



Darling Baaka River Health Project 2023 to 2025

Chapter 1 Summary and project overview

Department of Climate Change,
Energy, the Environment and Water



Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

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Summary

This technical report presents the findings for the Darling Baaka River Health Project (the project), delivered by the NSW Department of Climate Change, Energy, the Environment and Water (the department) in partnership with the NSW Environment Protection Authority (EPA) between September 2023 and June 2025. It was delivered under the EPA's Recovery Program for Water Quality Monitoring in the Darling Baaka and funded as a Category D recovery measure under the joint Commonwealth and NSW Government Disaster Recovery Funding Arrangements.

Additional data from April 2023 to July 2023 are also used in this report, including data collected by the department's Science and Insights Division under the EPA incident response program, and algae samples from WaterNSW.

Data collected have been analysed in alignment with the *River Condition Index: method report* (DPE 2023a) to assess river health from Wilcannia to Wentworth, including the Great Darling Anabran. The method combines data from 6 indexes – geomorphic condition, water quality, biodiversity condition, riparian vegetation condition, hydrological stress and landscape disturbance – to assess the overall river health within the study area. This project has implemented several modifications to the River Condition Index (RCI) framework (DPE 2023a) to allow a high-resolution assessment of river health from Wentworth to Wilcannia, thus the 2023 RCI and the RCI presented in this project are not directly comparable. Data for this report was collected from 36 sampling trips, comprising 2,935 samples, from 41 sites across the study area.

The majority of the 28 subcatchments in the region are assessed as being in moderate condition, indicating that the river system has deviated from a healthy state and is under stress. The RCI framework, while important in gaining an overview of the health of the river system, oversimplifies complex interactions which may potentially mask significant findings of this report. A total of 152 individual metrics (with over 80,000 individual datapoints) have been combined into one overall score for each subcatchment in this project, thus caution is required when interpreting the single overall RCI grade for each subcatchment.

To combat this issue and to provide information more relevant for environmental and water management decision-making, it is important to interpret each of the 6 RCI indexes individually. There are several important findings which indicate that water quality and biodiversity condition throughout the majority of the subcatchments are in poor to very poor condition.

The entire project team is grateful to have had the opportunity to collaborate with the Barkandji Prescribed Body Corporate and work on Barkandji Country. In Aboriginal culture both Country and River have spirit(s), and we pay our respects to both.

Main findings

Geomorphic condition

Geomorphic condition varies in the study area depending on the degree of alteration to geomorphic processes associated with structures and river regulation. The poorest geomorphic condition scores occur around Lake Wetherell and Menindee township where weirs, embankments and artificial channels associated with the Menindee Lakes Storage Scheme negatively impact geomorphology. The key geomorphic threats to the lower Darling Baaka are the hydrological impacts of river regulation and water extraction, alluvial gully formation and expansion, and reduced river red gum (*Eucalyptus camaldulensis*) recruitment.

Water quality

The majority of the subcatchments received a poor water quality grade, with only 3 subcatchments receiving a moderate condition grade. The main contributing factors to these classifications are high levels of chlorophyll-a (a measure of algae levels), nutrients, turbidity and low dissolved oxygen concentrations. High nutrient levels can cause excessive algal growth, with the presence of toxin-forming algae observed on several occasions. Several pesticides were detected in the study, at levels mainly below guideline values. Overall, the study has indicated that water quality in the lower Darling Baaka River was persistently poor throughout the study period, with eutrophication of the river associated with elevated nutrient levels and high amounts of algal growth.

Riparian vegetation condition

River red gum communities dominate the riparian zones of the lower Darling Baaka, with coolibah (*Eucalyptus coolabah*) – black box (*Eucalyptus largiflorens*) woodlands dominating floodplain environments. Over the study area, riparian vegetation condition in most catchments was assessed to be in moderate condition. Several subcatchments on the Great Darling Anabranh were assessed to be in good to very good condition, whereas the Talyawalka Creek region displayed poor riparian vegetation condition. While the riparian vegetation within the study area can generally be considered to be of moderate health, low numbers of river red gum and black box recruits indicate these populations may not be viable into the future.

