Trial of oxygenation in the Darling Baaka River near Menindee

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Executive Summary

The NSW Department of Climate Change, Energy the Environment and Water (DCCEEW) and WaterNSW entered into a funding agreement for a micro bubble technology trial in the Darling Baaka River near the town of Menindee, NSW. The trial was to test the efficacy of micro bubble aeration to increase the dissolved oxygen (DO) concentration within the river. This report draws together the findings from monitoring and predicted river oxygen concentrations based on river flow rates and oxygen input from the SOLVOX® aeration unit. The micro bubble technology used within the trial was supplied by BOC and utilises a proprietary SOLVOX® aeration unit.

Findings from Plant Operation

The trial plant was operational as of 1 February to the 4 June 2024, with water quality being monitored in the operational area.

- The SOLVOX® technology can supply oxygen and diffuse it through the target area.
- The SOLVOX® plant has continuously supplied 10kg of oxygen per hour since 1 February and 20kg from April the June 2024, with only a minor interruption from an electrical supply fault and a failed gasket.

During the first two months, larger than anticipated river flows, of 500-750ML/day from environmental releases of highly oxygenated water from Lake Paramaroo, limited the ability to assess the efficacy of plant as these flows were above the capacity of the plant. The following months flows dropped to 300 - 350ML/day and the data show that:

- water velocity measurements showed water from oxygenation unit increased its influence with reduced flows;
- oxygen levels in the bottom water of the river were higher downstream than upstream of the oxygenation unit; and
- oxygen levels in the bottom waters of the river were higher up to 180m away from the oxygenation unit.

Oxygenation Potential in Weir 32

The technology has shown at low to no flows, oxygenation of bottom water is possible within weir 32. The area of influence is based on flow conditions, the amount of oxygen injected into the system and the number of diffuser points.

The technology does offer the capacity to reduce or mitigate hypoxia events under low to no flow conditions. A further review into the most appropriate sites for any expansion of this technology should be done and be supported by data on biological and sediment oxygen demands of the system.

It is therefore concluded that:

- based on the data available, the SOLVOX® technology worked within the expectations and performance criteria; and
- at reduced flows the SOLVOX® unit did increase oxygen levels in the bottom waters of the river.

Deployment of additional aeration devices

It is recommended that early engagement is sought with the First Nations Traditional Owners, Native Title representatives and community regarding the proposed location of any future aeration sites. Early engagement and the appropriate exchange of information and knowledge with the local First Nations community, who hold deep connection and knowledge of the river could enhance our understanding of the best locations and sites for installation.

Introduction

Background

The Darling Baaka River near Menindee has experienced several large-scale fish deaths, culminating in 2023 where an estimated 20 - 30 million fish died within the river system. Following the 2023 fish deaths, the Office of the Chief Scientist & Engineer prepared a report investigating the causation of the fish deaths. The report provided several recommendations which could reduce the likelihood of future fish deaths.

In response to the report, the SOLVOX® oxygenation plant (drop-in unit) was trialled to increase DO in the river. This plant represents the best-known technology to achieve an emergency response to low oxygen levels in a stratified water body such as the Darling Baaka River during low flows. The SOLVOX® oxygenation plant (drop-in unit) has been trialled in the Vasse estuary inlet channel at Busselton Western Australia and artificial oxygenation has been extremely effective in increasing oxygen conditions in the Swan and Canning rivers in Western Australia. This report outlines how the effectiveness of the trial plant will be measured, evaluated, and provide recommendations for future use.

Purpose

Specifically, the purpose of the trial is to assess:

- to test the theory that hypolimnetic oxygenation is a viable technique for oxygenating sections of the river; and
- the ability of the BOC SOLVOX® plant to increase dissolved oxygen concentrations to a level that sustains aquatic health (known as hypolimnetic oxygenation).

The principle of hypolimnetic oxygenation

Oxygen is supplied to water in situations where conditions reduce the amount of DO in the deeper sections of the river. In the Darling Baaka River, a supersaturation technique is being trialled. In this process water is drawn from the river, supersaturated with pure oxygen, and delivered back to the water at depth by diffusers from the SOLVOX® unit. The hypotheses was that the trial will improve DO concentrations at depth and provide refuge for aquatic species during low to no flows.

Trial installation

Initially two trial locations were proposed, however it was decided to only progress with one location for the following reasons:

- Time – more than one site would have impacted the project timeline, the second site would not have been commissioned until after summer due to difficulties in sourcing a second SOLVOX® unit and a lack of a suitable site that had been assessed for environmental and Cultural Heritage considerations;

- Security – The site which was selected was within an existing secure compound which reduced the risk of theft, arson, tampering that could result in injury, environmental impact or equipment damage; and
- Power – The selected site provides mains power. The second site would have required a generator which would have required significantly higher resources to operate and maintain.

The location was within the compound of the Menindee Water Filtration Plant and former Pumping Station for the Broken Hill Pipeline. The site is owned and operated by Essential Water. In addition to the advantages listed above, it is also adjacent to the deepest section of the river (thalweg) on the western side, near to the Filtration Plant compound. This is situated downstream of Lake Wetherell and Lake Pamamaroo Outlet Regulators, but upstream of Menindee township, Lake Menindee and Lake Cawndilla Outlet Regulators. This is the stretch of river that has experienced fish kills in the past and was an area where the SOLVOX® unit could achieve maximum benefit.

