some relief to struggling fish in the lower Darling River.

NSW and Commonwealth agencies will continue to monitor dissolved oxygen levels and assess the risks as low oxygen water makes its way down the lower Darling River. Ongoing monitoring will inform the best operational flow measures to mitigate risks to aquatic life as much as possible.

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To report dead fish, fish struggling or starting to gasp at the water surface, or crayfish exiting the water please call the NSW Department of Primary Industries Fisheries, Fishers Watch Phoneline 1800 043 536 or fill in a fish kill protocol and report form at: www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

Dissolved oxygen levels – Menindee Lakes

It was identified that poorer quality water was entering Lake Pamamaroo from Lake Wetherell and was being drawn through the Pamamaroo outlet and discharged into the Darling River upstream from the town of Menindee. This increased the risk of stress to fish. To address this risk, the inlet regulator between lakes Wetherell and Pamamaroo was closed. Monitoring is showing the water quality now being released from Lake Pamamaroo into the Darling River at Menindee is of more suitable quality and is providing some relief for fish. Water is also being released from Lake Menindee to meet flow targets at Weir 32, downstream of Menindee town.

Figure 1 is a satellite-derived Sentinel colour infrared image of lakes Wetherell, Tandure, Pamamaroo and Menindee on 4 March. The image highlights the darker-coloured low oxygen flood water from the upper Barwon- Darling River is being captured in Lake Wetherell and is no longer flowing into Lake Pamamaroo. Some of the darker coloured floodwater from Lake Wetherell is pushing into Lake Tandure. As well as the mixing of floodwater with the more oxygenated water, these large shallow lakes allow the water to be more quickly aerated and provide a refuge area for smaller fish and crustaceans to move into if dissolved oxygen conditions deteriorate in Lake Wetherell.

Figure 1 also shows dissolved oxygen results (in mg/L) collected 8 March. The samples were taken close to the water surface during the day. The lowest results were collected in Lake Wetherell (1.49 mg/L) and upstream of Menindee township (2.55 mg/L). As a general guide, native fish and other large aquatic organisms require at least 2 mg/L of dissolved oxygen to survive, but may begin to suffer if levels are below 4 to 5 mg/L for prolonged periods.

To maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Pamamaroo outlet will continue during the recession of flows back to regulated conditions. Releases from Lake Menindee have also been reduced to assist in the flow of water from Lake Pamamarooo past Menindee town and through to the lower Darling River, but is still delivering good flows at Weir 32.

Lower dissolved oxygen results are being recorded overnight and early in the morning in some areas. Dissolved oxygen levels drop overnight when respiration (microbes and animals breathing oxygen) outpaces oxygen replenishment (photosynthesis from aquatic plants and algae) that occurs during the day.

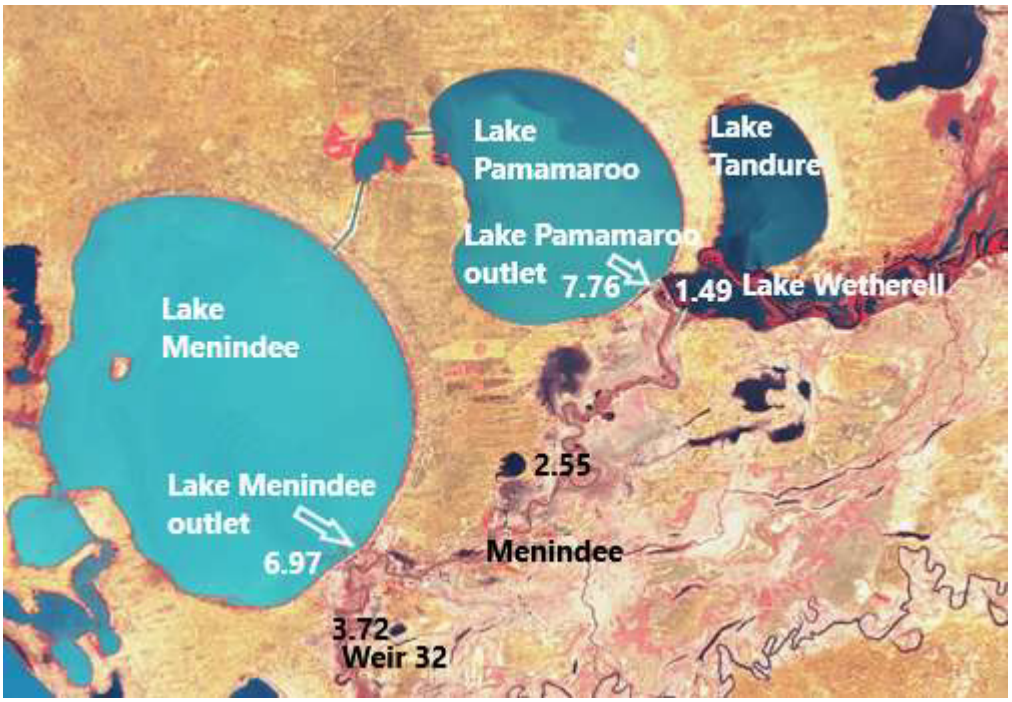

Figure 1: Satellite derived Sentinel colour infrared image – Image 4 March. Data collected 8 March (mg/L)

Dissolved oxygen in the Darling River downstream of Menindee at Weir 32 had been low, decreasing to less than 2 mg/L on 25 February. These levels have now improved above 2 mg/L in response to the operational measures implemented and are continuing to increase toward the safer level for fish health of 4 mg/L (Figure 2).

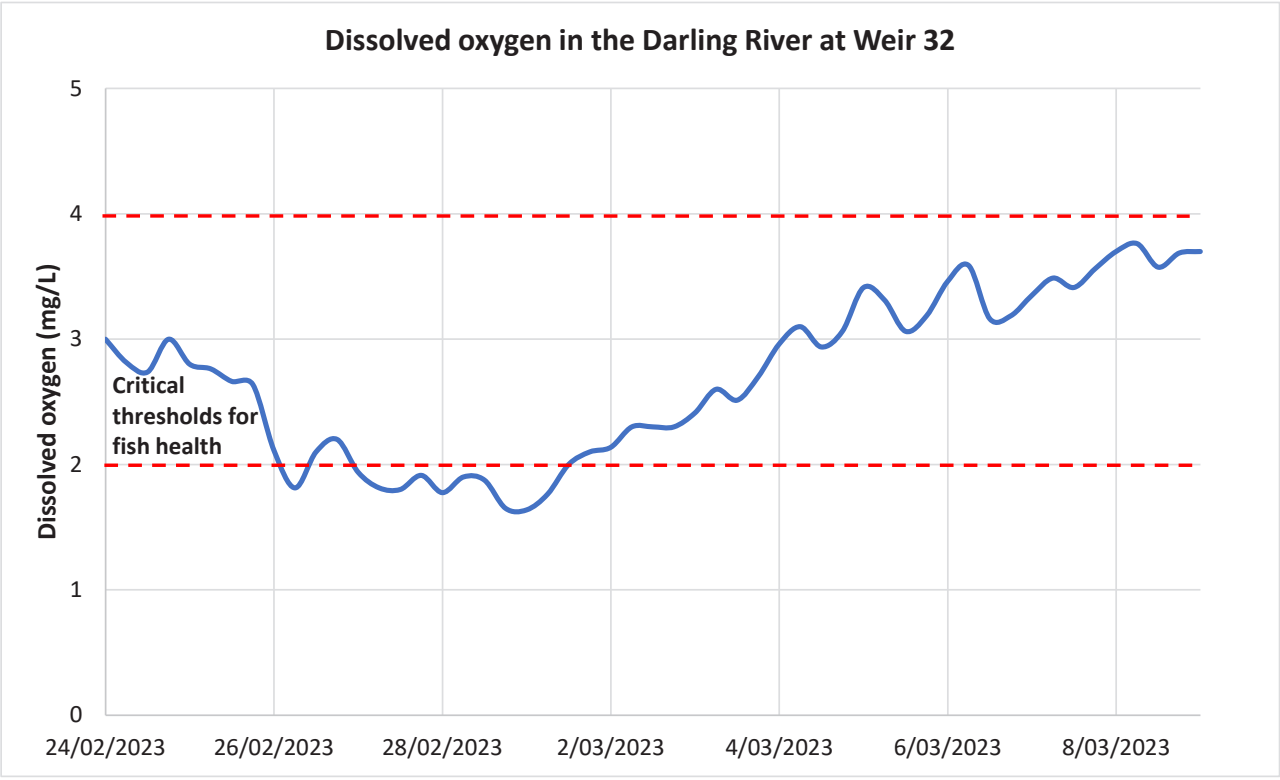

Figure 2: Dissolved oxygen (mg/L) in the Darling River at Weir 32 – 24 February to 8 March 2023

NSW and Commonwealth agencies will continue to work together and monitor dissolved oxygen levels in this area and advise the best operational measures to mitigate risks to aquatic life as much as possible. This can involve adjusting the timing, size and location of releases from the Lakes into the lower Darling River to maintain the quality of the water in the river.