Biodiversity condition

All subcatchments on the lower Darling Baaka River were assessed to be in poor biodiversity condition. The Great Darling Anabranh was assessed as having a slightly better biodiversity condition, with one catchment in good condition, 3 in moderate condition, and 5 in poor condition. Fish communities were dominated by European carp (*Cyprinus carpio*), with fish community condition graded as poor to very poor in all river reaches. Likewise, the results of the macroinvertebrate sampling indicated a system under high stress on the lower Darling Baaka River, with slightly better macroinvertebrate community condition on the Great Darling Anabranh. Zooplankton

surveys indicated that community health throughout the study area was moderate to poor.

Hydrological stress

Modelling indicates 95% of the study area is graded between moderate to very poor condition, indicating a significant degree of hydrological stress in the lower Darling Baaka River system. The poorest hydrological conditions occurred between Lake Wetherell and the Anabranche offtake. The key drivers of these conditions are significant changes to the frequency and duration of zero-flow events. The importance of groundwater in the region has been modelled, with results indicating intricate surface water and groundwater exchanges. In general, the lower Darling Baaka River tends to lose water to groundwater storages in the upstream regions, and gains water below the Main Weir at Lake Wetherell. More complicated exchanges appear during times of flooding and drought.

Landscape disturbances

Over 85% of the subcatchments in the study area were found to be in good or very good landscape condition. With the exception of farm dams and weirs, there is relatively minimal infrastructure influencing river health in the catchments. Refinement of this indicator is required as it does not take into account widespread historical vegetation clearing and river de-snagging in the 1800s and 1900s. The legacy of this vegetation clearing and de-snagging is likely to be continuing to impact the river, potentially contributing to the expansion of gullies and riverbank erosion.

Overall river health

The 6 indexes above were combined to assess the overall river health of the study area. The fundamental driver of poor river condition in most indexes is the alteration of natural flow by water extraction and river regulation. Over the last 200 years the entire Murray–Darling Basin has been subjected to widespread changes to flows associated with river regulation. Along with land clearing and water abstractions (to sustain agricultural industries, mining and to provide potable water for townships), this has heavily impacted the natural flows of the Darling Baaka River and its tributaries. The result is downstream reaches are receiving substantially lower flows than would naturally have occurred. Compounding these issues, groundwater abstraction has resulted in a disconnect between rivers and aquifers in areas of the wider Murray–Darling Basin, meaning river baseflow (often augmented by groundwater) has been reduced.

The hydrological stress caused by river regulation and abstractions, combined with historic landscape disturbances (e.g. vegetation clearing) and poor riparian vegetation condition manifests in poor water quality and biodiversity condition.

Key recommendations

1. Restore flows and connectivity across the catchment

Hydrological stress, associated with river regulation, was found to be a primary driver for poor water quality, biodiversity condition and riparian vegetation in the study area. Major weirs throughout the study area not only contribute to water quality issues, but they provide significant barriers to fish movement. New fish passageways installed in early 2025 are designed to improve fish movement. These findings support the Office of the Chief Scientist and Engineer's (OCSE) 2023 review into the fish deaths at Menindee.

2. Incorporate cultural indicators into the RCI framework

This would recognise the importance of cultural knowledge in river management and aid the protection of culturally significant species. Cultural indicators have been established by the Barkandji Prescribed Body Corporate, through their Ngarratja Warrkina Project and are recommended to be incorporated, via a multi-criteria assessment process, into the RCI framework for the Darling Baaka. This would allow a more holistic approach to water management and monitoring of river health.

3. Continue the biological and water quality monitoring program

Extended sampling would allow a robust characterisation of the variation in both water quality and biota across a wide range of seasons and flows. Continuation of monitoring and the real-time data collection and reporting system (smart buoys) is important for:

- water managers – data can, and has been, used to inform water release and management priorities
- local communities – real-time data can be, and has been, used to inform stock watering and swimming
- assisting with the development of local water quality guidelines. This would include setting trigger values to guide future environmental water releases
- assisting with appropriate guidelines for macroinvertebrate and zooplankton communities
- providing early warning systems of deteriorating conditions (both chemical and biological monitoring)
- recognising the contribution of biota to river health.