The SOLVOX® unit was positioned approximately 1/3 of the distance across the river from the western embankment (Filtration Plant Compound side). The reasons for this included:

- This was a deep section of river, without compromising the following;
- The likelihood that water traffic would collide with the buoy and equipment was reduced. Note: this was within the line of the Filtration Plant Pumps Jetty and WaterNSW installed Warning Buoys and signs to provide an exclusion zone;
- The internal WaterNSW Environmental Approval stipulated we could not impede river traffic; and
- The likelihood of the public tampering with the equipment was reduced as it was not in the middle of the river and was close to existing Filtration Plant Infrastructure.

For a permanent solution, these factors would need to be further evaluated to determine the optimum location.

Measures of Effectiveness

Effectiveness of plant

Establishing efficiency of plant design

To evaluate how well the plant is working, a theoretical efficiency of oxygen diffusion with the current SOLVOX® configuration was calculated with BOC. This was to estimate the expected delivery from the diffuser configuration, including consideration of the flow rates in the river (Figure 1). The trial optimum flow rates would be less than 200ML/day and preferably 50-100 ML/day. Increasing the likelihood of stratification and low oxygen conditions. At an oxygen dosage rate of 20 kg of oxygen per hr the SOLVOX® unit should achieve an in river hypolimnetic oxygen increase of up to 2.4 mg/L and 9.6 mg/L up to when river flow is at 50 ML/day and 200 ML/day respectively.

Outcome: Assess whether the theoretical amount of oxygen able to be delivered by the trial plant for oxygenation is achievable under real-world conditions.

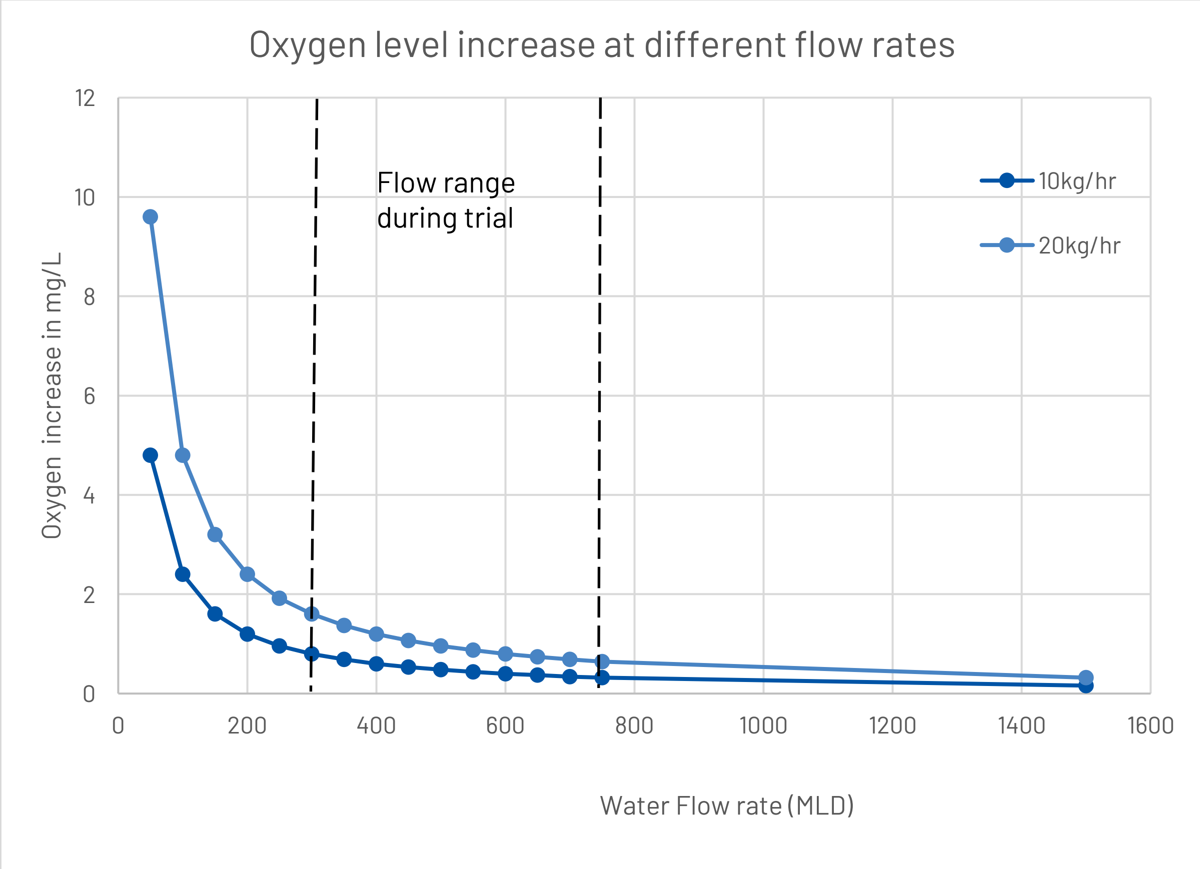


Figure 1: Predicted oxygen level increase at different flow rates

Ability to inject oxygen into water

Once the water which has been supersaturated with oxygen exits the diffuser, the oxygen is detrained into the surrounding water body in the vicinity of the outlet (Figure 2). Environmental oxygen levels were measured via two methods. The first using multi-parameter EXO^2 Sonde probe to profile the water from the surface to the riverbed, which gives a monthly snapshot from a range of sites upstream and downstream of the oxygenation plant (Figure 2, 3). The trial monitored a 2.7km reach of the river in total. The second method is in-situ monitoring buoys (Figure 2). The in-situ buoys have HOBO U26 - dissolved oxygen data loggers installed 0.5 and 1 m above the riverbed (Figure 2). The loggers are in water depths that are typically anoxic and are situated 50m and 150m downstream and monitored oxygen every 15 minutes over the trial period. An existing DEECW in-situ buoy upstream (50M) with oxygen probes at the surface and bottom was used as a control. This monitoring strategy allowed practical measurement of oxygen concentrations upstream and downstream of operation and relative to adjacent areas that are not oxygenated.