Dissolved oxygen levels – lower Darling River

Figure 3 is a series of satellite derived Sentinel colour infrared images. The image on the left was taken on 22 February 2023 during minor flooding at Pooncarie. The centre image (27 February) shows, as river levels drop, floodwater is draining back into the main channel. By 4 March (right) the majority of the floodwater had returned to the channel with some water remaining in billabongs and depressions.

As mentioned above, poor quality water returning from the floodplain containing large volumes of nutrients, organic matter, sediment and fish biomass is being concentrated in the river channel. The nutrient-rich return flows combined with warm, still water provide ideal conditions for the growth of algae and this increases the risk of large oxygen fluctuations, with high oxygen concentrations during the day from photosynthetic activity then very low oxygen concentrations overnight when photosynthesis ceases.

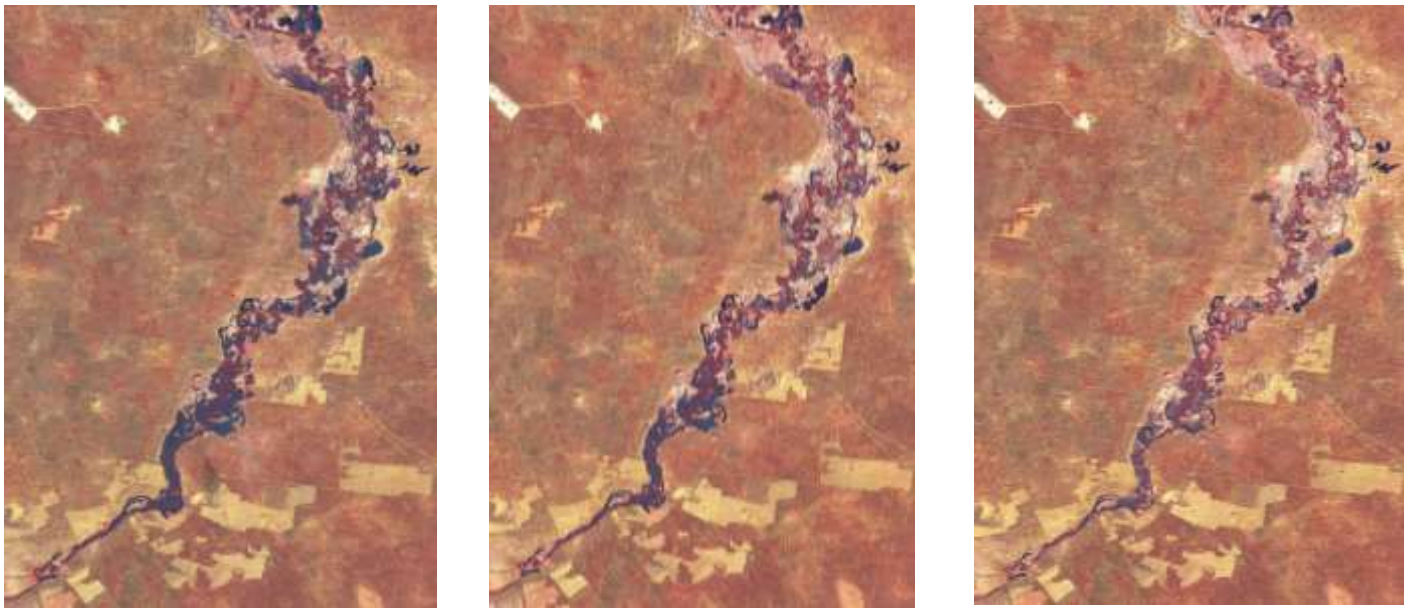

Figure 3: Series of satellite derived Sentinel colour infrared images of the lower Darling River including Pooncarie and Burtundy. Images 22 February (left), 27 February (middle) and 4 March (right)

As the low oxygen floodwaters continue downstream, dissolved oxygen levels in the Darling River downstream of Pooncarie at Burtundy has decreased to less than 2 mg/L (Figure 4). Oxygenated water is being released from Menindee Lakes, but it will be some weeks before it reaches Burtundy. There may be some improvement in dissolved oxygen with lower air temperatures expected this week.

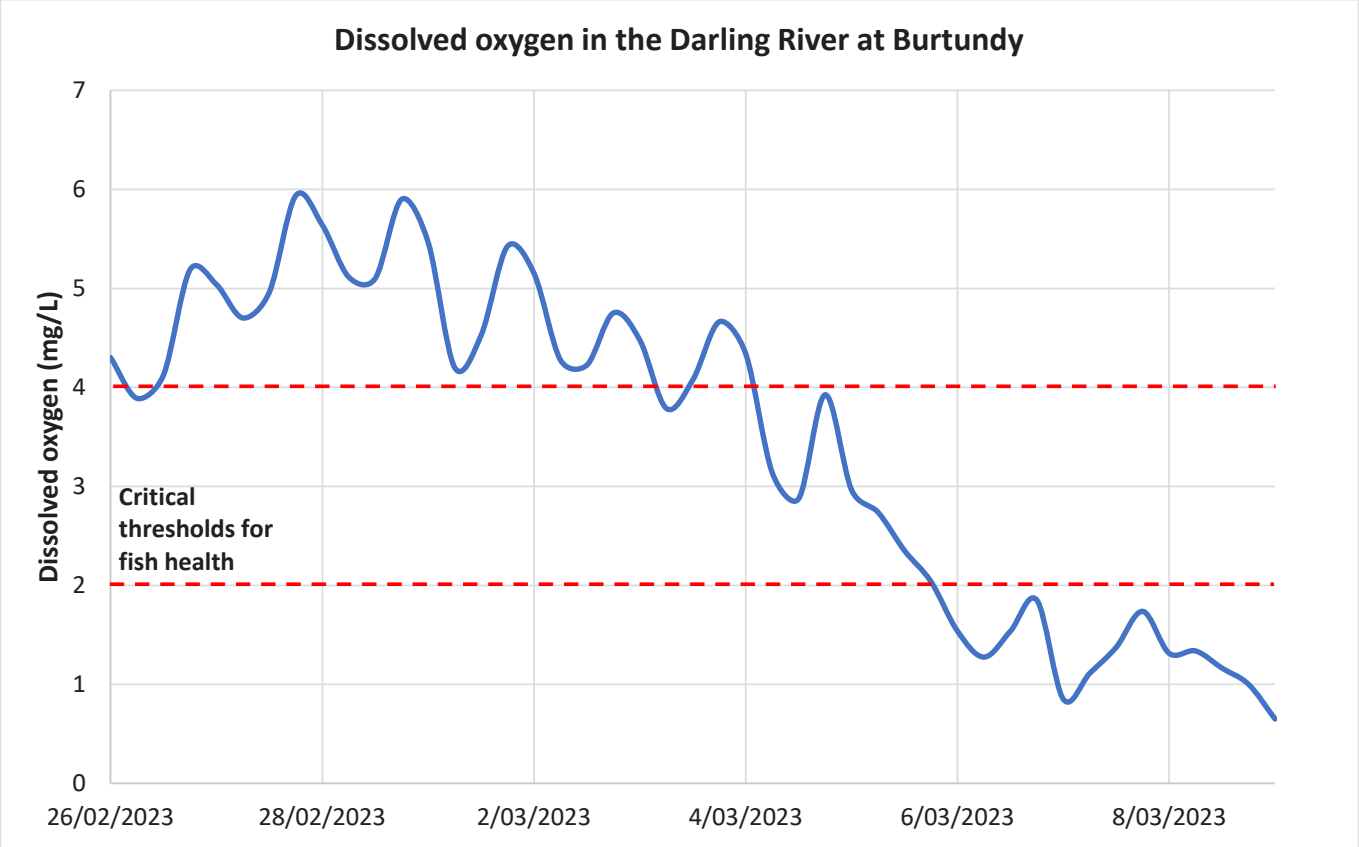

Figure 4: Dissolved oxygen (mg/L) in the Darling River at Burtundy – 26 February to 8 March 2023