These recommendations align with OCSE 2023 Recommendation 2 and 4.

4. Refine the RCI approach

The RCI framework can be further refined by:

- assessing alluvial gully formation and contribution of overbank flooding to river nutrient loads
- developing site-specific water quality guidelines
- ongoing monitoring of riparian vegetation, particularly recruitment and population sustainability

- assessing interactions between biotic and abiotic components and their impacts on water quality
- incorporating bacterial, algal, and groundwater indicators of health into the RCI framework
- improving water quality monitoring, for example the development of nutrient load models
- incorporating historic landscape disturbances into the Landscape Disturbance Index.

5. Manage invasive species

This study indicated that over 70% of the total fish biomass in the region was European carp. This species is known to contribute to declines in water quality and biodiversity condition, and carp often outcompete native species. Carp can also survive in particularly low oxygen concentrations, when native species cannot.

The OESC 2023 report recommends an integrated national invasive fish species management strategy (Recommendation 4). The finding from the fish surveys conducted under the Darling Baaka project, support this recommendation.

6. Improve understanding of the complex relationships between surface waters and groundwaters, and the importance of groundwaters to river health

Further investigate the contribution of groundwater to river health through modelling, water chemistry and biological indicators is suggested. This was identified as a data gap by the project's working groups.

7. Investigate and analyse the most appropriate suite of indicators that can be used, to reduce sampling intensity and be more cost-effective

There is a need to identify the abiotic and biotic indicators that are most sensitive to changing conditions and thereby provide a more cost-effective method to assess broader ecosystem health, rather than the large-scale intensive sampling as undertaken in this project.

These recommendations are detailed further in Chapter 9.

1. Project overview

1.1 Project drivers

1.1.1 Darling Baaka River Health Project background

The Darling Baaka River has been subjected to significant human disturbances, including landscape changes, vegetation clearing and the construction of weirs and regulators. Combined with extensive extraction of water for agricultural, industrial and domestic uses, this has altered river flow dynamics, resulting in a decline in water quality in many regions. This decline in water quality has caused immense concerns for local communities. These concerns were amplified by significant flooding in January 2023 and a subsequent mass fish death event in the vicinity of Menindee in March 2023.

The NSW Government's response to the mass fish death event in 2023 was undertaken through its emergency management arrangements, activated due to the declared natural disaster (Australian Government Reference Number [AGRN] 1034). The NSW Environment Protection Authority (EPA) led the Environmental Services Functional Area (also known as EnvSFA) incident response between March and July 2023. Beginning in April 2023, the EPA worked closely with the Science and Insights Division of NSW Department of Climate Change, Energy, the Environment and Water (the department) to conduct comprehensive water quality monitoring in the lower Darling Baaka River near Menindee. These data were used by the EPA to undertake an independent investigation into the cause of the fish death event under the *Protection of the Environment Operations Act 1997* and informed the independent review into the fish death event by the NSW Chief Scientist and Engineer.

The NSW Chief Scientist and Engineer's report on the 2023 fish kills at Menindee, published on 29 September 2023 (OCSE 2023), provided an in-depth analysis of the contributing factors of the mass fish deaths in the Darling Baaka River and offered recommendations for improving river management (see section 1.2).

The Darling Baaka River Health Project (the project) was established as a longer-term river health monitoring program as part of the recovery from the 2023 flooding disaster. It transitioned the NSW Government's initial emergency response, led through Environmental Services Functional Area, into an ongoing program focused on river health and recovery. The project was delivered from September 2023 to June 2025 by the department's Science and Insights Division.

The project: Refers to the Darling Baaka River Health Project and includes the actionable set of initiatives designed and delivered by the department's Science and Insights Division that achieve key results of the overarching objectives of the program.

The project is separate from existing regulation by WaterNSW and the department's Water Group and is independent of the EPA's investigation into the cause of the fish death event under the *Protection of the Environment Operations Act 1997*. It is delivered under the EPA's Recovery Program for Water Quality Monitoring in the Darling Baaka and funded as a Category D recovery measure under the joint Commonwealth and NSW Government Disaster Recovery Funding Arrangements.