Outcome: Understand the range of influence of the plant under varying environmental and flow conditions.

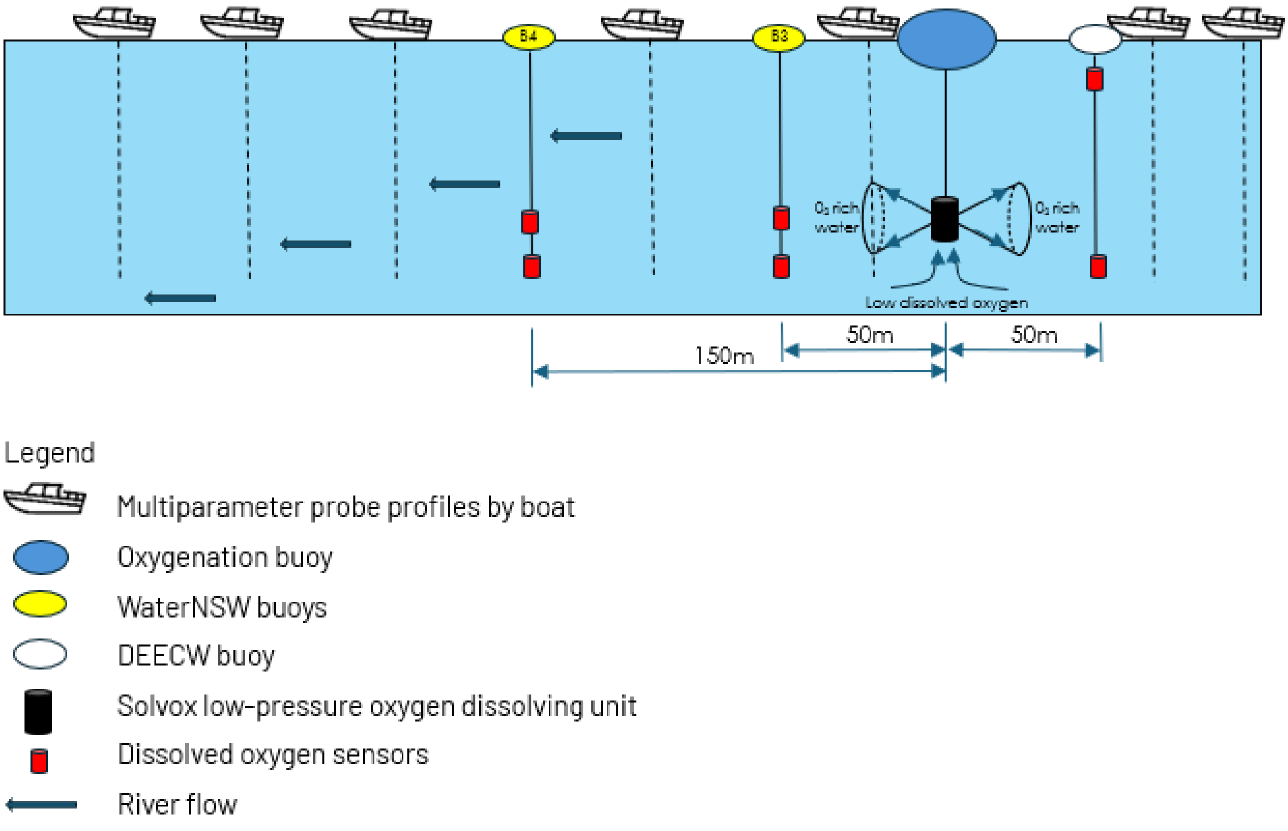


Figure 2: Schematic of the oxygenation trial monitoring.

Figure 3: Oxygen and temperature monitoring sites established around the oxygenation plant covering 2.7km.

Ability to retain oxygen in the water

The principle is that supersaturated water delivered to denser bottom waters, below the thermocline, will improve the oxygen concentration, thus allowing diffusion into the bottom waters. Oxygenation will be more effective when the water density difference is greatest, typically when there is low to no flow and a strong thermocline. Measures will be made of oxygenation levels to augment visual observation of bubbles or plume appearance in the surface water.

Outcome: An understanding of water density differences and impact on oxygenation of the bottom waters which allow effective operating windows to be determined.

Ability to disperse oxygenated water under range of conditions

The design principle also assumes dispersion of the plume of oxygenated water, away from the diffusers by the water movements in the river. Measurement will be obtained by the oxygen profile sampling and the in-situ buoys. Flow measurements will be made with an in situ Acoustic Doppler Current Profiler (ADCP), which visualises water movements into 10-20cm bins to confirm oxygen levels are connected to SOLVOX® oxygenated water dispersal from the oxygen delivery site.

Outcome: Measures of possible range of influence and volume of water oxygenated. For example, very large water movements may exceed the capacity of the plant to change oxygen concentration.