Hypoxic blackwater fish death summary

In recent months NSW DPI Fisheries has received reports of fish deaths, fish struggling and crustaceans leaving the water across a broad area in the Murray-Darling Basin, including in the Murray, Kolety/Edward, Wakool, Murrumbidgee, Lachlan, Gwydir, Darling, Barwon, Namoi and Macquarie rivers and Yanco-Billabong Creek system. High air temperatures increase the risk of further reductions in dissolved oxygen in some areas and the potential for further fish death events.

In the last few weeks there have been confirmed fish deaths in the Darling River upstream of Pooncarie related to poor quality floodplain return water and the stranding of fish in off-channel wetlands as the river disconnected. Large numbers of Bony herring and Carp have been affected with increasing numbers of large-bodied native fish, such as Murray cod and Golden perch, also dying. The speed of the recession of floodwater is typical of floods in the lower Darling River, which makes the stranding of these native species in this manner somewhat unusual, as the fish appear to have avoided returning to the river channel, presumably because the quality of the water in the channel at the time was poorer relative to that on the floodplain.

On 1 March there was a report of five (5) dead Murray cod in the lower Lachlan River near Hunthawang. The cause of the deaths is unknown, however; spot measurements showed dissolved oxygen levels were above concern levels for fish, so the deaths are likely unrelated to low oxygen. The fish may have been in poor overall condition and infection by the parasitic Lernea was observed on the dead fish.

On 3 March, there was a report of a low number (in the tens) of dead Golden perch, Spangled perch, Carp, Bony herring in the Bogan River, Nyngan Weir Pool. Cause was unclear, however; it is suspected that low flow, combined with very warm temperatures, resulted in low dissolved oxygen levels.

On 6 March there was a report of a large number of dead Redfin perch (hundreds) in Carcoar Dam, with no other species appearing affected. The Redfin were mostly small fish. Investigation into the cause is ongoing.

NSW agencies are working together to investigate and determine if any other native fish have been affected. There may be other fish death incidents that have not yet been reported directly to NSW Department of Primary Industries Fisheries.

Programs to benefit native fish, such as improving fish passage and habitat restoration to provide conditions conducive to fish breeding and population growth, are ongoing. These works are vital and provide an environment where fish populations can bounce back from low oxygen events.

What is being done?

To maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Pamamaroo outlet will continue. Releases from Lake Menindee have also been reduced (currently at 3 gigalitres/day) to assist in the flow of water from Lake Pamamaroo, past Menindee town and through to the lower Darling River. Utilising the lower Darling Water Quality Allowance is providing a flushing flow of oxygenated water to the Darling River through Menindee town. The discharge will also maintain flow velocity that research has shown provides conditions that are less favourable for harmful algal bloom formation. Ongoing monitoring will identify if the operations continue to achieve the desired results. Discharge from Pamamaroo is slowly decreasing at a slower rate than normal operational requirements, as monitoring of water quality suggests that there are improvements in the reach downstream of Lake Pamamaroo.

There are no operational measures available to reduce the current risk of further fish deaths in the lower Darling River downstream of the Menindee Lakes. Oxygenated water is being released from Menindee Lakes, but this will take some weeks to pass along the system. The volume of water being released will not be sufficient to reconnect billabongs on the floodplain to allow any remaining stranded fish to return to the main river channel.

Weather outlook

The Bureau of Meteorology has forecast median maximum air temperatures will remain close to average to slightly higher for March, with a higher chance of exceeding the median maximum temperature for March to May across most of NSW. The forecast is that rainfall figures for March through to May will be lower than historic averages for the majority of NSW. Refer to the Bureau of Meteorology website for the latest forecasts.

Additional information

To notify the NSW Department of Planning and Environment – Water of potential blackwater events email: waterqualitydata@dpie.nsw.gov.au

To report dead fish, fish struggling or gasping at the water surface, or crayfish leaving the water please call the NSW DPI Fisheries Phoneline 1800 043 536 or fill in a fish kill protocol and report form at: www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

Information on recent fish deaths is available at: Fish kills in NSW. When reporting, please include the name of the river/waterbody, location and date of your observation. If possible, please also record what species are affected and an estimate of number of each species observed.

Further information on blackwater events can be found at the DPE Water website at: www.industry.nsw.gov.au/water/allocations-availability/droughts-floods/drought-update/managing-drought-recovery/blackwater

Additional information is also available on the Murray-Darling Basin Authority website at: www.mdba.gov.au/publications/mdba-reports/water-management-101-factsheets

Operational updates are available at: WaterInsights - WaterNSW

Flood updates can be found on the Environment Protection Authority web page at: www.epa.nsw.gov.au/news/news/2022/nsw-storm-and-flood-updates-2022

To report suspected algal blooms see the WaterNSW website.

Murray Darling Basin – water quality and dissolved oxygen results

Multiple agencies are undertaking water quality monitoring to review dissolved oxygen conditions across NSW, identify potential risks to ecological communities, and implement mitigating measures. This update provides a summary of information collected up to 15 March 2023.

The main focus of activities is on Menindee Lakes and the lower Darling River. Dissolved oxygen in the Darling River is at levels that could be detrimental to fish health. There are fish deaths (predominantly Bony Herring) in the Darling River between Lake Wetherell (Menindee main weir) and Menindee township.

The Bureau of Meteorology has forecast maximum air temperatures at Menindee will increase to 40°C this weekend, before returning to cooler temperatures again next week. Low intensity heatwave conditions have been forecast from Friday 17 March through to Sunday 19 March. As air temperature increases, so does the water temperature. The amount of dissolved oxygen water can hold decreases with increasing water temperature which can add additional stress to fish that may already be struggling. Ongoing monitoring will inform operational measures to mitigate risks to aquatic life as much as possible. NSW and Commonwealth agencies are continuing to assess the risks to fish health in this area.

Further downstream, river levels in the lower Darling River are continuing to recede and are flowing down the Darling River arm of the Wentworth weir pool and merging into the Murray River. As the river level drops, the last of the floodwaters around Burtundy are draining off the floodplain and back into the main river channel. As flows recede, fish can become stranded in disconnected waterbodies and billabongs on the floodplain where they may suffer from declining water depth, dissolved oxygen depletion (particularly overnight when photosynthetic production of oxygen ceases), higher air and water temperatures and exposure to predators as these waterbodies dry out.

Since mid-February fish deaths have been recorded upstream of Pooncarie both in the main channel of the Darling River and in off-channel wetlands and depressions where fish became stranded as water levels dropped. Most of the dead fish were native Bony Herring and non-native Carp, although high numbers of large-bodied native fish such as Murray Cod and Golden Perch were also documented. The stranding of substantial numbers of Murray Cod and Golden Perch during flood recession in this manner is unusual, suggesting fish were avoiding the particularly poor water quality in the river channel during the recession of this flood event. Typically, we expect Murray Cod and Golden Perch to exit off channel habitats before disconnection.