The project aimed to support recovery efforts by providing extended monitoring of the health of the lower Darling Baaka River. The main objectives were to:

1. Improve understanding of Darling Baaka River health.
2. Support local capacity to monitor water quality for flood events.

To meet those objectives, the project aimed to deliver a range of key results, including:

- Consolidating data from existing ecological programs for integration into a revised sampling program and reporting. Data will inform the potential need to increase sampling frequency or scope and will contribute to evidence-based decisions on river management
- Increasing awareness and understanding of how the project's work will result in better management outcomes
- Developing and implementing a supplementary water quality and river health monitoring program aligned to the River Condition Index
- Engaging with stakeholders and community to inform future research and water management of the system
- Collaborating with the Barkandji Prescribed Body Corporate (and Barkandji Rangers) to assist in caring for Country through knowledge sharing and training in monitoring methods.
- Provision of publicly accessible data used for the river health assessment.

1.1.2 NSW Government response to the OCSE report and the value of the River Condition Index

The NSW Office of the Chief Scientist and Engineer (OCSE) report into the 2023 Menindee mass fish deaths made a series of recommendations to guide future research, water management and emergency response. The Darling Baaka River Health Project is funded under NSW and Commonwealth Disaster Recovery Funding Arrangements, however, outputs of the project are strongly aligned to addressing key recommendations from the OCSE report, in particular **Recommendation 2 – better decisions require better data** (OCSE 2023).

Recommendation 2 details:

- a. the data must cover the whole of the river system as all parts are connected. The monitoring network needs to be expanded to address key gaps (e.g. sites, resolution, and indicators)

The project expanded the sampling and real-time monitoring regime in the lower Darling Baaka to cover the whole of the river system between Wilcannia and Wentworth,

including the Great Darling Anabranch, and shallow aquifers. A total of 41 surface and 18 groundwater sites were monitored for a variety of water quality measurements. In addition, 32 surface and 18 groundwater sites were monitored for biodiversity condition indicators, 49 sites had riparian vegetation condition assessments completed and a range of spatial data was used to complement conventional water monitoring programs.

b. the data must minimally cover water flow rates and water quality (including dissolved oxygen), fish and algal biomass, and monitoring cause and effect variables to provide early warning of deteriorating conditions and ecosystem response

The project expanded the measured parameters to include all recommendations in the Chief Scientist's report. It also expanded this to include measures of macroinvertebrates, stygofauna, zooplankton, bacteria, riparian vegetation, geomorphic condition, and modelled hydrological stress indicators.

c. the data must be open and accessible to all (Findable, Accessible, Interoperable, and Reusable – FAIR).

The project made the data openly accessible via multiple communication channels. Smart buoy water quality data are publicly available and used by local communities as well as water managers for decision-making. Direct data sharing occurred between state and federal agencies including the department's Water Group, EPA, WaterNSW, Fisheries NSW (part of the Department of Primary Industries and Regional Development), Murray–Darling Basin Authority, and numerous universities. Water quality reports, and raw data, are published on the EPA website, with all data available on SEED.

d. investment in new sensors and technology platforms (including telemetry), and their maintenance, to provide adequate coverage and early warning

The project deployed new telemetry technology (smart buoys) to provide early warning of poor water quality for management agencies. The real-time water quality monitoring buoy network has been instrumental in informing water releases to combat declining oxygen levels, weir pool stratification, and algal blooms in the river downstream of Main Weir. The data from these buoys are available in real time online and were critical in informing real-time water management decision-making to avoid hypoxic events throughout the summers of 2023–24 and 2024–25. See link to *Darling Baaka River Health Program – Smartbuoy locations* page in the 'More information' section at the end of this chapter).

e. development and use of probabilistic models and baseline steps towards a catchment digital twin, drawing on real-time data, machine learning algorithms and insights

The project improved the current operational WaterNSW model to include the influence of groundwater on flow and water quality, bringing it closer to the recommended digital twin.

f. recognition and integration of community observations and Aboriginal Traditional Knowledge as important sources of evidence.