Results

Flow rates in weir 32 during the trial period, ranged between 300 and 750ML/day which were above the optimum flows for the SOLVOX® dosing unit of 50-200 ML/day (Figure 4). Theoretical increases in dissolved oxygen at highest flows of 750 ML/day at 10kg per hr of oxygen is an increase of 0.32mg/L, and the lowest flows of 300ML/day at 20kg per hour of oxygen would be an increase of 1.60mg/L (Figure 2).

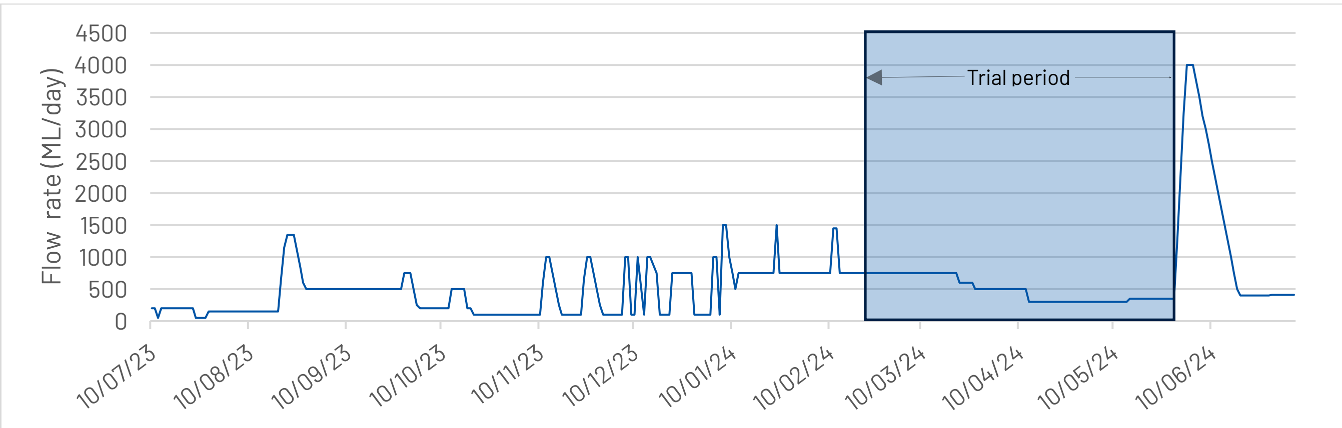


Figure 4: Flow rates past the oxygenation site over the last year and during trial period highlighted.

River flow and Oxygenation unit velocity measurements

Water velocity measurements were made using an ADCP on two occasions at two different flow rates in the river. On 13 March when flows were 750ML/day and on 15 May when flows were 350ML/day (Figure 5, 6). The ADCP was able to detect an increased zone of influence from the oxygenation SOLVOX® unit when river flows were reduced (Figure 6). The cross-sectional images show an increased flow near the unit and up to 10m downs stream when the SOLVOX unit was running at 20kg/hr of oxygen and river flow was 350ML/day.