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To report dead fish, fish struggling or starting to gasp at the water surface, or crayfish exiting the water please call the NSW Department of Primary Industries Fisheries, Fishers Watch Phoneline 1800 043 536 or fill in a fish kill protocol and report form at: www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

Dissolved oxygen levels – Darling River at Menindee

Figure 1 is a satellite-derived Sentinel natural colour image of lakes Wetherell, Tandure, Pamamaroo and Menindee on 14 March. The image highlights the darker-coloured low oxygen flood water from the upper Barwon-Darling River is being captured in Lake Wetherell. As a temporary measure to prevent the poorer quality water from Lake Wetherell being drawn through the Pamamaroo outlet and discharged into the Darling River, the inlet regulator between lakes Wetherell and Pamamaroo was closed in late February. The inlet regulator will be opened again this week to allow the water levels between lakes Wetherell and Pamamaroo to even out.

Figure 1 shows dissolved oxygen results (in mg/L) collected 14 March. The samples were taken close to the water surface during the day. The lowest results were collected in the Darling River upstream of Menindee township (1.39 mg/L). As a general guide, native fish and other large aquatic organisms require at least 2 mg/L of dissolved oxygen to survive, but may begin to suffer if levels are below 4 to 5 mg/L for prolonged periods.

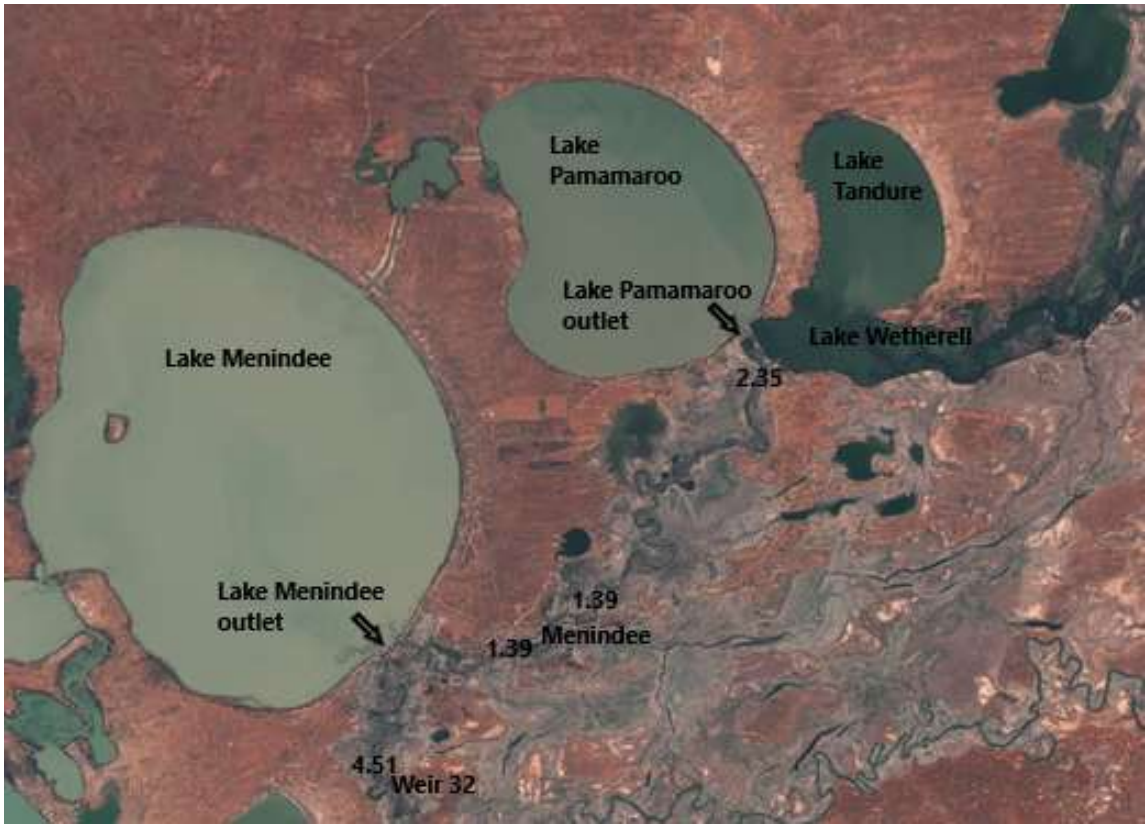

Figure 1: Satellite derived Sentinel natural colour image – Image 14 March. Data collected 14 March (mg/L)

After successive years of high flows and successful fish breeding events, a large biomass of fish is congregating in the reach of the Darling River between Lake Wetherell main weir and Menindee town. There have been reports of fish deaths in this area this week (predominantly Bony Herring) as

dissolved oxygen levels dropped below 2 mg/L. Dissolved oxygen levels drop overnight when respiration (microbes and animals breathing oxygen) outpaces oxygen replenishment (photosynthesis from aquatic plants and algae) that occurs during the day.

The majority of water being released to meet flow targets at Weir 32, downstream of Menindee town, is being drawn from Lake Menindee. However, in an attempt to maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Lake Pamamaroo outlet are being maintained. Releases from Lake Menindee have been reduced to assist in the flow of water from Lake Pamamaroo, past Menindee town and through to the lower Darling River. This action will have an impact on the volume of water in the top lakes.

Lower dissolved oxygen results are also being recorded overnight and early in the morning in the upper reaches of Lake Wetherell.

Dissolved oxygen in the Darling River downstream of Menindee at Weir 32 had been low, decreasing to less than 2 mg/L on 25 February. In response to the operational measures implemented, and the better quality water being drawn from Lake Menindee, dissolved oxygen levels have improved above the safer level for fish health of 4 mg/L (Figure 2).

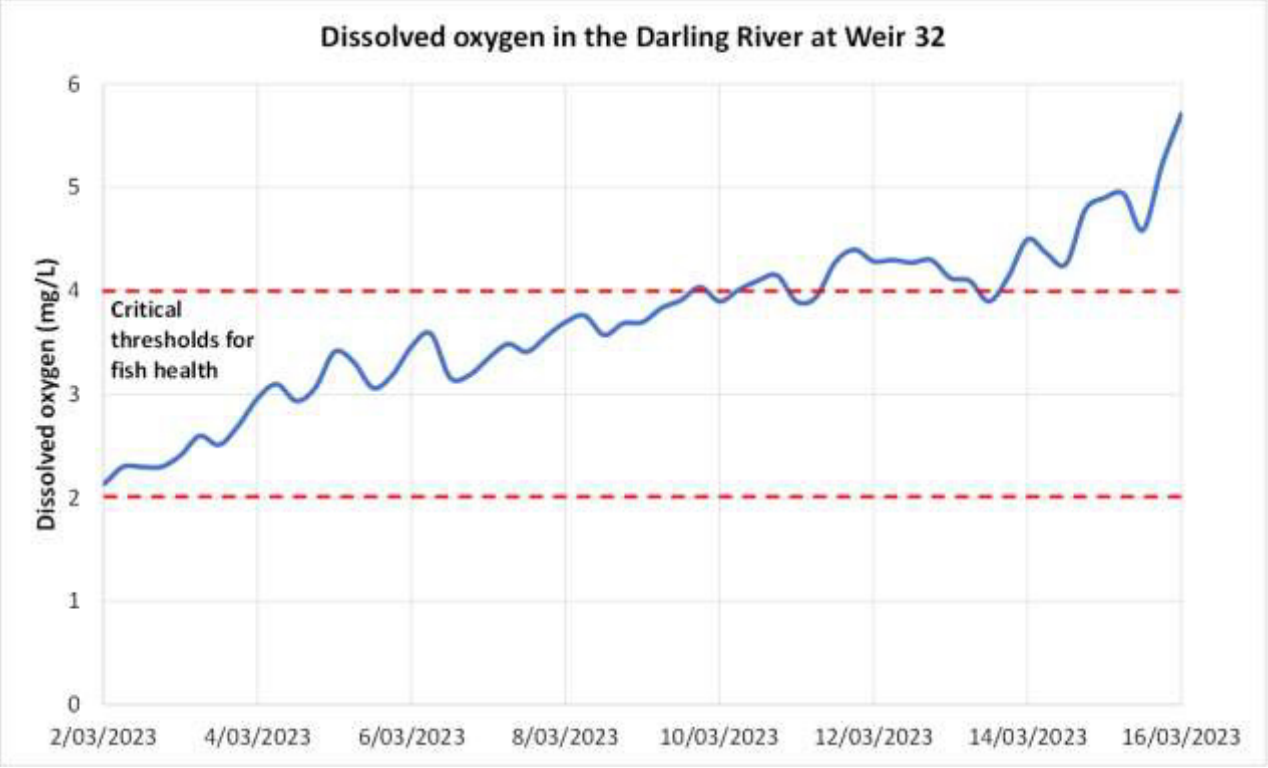

Figure 2: Dissolved oxygen (mg/L) in the Darling River at Weir 32 – 2 to 15 March 2023

NSW and Commonwealth agencies will continue to work together and monitor dissolved oxygen levels in this area and advise the best operational measures to mitigate risks to aquatic life as much as possible. This can involve adjusting the timing, size and location of releases from the Lakes into the lower Darling River to maintain the quality of the water in the river.