The project developed a close partnership with the local community and the Barkandji Prescribed Body Corporate, beginning the process of incorporating Aboriginal knowledge into the assessment of the river's condition.

Long-term monitoring is particularly essential in dynamic and complex river systems such as the Darling Baaka, where interannual and interdecadal climatic variability drives a boom-and-bust river ecosystem. This project has established a method by which to continue monitoring both biotic and abiotic functioning of the river and has paired it with an extensive real-time water quality monitoring system. Combined with local cultural knowledge, the RCI should be further developed into a comprehensive framework for monitoring the health of the Darling Baaka River. Further targeted research in conjunction with long-term monitoring will help to assess key drivers of poor river condition to inform land and water management strategies.

1.1.3 The Ngarratja Warrkina project

Concurrent with the project, the EPA funded a complementary Aboriginal Knowledge Project, led by Barkandji Prescribed Body Corporate, called the Baaka River Recovery Project, Ngarratja Warrkina or 'all working together'. This knowledge-sharing project aimed to incorporate local and Aboriginal knowledge and cultural values into river health management, to better inform our understanding of river conditions.

Integrating cultural knowledge and practices into water quality monitoring is aimed at improving understanding of the health of the Baaka River. By combining both cultural and conventional scientific knowledge of river health, a more holistic understanding of environmental impacts can be achieved. It is suggested that, in the future, cultural indicators could be incorporated into the RCI framework (see Chapter 9). This will provide a more holistic view of river health and will aid the NSW Government to protect natural and cultural values in river systems.

In support of two-way learning and knowledge sharing, departmental scientists facilitated the training of 6 Barkandji Rangers in Certificate II in sampling and measurement (Figure 1). This training was provided to the rangers, along with mentorship from departmental scientists who regularly met with rangers to demonstrate water sampling methods and sample collection. The collaborative partnership formed between departmental scientists and the Barkandji created a deeper understanding of river health in the region.



Figure 1 Dr Kathryn Korbel training the Barkandji Rangers on the Darling Baaka River at Kinchega National Park. Photo: Stuart Cohen/Bottlebrush Media

1.2 Significance of the river to the Barkandji

The Darling Baaka River system is home to over 40 Aboriginal nations (MLDRIN 2025). The river system holds deep cultural and spiritual significance for these communities. Within the study area, the Barkandji people have been caring for the Baaka for at least 45,000 years (Cupper and Duncan 2006). These communities have a strong connection to the river and have intimate knowledge of the river's behaviour and history.

Water is vital for survival in the semi-arid region of the lower Darling Baaka and is strongly linked to the spirituality of the Barkandji. For example, Ngardji holes and the links between surface waters and groundwaters are areas of cultural significance to the Barkandji. Over the last century the Barkandji people have been observing and recording the health of the Darling Baaka River through oral history, detailing its decline.

The significance of the Barkandji's connection to the Baaka was formally recognised through the Barkandji native title determination in 2015 (Barkandji PBC 2025). This determination acknowledges the Barkandji people's legal rights to their traditional lands and waters. The native title determination is unique in its extent and significance, covering a vast area of western New South Wales, including the Darling Baaka River and its tributaries.

Below is a statement from William Brian (Badger) Bates, former director of the Barkandji Native Title Prescribed Body Corporate, to the Murray–Darling Basin Royal Commission in 2019 (Murray-Darling Basin Royal Commission, 2019). The section refers to water quality and the declines in river health observed in the last 100 years:

We did not have issues with water quality like we do now. Over the last few years they have put warning signs up all around the river near Wilcannia and elsewhere telling people the water is unfit to drink, unfit for stock to drink, and not to swim, or take fish or yabbies... The water was not salty like it is often now. We never heard of 'blackwater events', this happens when there is a big flood after many years of no floods, they say it is natural but before it probably only happened every 100 years or so, but now happens every flood and kills millions of fish.

William Brian (Badger) Bates to the Murray Darling Basin Royal Commission 2019

1.3 The Darling Baaka River study area

The Darling Baaka River flows south-west from northern New South Wales for nearly 1,500 km, eventually meeting the Murray River at the NSW town of Wentworth (Geoscience Australia 2014). The river and its surrounding floodplains hold significant environmental value. The river supports extensive biodiversity, providing critical habitat for birds, fish and riparian vegetation (Ellis et al. 2021). When combined with groundwater resources, it also provides a reliable source of water in far western New South Wales. The river supports a diverse array of wetlands and floodplains, which are vital for nutrient and carbon cycling and water purification.