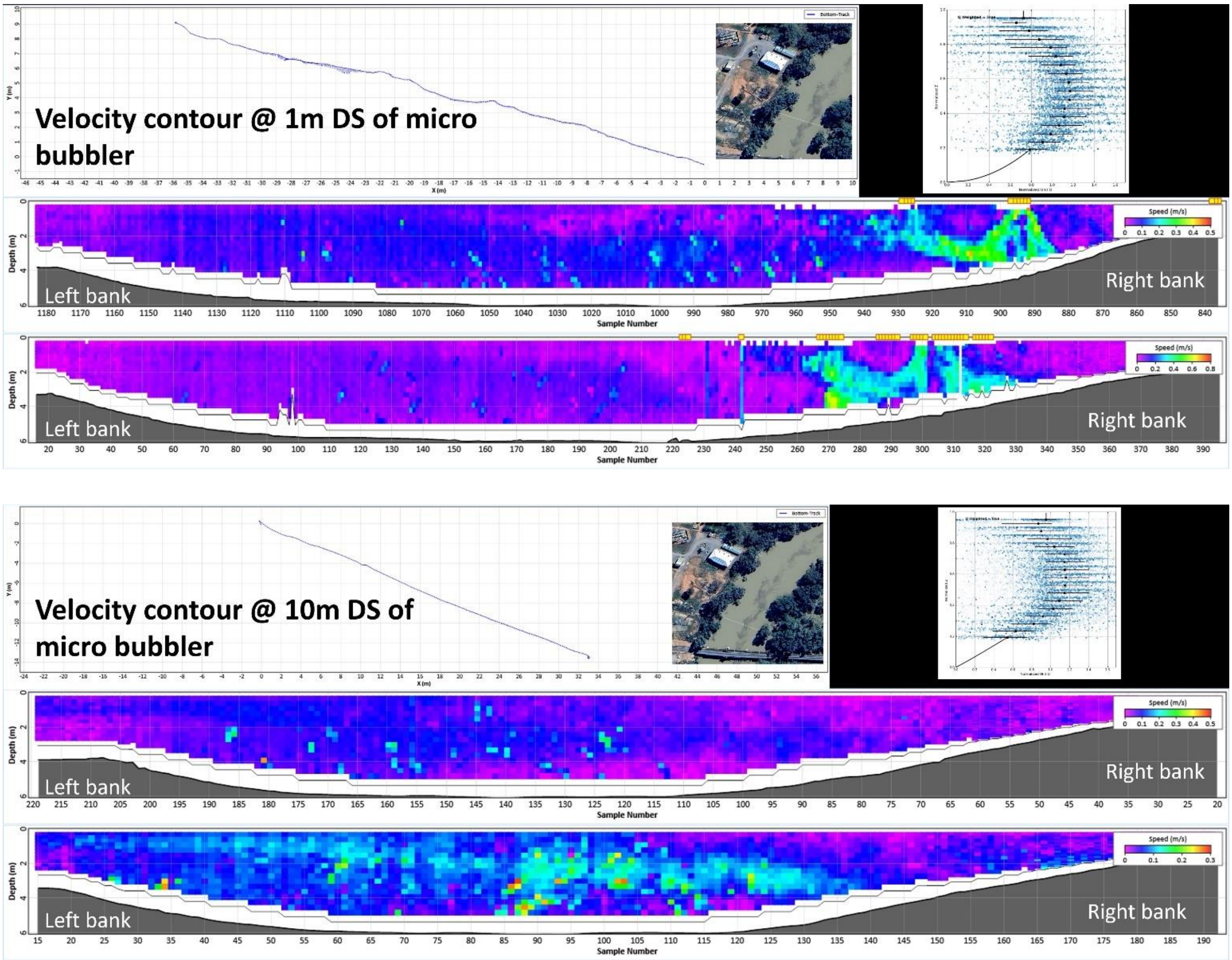


Figure 5: cross sectional water velocity measurements of the Darling Barker River 1m and 10 downstream of the oxygenation buoy on the 13 March at 750ML/day flow. Oxygen flow rate at 10kg/hr.

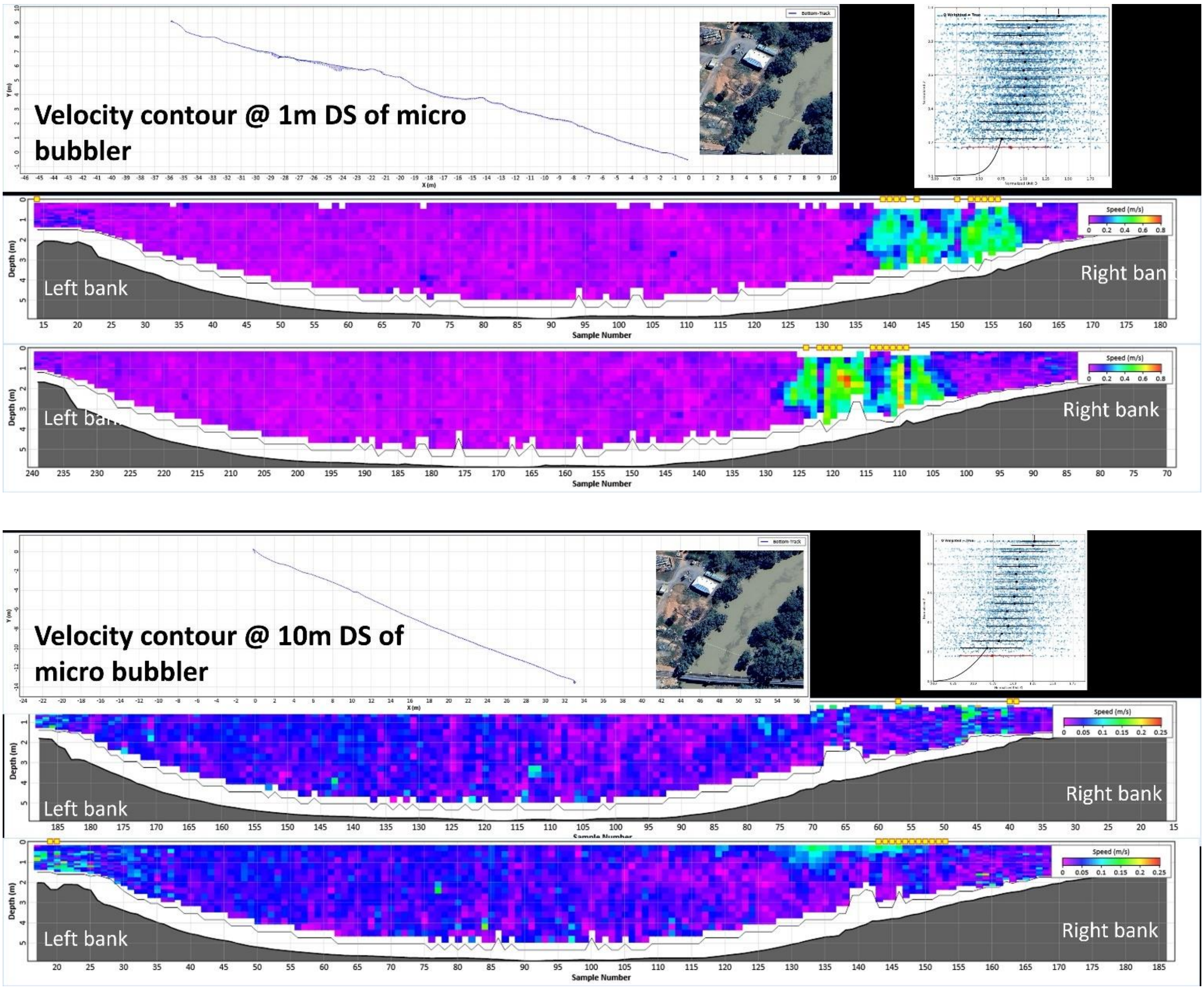


Figure 6: cross sectional water velocity measurements of the Darling Barker River 1m and 10 downstream of the oxygenation buoy on the 15 May at 350ML/day flow. Oxygen flow rate at 20kg/hr.