Dissolved oxygen levels – lower Darling River

In the lower Darling River, the majority of the floodwater has returned to the channel with some water remaining in larger billabongs and depressions. Figure 3 is a series of satellite derived Sentinel colour infrared images of the lower Darling River at Burtundy. The image on the left was taken on 27 February during flooding at Burtundy. The centre image (4 March) shows, as river levels drop, floodwater is returning back into the main channel. By 14 March (right) the majority of the floodwater has returned to the channel with the remaining water in larger billabongs and depressions.

As the low oxygen floodwaters continue downstream, dissolved oxygen levels are being monitored in the Darling River arm of the Wentworth weir pool (Lock 10). Results show that dissolved oxygen levels through the weir pool are between 2 and 4 mg/L as the last of the flood water continues down the Darling River arm of the Wentworth weir pool and merges into the Murray River.

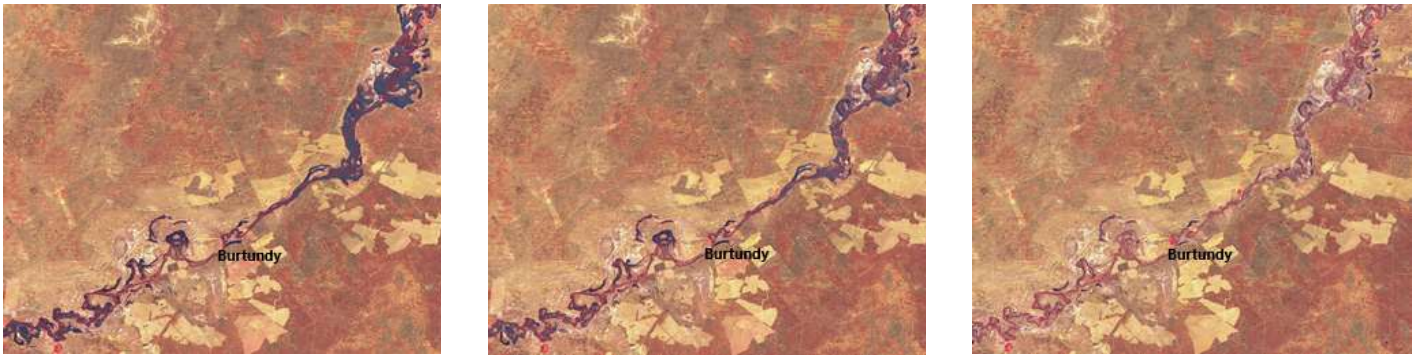

Figure 3: Series of satellite derived Sentinel colour infrared images of the lower Darling River at Burtundy. Images 27 February (left), 4 March (middle) and 14 March(right)

Hypoxic blackwater fish death summary

In recent months NSW DPI Fisheries has received reports of fish deaths, fish struggling and crustaceans leaving the water across a broad area in the Murray-Darling Basin, including in the Murray, Kolety/Edward, Wakool, Murrumbidgee, Lachlan, Gwydir, Darling, Barwon, Namoi and Macquarie rivers and Yanco-Billabong Creek system. High air temperatures increase the risk of further reductions in dissolved oxygen in some areas and the potential for further fish death events.

DPI Fisheries have received reports of additional dead fish in the Darling River near Menindee (downstream of Menindee Main Weir) this week. These deaths are likely related to low dissolved oxygen levels in the water (which we are seeing in other areas where flood waters are receding). Hot temperatures this week, coupled with high biomass in the water, are exacerbating this hypoxia, causing ongoing high risk of fish deaths. Large numbers of Bony Herring, potentially hundreds of thousands, are being affected with the potential for large-bodied native fish, such as Murray Cod and Golden Perch, to also be affected.

In the last few weeks there have been confirmed fish deaths in the Darling River upstream of Pooncarie related to poor quality floodplain return water and the stranding of fish in off channel wetlands as the river disconnected. Large numbers of Bony Herring and Carp were affected with increasing numbers of large-bodied native fish, such as Murray Cod and Golden Perch, also dying.

The speed of the recession of floodwater is typical of floods in the lower Darling River, which makes the stranding of these native species in this manner somewhat unusual, as the fish appear to have avoided returning to the river channel, presumably because the quality of the water in the channel at the time was poorer relative to that on the floodplain.

NSW agencies are working together to investigate and determine if any other native fish have been affected. There may be other fish death incidents that have not yet been reported directly to NSW DPI Fisheries.

Programs to benefit native fish such as improving fish passage and habitat restoration to provide conditions conducive to fish breeding and population growth are ongoing. These works are vital and provide an environment where fish populations can bounce back from low oxygen events.

What is being done?

Water for the environment is being delivered to reduce the risk of fish deaths by maintaining oxygenated releases from the Menindee Lakes and providing of water between Main Weir and Weir 32. With forecast heatwave conditions this weekend, to maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Lake Pamamaroo outlet will continue. Releases from Lake Menindee have also been reduced to assist in the flow of water from Lake Pamamaroo, past Menindee town and through to the lower Darling River. The discharge will attempt to maintain flow velocity that research has shown provides conditions that are less favourable for harmful algal bloom formation. Ongoing monitoring will identify if the operations achieve the desired results.

There are no operational measures available to reduce the current risk of further fish deaths in the lower Darling River downstream of the Menindee Lakes. Oxygenated water is being released from Lake Menindee, but this will take some weeks to pass along the system. The volume of water being released will not be sufficient to reconnect billabongs on the floodplain to allow any remaining stranded fish to return to the main river channel.

Weather outlook

The Bureau of Meteorology has forecast median maximum air temperatures will remain higher than the median for April with a very high chance of exceeding the median maximum temperature for April to June across most of NSW. The forecast is that rainfall figures for April through to June will be lower than historic averages for the majority of NSW. Refer to the Bureau of Meteorology website for the latest forecasts.

Additional information

To notify the NSW Department of Planning and Environment – Water of potential blackwater events email: waterqualitydata@dpie.nsw.gov.au

To report dead fish, fish struggling or gasping at the water surface, or crayfish leaving the water please call the NSW DPI Fisheries Phoneline 1800 043 536 or fill in a fish kill protocol and report form at: www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

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Operational updates are available at: WaterInsights - WaterNSW

Flood updates can be found on the Environment Protection Authority web page at: www.epa.nsw.gov.au/news/news/2022/nsw-storm-and-flood-updates-2022

To report suspected algal blooms see the WaterNSW website.

Murray Darling Basin – water quality and dissolved oxygen results

Multiple agencies are undertaking water quality monitoring to review dissolved oxygen conditions across NSW, identify potential risks to ecological communities, implement mitigating measures and responding to a mass fish death event in the Darling River. This update provides a summary of information collected up to 23 March 2023.

On 17 March there were mass fish deaths in the reach of the Darling River between Lake Wetherell main weir and Menindee town. The dead native fish species were predominantly Bony Herring, with large-bodied natives including Murray Cod and Golden Perch, also observed in this event.

After successive years of high flows and successful fish breeding events, a large biomass of fish has accumulated in this reach of the Darling River. To maintain an oxygenated flow in the Darling River through Menindee township to sustain this large fish population and reduce the risk of fish deaths, releases of good quality water from the Lake Pamamaroo outlet had been continued. Simultaneously, releases from Lake Menindee had been reduced to assist in the flow of water from Lake Pamamarooo, past Menindee town and through to the lower Darling River. Despite these operational measures, fish deaths have occurred.