In addition to environmental values, the Darling Baaka River system holds cultural and economic value. The Barkandji people have lived and interacted with the Baaka for over 40,000 years. Their long and continuous relationship with the river has deeply influenced their culture, traditions and spirituality. The river also plays a key role in modern Australia's economic wealth. The waters of the Darling Baaka River, its tributaries and connected groundwaters support extensive agricultural and recreational activities, as well as providing water which supports numerous towns. The Murray–Darling Basin contributes around \$24 billion annually to agricultural production, and over \$8 billion through tourism (ABARES 2025).

The health of the Darling Baaka River has long been impacted by complex regulation and changing environments. The upper reaches of the river are highly regulated, with headwater dams in many major tributaries and numerous weirs interrupting natural flow regimes along the mainstem river and within its tributaries (Thoms and Sheldon 2000). Regulation in the study area began in the 1960s. The Menindee Lakes were previously a series of shallow, natural ephemeral wetlands which filled in wet periods and drained to the Darling Baaka during subsequent dry periods. As part of the development of the Menindee Lakes Storage Scheme the lakes were converted into a series of more permanent lakes through the construction of weirs and causeways. This complex regulation around the Menindee Lakes was initiated to provide a reliable water supply to townships in this region, including the mining town of Broken Hill (Ford et al. 2023).

Water extraction for irrigation and for drinking water, combined with extensive regulation, has completely altered natural river dynamics. The declining health of the Darling Baaka River system since European colonisation has been observed by the Barkandji people and local communities, causing strong community concerns. These concerns were amplified by severe flooding in January 2023, and subsequent mass fish deaths near Menindee in March 2023.

1.4 Assessing river health

1.4.1 River health defined

River health refers to the overall condition of a river ecosystem, including its water quality, physical structure and biodiversity. It also includes the river's ability to maintain natural functions and provide ecosystem services, such as the provision of clean water for communities, and the ability to sustain biodiversity.

There are a range of factors which impact river health and place stress on the ecosystem. These can be natural factors such as drought and flood, or human stressors such as contamination, overextraction and degradation to the river's natural form (for example, excessive erosion). There are several methods to measure river health. These methods may measure one specific river health indicator (for example water quality; see Chidiac et al. 2023) or they can measure ecosystem processes and functioning (for example ecosystem metabolism, which measures rates of primary production). Other developed indices, such as the River Condition Index (DPE 2023a) combine several individual indicators to give a standardised way to assess and compare river health across a study area.

1.4.2 The River Condition Index framework

The River Condition Index (RCI) is a comprehensive, coarse-scale framework used to assess the health of river ecosystems in New South Wales. It was developed using the *Framework for the assessment of river and wetland health* (National Water Commission 2011) and combines multiple indicators into a single condition score. The first version of the RCI was developed in 2012 (Healey et al. 2012), before being updated and republished in 2023 (DPE 2023a; referred to as '2023 RCI').

The RCI incorporates 6 key indexes:

- Geomorphic Condition Index
- Water Quality Index
- Riparian Vegetation Condition Index
- Biodiversity Condition Index
- Hydrological Stress Index
- Catchment Disturbance Index.

It is the combination of the 6 key indexes which provides a comprehensive understanding of river health. Each index interacts with the others, and changes in one can affect the health of the waterway.

The large scale at which the 2012 and 2023 RCI were developed (that is, the entire state of New South Wales), and its original purpose to inform the monitoring and evaluation of water sharing plans, made the assessment reliant on spatial analyses with limited field data and ground-truthing. These assessments used large, statewide datasets to inform river assessments and provided a first assessment of the entire state's river health. The

2023 RCI assessment framework detailed in the *River Condition Index: method report* (DPE 2023a) has much merit, and this framework has been used for the Darling Baaka River Health Project.