Dissolved oxygen measurements

Ability to inject oxygen into water

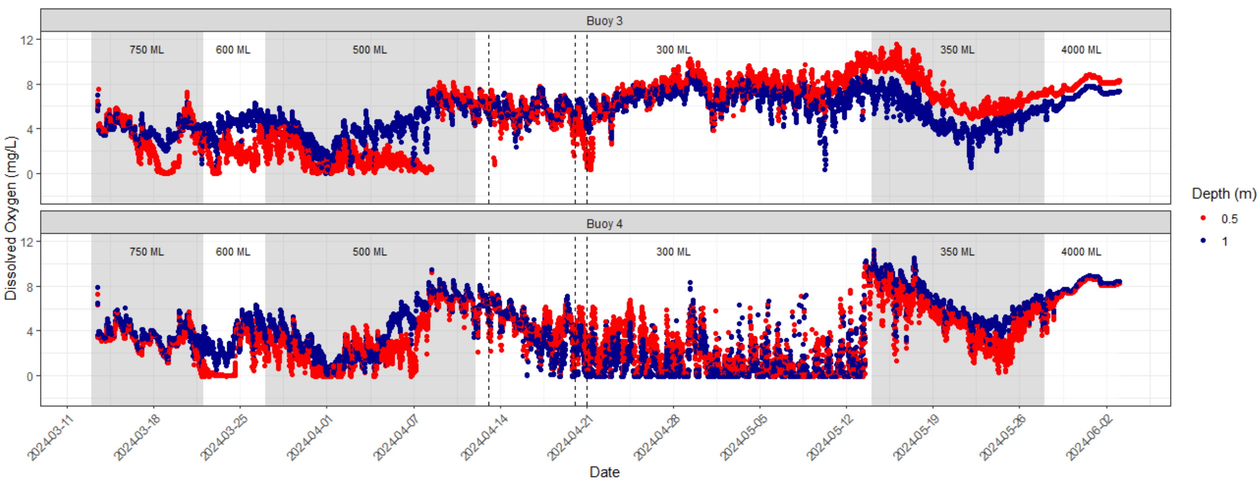
The oxygenation unit operated within performance expectations during the trial period. The unit continued to work in a range of air temperatures with only minor adjustments needed to keep pressures and flows within design specifications. Mooring and floats also worked within the range of flow conditions. There were some issues with power supply, and this led to several outages in the second half of the trial period.

Ability to retain oxygen in the water

The stronger the thermocline, the more likely injected oxygenated water will stay in the lower layers mediating the natural anoxic conditions (low oxygen layer). During the trial period the thermocline was not particularly strong, with only a 0.5 to 2 degree difference between surface and bottom waters. Water velocity measurements indicated oxygen from the unit spread throughout the water column and to the surface (Figure 6). Figure 10 shows an increase in oxygen in the lower depths generally fading the further away from the unit when flows were 300ML/day and oxygen was set to 20kg/hr. However, in April drops in oxygen levels from the 0.5m above river bed DO probe at buoy 3 corresponded with the plant being off. This demonstrated that oxygen was being retained to some extent despite operational conditions not being ideal. These levels rose again when the plant was turned back on (Figure 8).

Ability to disperse oxygenated water under range of conditions

Data from Buoy 3 which was 50m downstream of the oxygenation unit showed an increase in oxygen in the 0.5m above riverbed probe (Figure 8). This deeper probe had consistently high readings of dissolved oxygen but did drop three times which also corresponded with the oxygenation plant being out of operation. In comparison to the upstream DCCEEW buoy, oxygen levels downstream of the SOLVOX® unit (Figure 9) are substantially higher (at buoy 3 and 4) over the trial period. The diurnal fluctuation in oxygen levels is also reduced at downstream buoys. This was from some fouling of the dissolved oxygen probes which may have led to lower readings for the second half of monthly services.