The maximum air temperature at Menindee increased to 37°C on Thursday 16 March, which is 6.2 degrees above average, and 42.6°C on Saturday 18 March which is 11.8 degrees above average. As air temperature increases, so does the water temperature. The amount of dissolved oxygen water can hold decreases with increasing water temperature. This may have increased the stress on fish that were already struggling to get enough oxygen.

Further downstream, dissolved oxygen levels in the Darling River between Weir 32 and Pooncarie are also remaining below the safe levels for fish health as low oxygen water continues to make its way downstream.

To report any further incidents of dead fish, fish struggling or starting to gasp at the water surface, or crayfish exiting the water, please call the NSW Department of Primary Industries Fisheries' Fishers Watch Phoneline 1800 043 536 or fill in a fish kill protocol and report form at: https://www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills-2019-2020/info-sheet

Dissolved oxygen levels – Darling River at Menindee

Planet satellite imagery taken on 17 March (Figure 1) shows dead fish accumulating along the banks of the Darling River through Menindee town. Imagery from 19 March (Figure 2) shows there is not the same extent of dead fish along the banks but there is an accumulation of dead fish upstream of the

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junction of the Darling River and Menindee Creek. The imagery from 22 March (Figure 3) shows that the accumulation of dead fish that was at the junction of the Darling River and Menindee Creek has been dispersed.

Figure 1: Planet satellite image from 17 March 2023 showing dead fish accumulating along the banks of the Darling River at Menindee

Figure 2: Planet satellite image from 19 March 2023 showing an accumulation of dead fish at the junction of the Darling River and Menindee Creek

Figure 3: Planet satellite image from 21 March 2023 showing the accumulation of dead fish that was at the junction of the Darling River and Menindee Creek has been dispersed

Figure 4 is a Planet satellite image showing the Darling River and Menindee Lakes at Menindee on 21 March. Dissolved oxygen monitoring results collected by WaterNSW on 22 March are shown on Figure 4.

Dissolved oxygen levels in the water being released from lakes Pamamaroo and Menindee is above the safe threshold for fish health. The bulk of the water being released is from Lake Menindee with a smaller flow from Lake Pamamaroo. As a general guide, native fish and other large aquatic organisms require at least 2 milligrams per litre (mg/L) of dissolved oxygen to survive but may begin to suffer if levels are below 4 to 5 mg/L for prolonged periods.

The lowest readings are in the Darling River from Menindee down to the junction of the Darling River and Menindee Creek (1.70 mg/L). These low dissolved oxygen results indicate that there is still a risk of further fish deaths in this area and downstream. The reading of 4.40 mg/L collected in the Darling River at the railway bridge was taken near the water surface, indicating there is some oxygen replenishment from the atmosphere. However, readings taken deeper in the water column show oxygen levels quickly drop below 2 mg/L at around 60 cm.

The image also highlights the green coloured low oxygen flood water from the upper Barwon-Darling River is being captured in Lake Wetherell. As a temporary measure to prevent the poorer quality water from Lake Wetherell being drawn through the Pamamaroo outlet and discharged into the Darling River, the inlet regulator between lakes Wetherell and Pamamaroo was closed in late February. The inlet regulator has been opened again this week to allow the water levels between lakes Wetherell and Pamamaroo to even out to retain infrastructure integrity. The green coloured water can be seen pushing out into the turbid water of Lake Pamamaroo. Ongoing monitoring will identify if this low oxygen water is once again being drawn into the Pamamaroo outlet.

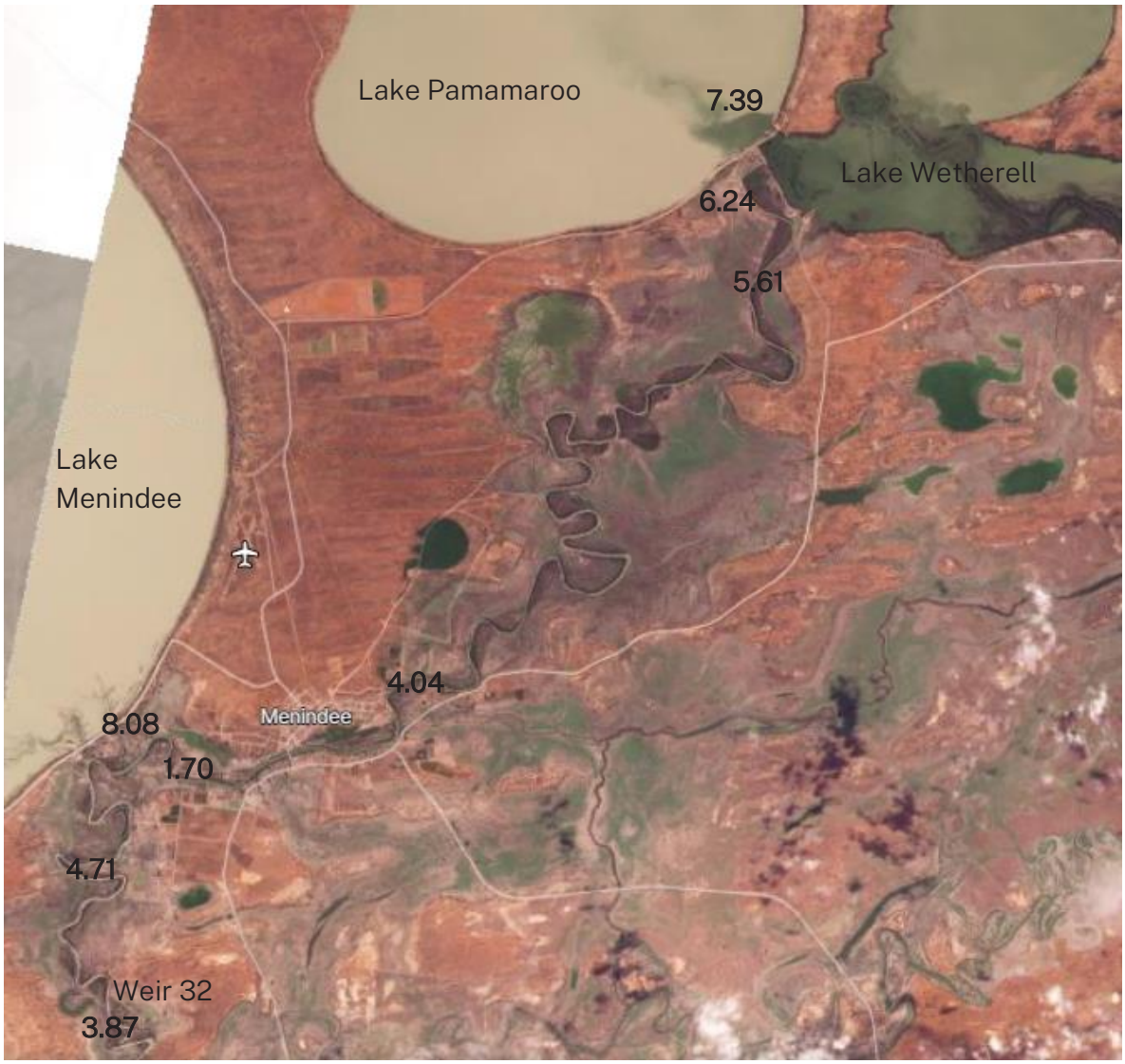

Figure 4: Planet satellite image – Image 21 March. Dissolved oxygen data collected 22 March (mg/L)

Dissolved oxygen in the Darling River downstream of Menindee at Weir 32 had been above the safe level for fish health but decreased rapidly on 17 March, coinciding with the fish deaths at Menindee upstream. Oxygenated water is being released from Lake Menindee to dilute the poor quality water coming down the Darling River. Monitoring on 22 March shows that dilution of the low oxygen water is occurring and that turbulence from the high flow velocity is mixing oxygen through the whole water column. The dissolved oxygen result from near the water surface at Weir 32 are higher than the readings from the continuous sensor at the gauging station (Figure 5). The sensor at Weir 32 is set at a fixed depth lower in the water column of the weir pool. Oxygen levels can be higher near the water surface than on the bottom of pools.