In contrast with the 2023 RCI, this project has incorporated a vast amount of field data with high temporal and spatial density. Given the resources available, this project has adapted and updated the RCI methodology to undertake a high-resolution river health assessment using the 6 broad indexes within the original RCI framework. Due to the smaller scale of the project, it was possible to modify and refine the 2023 RCI framework for the lower Darling Baaka study area. This was achieved primarily through an intensive on-ground sampling program to collect site-specific data.

Due to the differences in methodologies, sampling density and project aims, comparing the results of the 2023 statewide RCI with the 2025 Darling Baaka RCI presented in this report will not necessarily provide a true indication of changes to river health over that period. Such a comparison would be limited to providing an appraisal of 2 similar, but different, river health assessment methods; one developed at a large spatial scale using historic data for a statewide reporting purpose (the 2023 RCI), and the other developed using site-specific sampling at a fine resolution which is specifically targeted to assessing river health in a smaller study area (the 2025 Darling Baaka RCI).

Therefore, caution is advised if comparing results and grades of the 2023 RCI with the 2025 Darling Baaka RCI. The 2023 RCI classified most of the lower Darling Baaka River and Great Darling Anabranch as in either good or very good river health. This is likely due to the remoteness of the region resulting in few data points and limited datasets available for the area between Wilcannia and Wentworth. For example, the water quality indicator component of the 2023 RCI used data from 3 sampling sites in the 1,000-km stretch of river and averaged the data to provide RCI grades for water quality in all 28 RCI subcatchments in the current study area. In contrast, the 2025 Darling Baaka RCI used a monthly sampling regime to collect data from 41 sample sites to establish RCI river health grades.

Despite the differences in the application of the RCI framework, it is important to understand both the differences and similarities between the 2023 RCI and the 2025 Darling Baaka RCI methods used in this report. The 2023 RCI assessment was based on statewide datasets, with a paucity of information available in the Darling Baaka region. The current project has allowed an intensive sampling campaign to better characterise the on-ground river health at the time of the study. It is these differences in methodology that account for the majority of changes in RCI values from the 2023 RCI scores to the scores presented in this report. These differences, described in Chapter 9, highlight the importance of spatial scales within river health assessments as well as the need to ground-truth and collect real-time data for localised river health assessments to aid river management decisions.

1.4.3 Adapting the River Condition Index for the project

The conditions present in the Darling Baaka River system, one of the largest rivers in inland Australia, are quite unique. The highly variable climate sees irregular cycles of flooding and drought which heavily influence water quality and quantity in the river. In times of drought, groundwater can sustain refugial waterholes and support ecosystems. In times of flood, large fluxes of nutrient-rich and sediment-rich waters can influx into the river, impacting water quality. River health in this region is also heavily influenced by fluctuations in temperature which cause stratification in the water column, particularly evident in the lakes, deep waterholes and weir pools, which may result in decreased oxygen within the water column. Using this knowledge, a conceptual model of key processes and linkages was produced to help capture important ecological processes in the monitoring program (Figure 2).