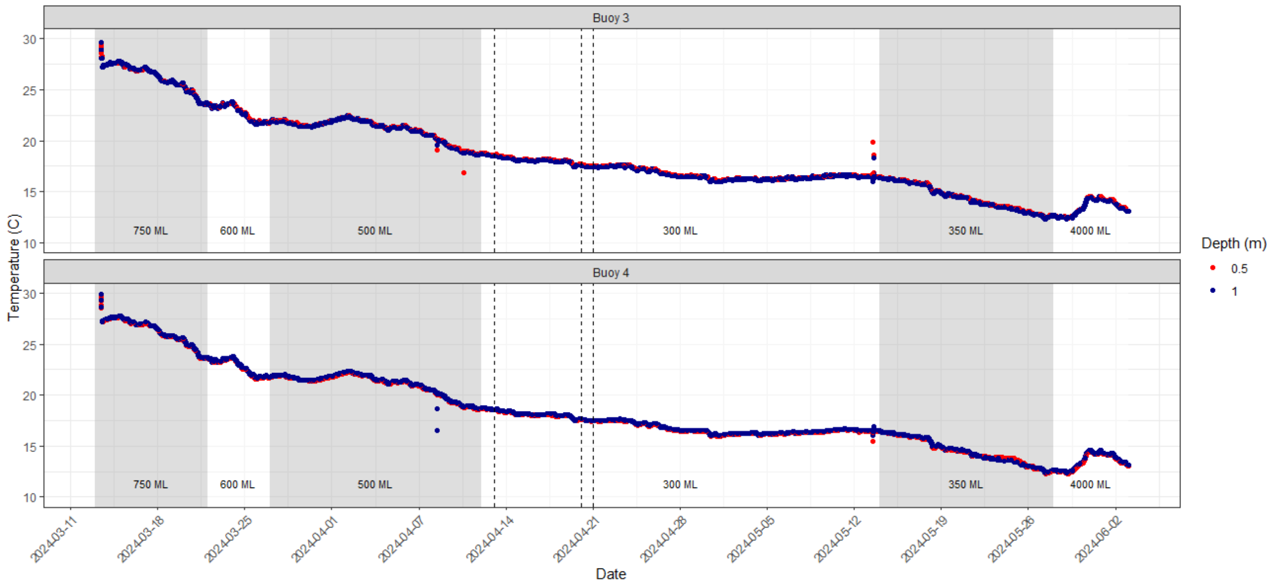


Figure 8: Dissolved oxygen and temperature at buoy 3 (50m downstream) and buoy 4 (150M) downstream from depths 0.5m and 1m off the riverbed.

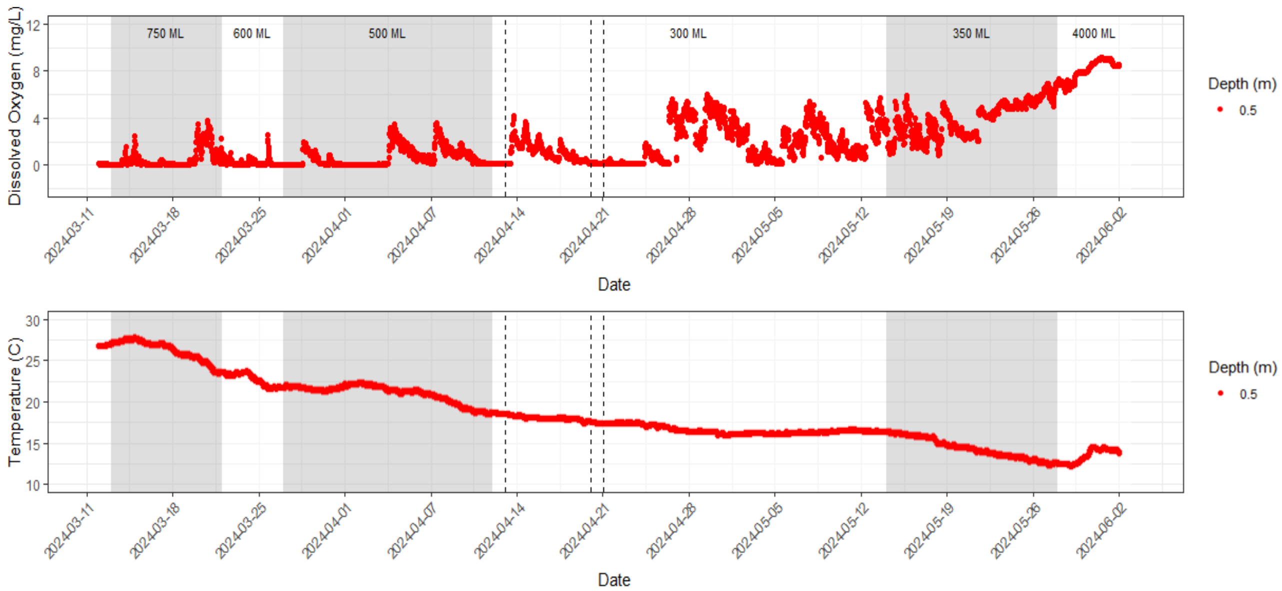


Figure 9. DEECW buoy (50m upstream) 0.5m off the riverbed

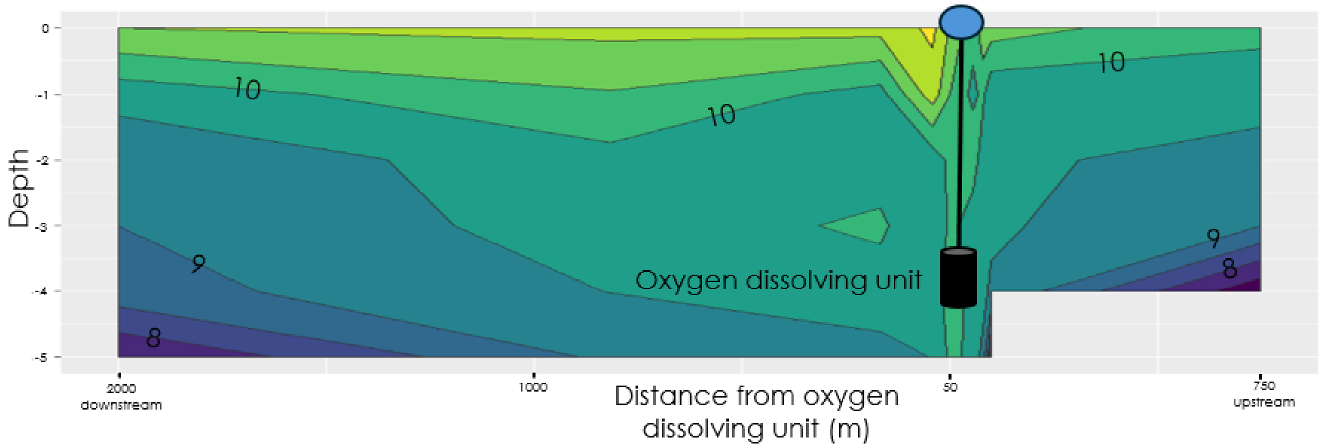


Figure 10: Heat map of dissolved oxygen profiles at flow 350ML/day and oxygen 20kg/hr in the reach of the river where the Oxygenation unit is deployed.