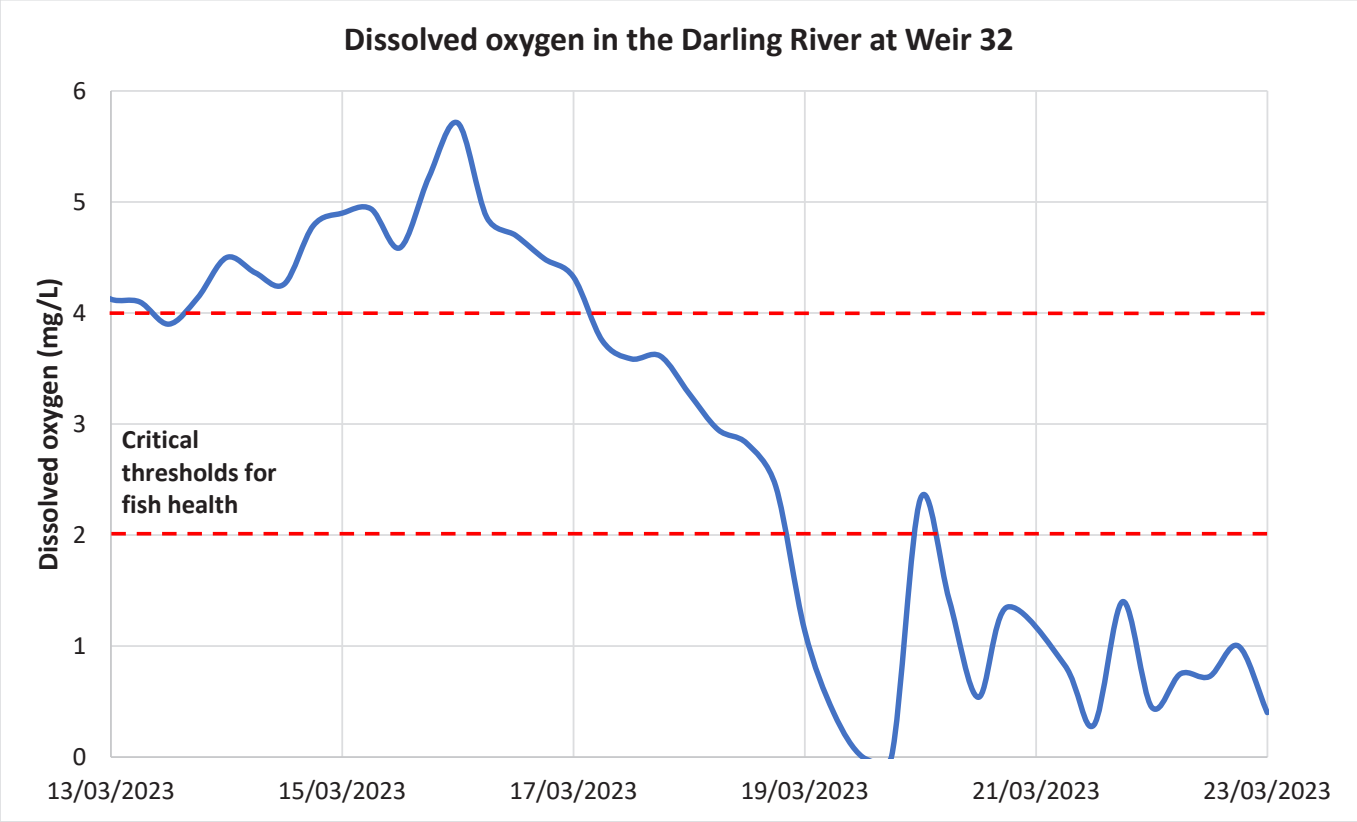

Figure 5: Dissolved oxygen (mg/L) in the Darling River at Weir 32 – 13 to 23 March 2023

NSW and Commonwealth agencies will continue to work together and monitor dissolved oxygen levels in this area and advise operational measures to mitigate risks to aquatic life where possible. This can involve adjusting the timing, volume and location of releases from the Lakes into the lower Darling River to maintain the quality of the water in the river.

Dissolved oxygen levels – lower Darling River

In the lower Darling River, the majority of the floodwater has returned to the channel with some water remaining in larger billabongs and depressions. As the river level drops, the last of the floodwaters around Burtundy are draining off the floodplain and back into the main river channel. As flows recede, fish can become stranded in disconnected waterbodies and billabongs on the floodplain where they may suffer from declining water depth, dissolved oxygen depletion (particularly overnight when photosynthetic production of oxygen ceases), higher air and water temperatures and exposure to predators as these waterbodies dry out.

As the low oxygen floodwaters continue downstream, dissolved oxygen levels are being monitored in the Darling River arm of the Wentworth weir pool (Lock 10). Results show that dissolved oxygen levels through the weir pool are between 2 and 4 mg/L as the flood water continues down the Darling River arm of the Wentworth weir pool and merges into the Murray River.

Hypoxic blackwater fish death summary

In recent months NSW DPI Fisheries has received reports of fish deaths, fish struggling and crustaceans leaving the water across a broad area in the Murray-Darling Basin, including in the

Murray, Kolety/Edward, Wakool, Murrumbidgee, Lachlan, Gwydir, Darling, Barwon, Namoi and Macquarie rivers and Yanco-Billabong Creek system. High air temperatures increase the risk of further reductions in dissolved oxygen in some areas and the potential for further fish death events.

On 17 March there were mass fish deaths in the reach of the Darling River between Lake Wetherell main weir and Menindee town. Hot temperatures coupled with high biomass of fish and organic matter in the water exacerbated the existing low oxygen conditions in this area. The dead species were predominantly Bony Herring, with large-bodied natives (Murray Cod and Golden Perch) also observed in this event.

There has been a report on 17 March of fish deaths in the Lachlan River near Hillston. Up to 100 Murray Cod were observed along with high levels of algae and very warm temperatures. High levels of algae may have resulted in wide daily fluctuations in dissolved oxygen, caused when algae stop producing oxygen overnight when photo synthesis stops. Earlier reports of some of the fish struggling in this area indicated they had high rates of infection by the parasitic crustacean Lernea and this may have made some fish more susceptible to low dissolved oxygen levels.

NSW agencies are working together to investigate and determine if any other native fish have been affected. There may be other fish death incidents that have not yet been reported directly to NSW Department of Primary Industries Fisheries.

Programs to benefit native fish such as improving fish passage and habitat restoration to provide conditions conducive to fish breeding and population growth are ongoing. These works are vital to provide an environment where fish populations can bounce back from low oxygen events.

What is being done?

Water for the environment is being delivered to reduce the risk of further fish deaths by maintaining oxygenated releases from the Menindee Lakes and providing water between Main Weir and Weir 32. To maintain an oxygenated flow in the Darling River through Menindee township and reduce the risk of further fish deaths, releases from the Lake Pamamaroo outlet will continue. Releases from Lake Menindee will also continue, to dilute the low oxygen water coming past Menindee town. The discharge will attempt to maintain flow velocity that research has shown provides conditions that are less favourable for harmful algal bloom formation. Ongoing monitoring will identify if the operations achieve the desired results and be used to inform future operational decisions. Additional water testing is being done to see if there are toxins in the water that could be exacerbating the problem.

There are no operational measures available to reduce the current risk of further fish deaths in the lower Darling River downstream of the Menindee Lakes. Oxygenated water is being released from Lake Menindee, but this will take some weeks to pass along the system. The volume of water being released will not be sufficient to reconnect billabongs on the floodplain to allow any remaining stranded fish to return to the main river channel.

Weather outlook

The Bureau of Meteorology has forecast median maximum air temperatures will remain higher than the median for April with a very high chance of exceeding the median maximum temperature for

April to June across most of NSW. The forecast is that rainfall figures for April through to June will be lower than historic averages for the majority of NSW. Refer to the Bureau of Meteorology website for the latest forecasts.

Additional information

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To report suspected algal blooms see the WaterNSW website.