Report Findings

With very weak stratification within the river, oxygenation was not restricted to the hypolimnetic zone, but a weight of evidence approach to the data collected suggests the oxygenation unit, even at higher than optimal flows, was able to increase oxygen levels in the bottom water of the river. In a scenario where flows were lower, this technology could adequately oxygenate water to a level and provide a refuge that protects aquatic health during stagnant anoxic conditions.

- Water velocity measurements showed water from oxygenation unit increased its influence with reduced flows.
- The in-situ buoys showed higher levels of oxygen downstream in the bottom waters of the river than upstream of the oxygenation unit.
- The heat map suggested that oxygen levels in the bottom waters of the river were higher up to 180m downstream from the oxygenation unit and potentially influenced further.

Discussion

The trial has shown the SOLVOX® unit can increase oxygen in the bottom waters at lower flows. The data indicates the SOLVOX® unit would be more effective at no flows where there is likely to be mild stratification. Levels of oxygen increase at river flow rates of 300ML/day were within the hypothetical range of 1-1.5mg/L. The trial has also highlighted that higher flows reduce the oxygenation impact in two ways:

- by diluting its input as the newly oxygenated water is moved downstream; and
- a mild thermocline prevents newly oxygenated water being retained in the bottom waters, dispersing the oxygenated water over a larger vertical area as well as longitudinally.

Oxygenation systems in the Swan and Canning River, benefited from a strong stratification, which prevented vertical mixing and helped keep the oxygenated water at depth (Larsen et al 2019). The lack of strong stratification during this trial should be considered in any future deployment to ensure that there is minimal loss of newly oxygenated water to the surface waters.

A two-year trial of a similar oxygenation unit in the Vasse estuary exit channel in Western Australia, showed that even in a shallow deployment of only 2m depth, the unit was able to oxygenate the water body with minimal loss of oxygen to the atmosphere. This deployment was able to advert hypoxia and reduce the risk of fish kills between 67-82% of the time (Larson & Kam 2018). The Vasse trial increased the extent of oxygenation by utilising two SOLVOX® units operating from a single oxygen plant, thus allowing for a greater dispersal of oxygen. This approach should be considered at Menindee for any future deployment of SOLVOX® units.

Water quality data from monitoring buoys across the weir 32 indicated that the river system is dynamic, with noticeable differences in water quality throughout. At times of high flow the trial data indicated that water quality and oxygen levels naturally increased to the point where the SOLVOX® unit has negligible impact on improving river conditions. Previous fish kill events occurred in the old town weir and junction of Menindee Creek and the Darling River. The results from this trial indicate that sites would benefit from the deployment of oxygenation units during times of low to no flows. Further investigation is required to determine whether a permanent or temporary solution is the most appropriate and what infrastructure is needed to support operation of an oxygenation system, where there is currently no power or facilities for housing equipment.

Early engagement with the Traditional Owners, Native Title representatives and community within the project area would assist in the planning and/development of future aeration sites in the Darling Baaka River or Menindee Lakes system. This engagement opportunity should be co-designed to ensure collaboration and to understand how First Nations representatives would like to participate and contribute skills and knowledge. Any opportunities for monitoring, procurement, training and employment should also be explored and considered as part of project development and co-design to:

- Increase skill and training opportunities including in cultural heritage, environmental science, and construction;

- Increase procurement of local First Nations organisations and businesses; and
- Build long term positive relationships and benefits through tangible actions.

Recommendations

This trial has shown that microbubble oxygenation of bottom waters is possible under low flow conditions. A detailed scientific review should be done on potential sites where the technology could be deployed, as an emergency response and more permanent installations options. The review should take into consideration previous zones of the river that have had historical issues with water quality and periods of hypoxia. The review should estimate the likely operational period for an oxygenation system over drought vs non drought periods. Data on biological and sediment oxygen demands from the system should also be considered. The review would then provide the input for any future oxygenation options.

Although there were no fishkills in Lake Wetherell during the drought, it was a critical fish refuge, and as such a venturi oxygenation unit to maintain oxygen levels was installed. A microbubble oxygenation unit would be a more efficient way of delivering pure oxygen during a similar event. An oxygenation unit if scoped appropriately could prevent poor water quality from forming in the deeper parts of the Lake. This could allow more options when delivering water downstream and negate the need to isolate the Lake until water quality improves from inflows or winter turnover.

A preliminary design study based on the scientific review be prepared for future installations based on lessons from this trial and from the Western Australia installations. The design study should consider but not be limited to:

1. Early engagement with Menindee First Nations community.
2. Researching the most appropriate river sections for future deployment.
3. Engineering design and commissioning.
4. Construction approach and operational management.
5. Electrical connection, mains power and renewable options.
6. Running of electrical cable and oxygen pipework.
7. Breakdown of estimated cost.