Community update on response to fish deaths in Menindee

With the Emergency Operations Centre (EOC) standing down on Friday 31 March 2023, the coordination of operations has now returned to the control of individual agencies. NSW and Commonwealth Government agencies are continuing to monitor conditions, take samples and test water, and take actions to try to improve conditions, including dissolved oxygen (DO) levels, in the Murray-Darling Basin.

Established contacts and processes for clean-up in the event it is required in the future are also in place.

Is the drinking water safe?

Yes. Essential Water has increased sampling and testing of drinking water to ensure it continues to meet the Australian Drinking Water Guidelines.

Essential Water use laboratories certified to Australian standards and NSW Health reviews the results. Results of recent testing confirm the quality had not been impacted by event and therefore safe for customers to drink.

There is no need for community concern as there are multiple viable solutions to maintain water supply to the Menindee township and surrounds, if alternatives are required. The frequency of water quality testing has been increased, which will ensure immediate action if a switchover for supply is required.

What is the EPA advice on the water quality?

On 21 March 2023 WaterNSW collected six water samples from the Darling River for the NSW Environment Protection Authority (EPA).

Water sampling was undertaken to check for contaminants following a major fish death event that commenced on 16 March 2023 on the stretch of the Darling River between Weir 1 and Weir 32 at Menindee.

Water samples were checked for pesticides, nutrients and metals, as well as the presence of algae and algal toxins to inform community about the safety and use of the water in the river.

Pesticides were not detected in the water samples.

Elevated levels of Total Nitrogen and Total Phosphorus were detected, which may result in algal blooms if these nutrients remain elevated.

Algae, including blue green algae, have been detected in all samples at levels ranging from within the Green to Amber Alert Classification. An Amber Alert is currently in place for this part of the Darling River. This test indicates that the river water is unsuitable for potable use (i.e. not suitable for drinking without treatment) and may be unsuitable for stock watering.

Metal concentrations were within guidelines for recreational use. Copper was above the water quality guideline for protection of aquatic ecosystems, but well below concentrations known to be

harmful to fish. All other metals were below water quality guidelines for the protection of aquatic ecosystems.

The EPA and WaterNSW are continuing to monitor water quality in the Darling River, downstream of Menindee, following the recent fish kill event and will share results that differ from these.

Further details of the test results can be found on the EPA website.

What does an Amber Alert mean?

An Amber alert indicates that the river water is unsuitable for potable use (i.e., not suitable for drinking without treatment) and may be unsuitable for stock watering.

There are no restrictions on recreational use, for example swimming and canoeing. Contact with river water should be avoided if a scum on the water surface can been seen.

We know graziers are well versed in managing water for their stock. Local Land Service provides water testing kits to support them in tracking the quality of the water for their stock.

Is there currently harmful levels of blue-green algae in the Menindee Lakes and Darling River?

There are currently no red alert warnings in place for harmful blue-green algae in the Menindee Lakes.

Test results received in recent weeks following the Menindee fishkill event in mid-March, identified the presence of blue-green algae, but not at levels requiring a red alert.

These results for blue green algae from sampling conducted on 21 March and 30 March are available on the WaterNSW website.

The results are from a total of 10 sites where wider testing was conducted by the Environmental Protection Agency (EPA).

Results on the WaterNSW website at additional Menindee lakes sites are from routine blue-green algae sampling undertaken by WaterNSW in late February.

In the absence of algae concentrations at red alert level, WaterNSW sampling occurs monthly, as well as in response to requests from landholders and local government, or as otherwise required.

Are there health guidelines to provide advice for people using water from rivers?

Yes. NSW Health advise that surface water from farm dams, rivers and creeks should not be used for drinking or cooking without appropriate treatment. This applies to any location in NSW.

Surface water may be acceptable for non-potable uses such as washing clothes, irrigation, gardening, toilet-flushing, but we recommend that water used for bathing is at least disinfected before use.

NSW Health warns that heavy rainfall and flooding increases the risk of contaminated water which could contain disease causing micro-organisms, chemicals or algal blooms, entering surface waters such as rivers and creeks. Blue-green algae may cause skin irritation. Water quality may be affected during drought as flow and the amount of water is reduced.

Further information can be found on the NSW Health website.

What impact will the dead/decaying fish have on water quality?

Decaying fish create bacteria that could make people and animals unwell.

People should not drink untreated water and are advised not to swim, fish, use dead fish for bait or consumption and not allow pets to come into contact with the water in areas of large fish kills, as it may contain high levels of bacteria.

How do I mange my livestock if blue-green algae blooms are present?

We know graziers are well versed in managing water for their stock. Local Land Service provides water testing kits to support them in tracking the quality of the water for their stock.

Early identification of blue-green algae blooms in livestock water sources is important. Prompt removal of livestock from the water source and access to an alternative safe water supply for stock is important if water if algae levels are too high.

There are currently no red alerts for Menindee and there have been no reports of issues in relation to livestock access to water. However, if livestock owners have concerns, they can request a water sampling kits from Local Land Services.

Water NSW provides up to date information on algae alerts.

Is water carting continuing?

Yes. Water carting remains available for eligible residents at this time. The community will be advised as we transition to business as usual.

What if I need an alternative raw water supply?

For Menindee residents, not on the Main Weir Pool who require raw water, there is a standpipe available for access to raw water drawn from Stephens Creek. This raw water is as good or better quality than water from the Menindee weir pool prior to the fish kill.

This water is NOT for drinking.

The standpipe is located between Wilcannia west road and the railway crossing on the Broken Hill side of the turn-off. There is a circular drive through at the location with easy access.

There is currently no lock on the standpipe and is available for use by the community to fill IBC's or other tanks.

What has happened to clean up the dead fish?

Over ten tones of dead fish have been removed from the river and buried as landfill. The clean-up operation is now complete.

Processes for clean-up in the event it is required in the future, are also in place.

Is the water low in oxygen further down the river at Pooncarie?

There have been reports of isolated small fish death events associated with low oxygen water making its ways through the system. Dissolved oxygen at Pooncarie and further downstream has remained at critical levels for native fish, however; the water quality within the Wentworth weir pool itself has remained well above these thresholds.

Is the Wentworth Emergency Operations Centre (EOC) still operating?

No. The coordinated emergency response on the lower Darling-Baaka River has concluded following recent results of ongoing monitoring and assessments of water quality and conditions.

Throughout this week, experts reported promising improvements from water testing results, including dissolved oxygen levels, which informed the decision to stand-down the Wentworth EOC on Wednesday 5 April 2023.

Responsible agencies are continuing to meet regularly and operate throughout the Murray-Darling Basin and beyond.

In the unlikely event that conditions deteriorate, there is a capacity to immediately stand-up an EOC and initiate an emergency response.

What water quality monitoring is being undertaken?

Various agencies are monitoring dissolved oxygen and water temperature, with both remote monitors and field samples, with occasional field data on pH and electrical conductivity levels.

Water quality monitoring will continue across the Easter weekend.

Will there be further fish deaths?

Water quality within the Lower Darling-Baaka continues to show steady improvement over the last week. There have been no new reports of fish deaths in and around Menindee township.

Releases of oxygenated water are continuing from Lake Pamamaroo and Lake Menindee to boost dissolved oxygen levels and provide refuge for native fish.

With our responsibility to balance these releases against the need to maximise water in the Lakes for storage, flows are being gradually reduced and adjusted.

More information on water releases can be found on the WaterNSW website.

Monitoring is ongoing to minimise the risk of water quality deteriorating in different parts of the river.

Where else can I find information?

Information about the monitoring, management and maintenance of water quality, including detailed community updates from the Department of Planning and Environment, is available online: www.industry.nsw.gov.au/water/allocations-availability/droughts-floods/drought-update/managing-drought-recovery/blackwater

Observations of changes to water, including struggling fish or deaths can be reported directly to DPI Fisheries on 1800 043 536.

For more information about fish kills, as well as recent reports of observations and causes, visit: www.dpi.nsw.gov.au/fishing/habitat/threats/fish-kills

These types of events can be distressing to members of the community, and anyone who requires health, welfare or other support can contact local community support services. A comprehensive list of services can be located online: www.service.nsw.gov.au/transaction/customer-support-service-infoxchange-service-seeker