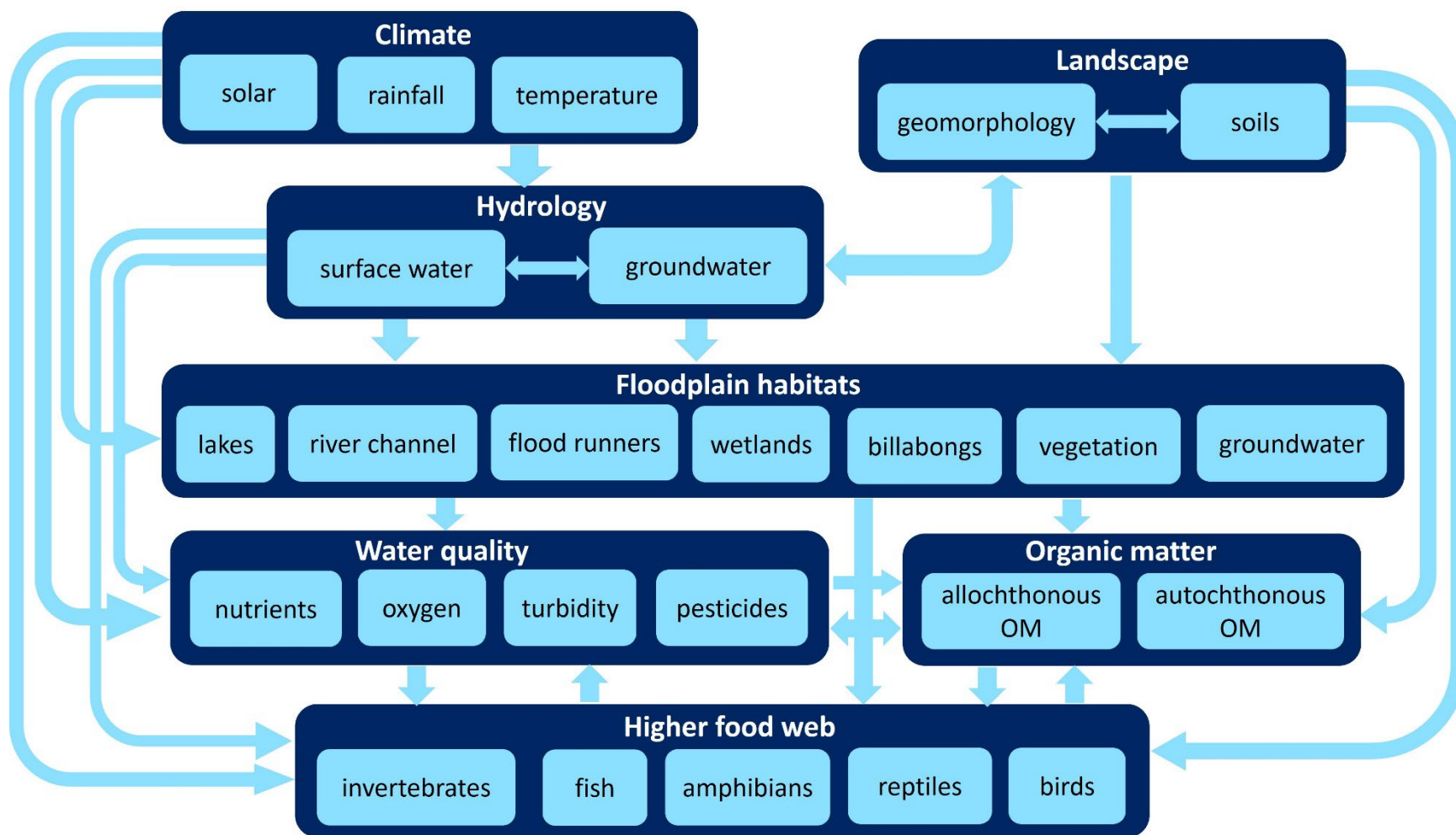


Figure 2 Conceptual model of the hierarchy of primary drivers and ecology that comprise the lower Darling Baaka system

Figure note: OM = organic matter; allochthonous means originating in a place other than where it is found / is material found away from where it was formed; autochthonous means originating in the places it is found / is material found where it was formed.

The RCI approach has been modified in this project to take account of the unique aspects of the Darling Baaka River system as outlined in the conceptual model (Figure 2) and an understanding of pressures exerted on the system (Appendix A). The project has been able to build upon the original RCI framework by incorporating an extensive field surveying campaign. This allowed the RCI to be adjusted for the study area by providing:

- improvements to the Geomorphic Condition Index (see Chapter 3), by:
 - undertaking field verification of River Styles (Fryirs and Brierley 2005)
 - updating assessments of geomorphic condition in the study area using a range of high-resolution remotely sensed products, including 2019–20 1-m light detection and ranging (LiDAR) digital elevation model (DEM).
- improvements to the Water Quality Index (see Chapter 4), through:
 - the addition of 12 months of river water quality data at a high spatial resolution
 - the inclusion of key water quality parameters, such as dissolved inorganic nutrients, chlorophyll-a, metals and pesticides
 - 2 sampling campaigns for groundwater chemistry
 - 6 sites with continuous water quality data through smart buoy technology.
- improvements to the Riparian Vegetation Condition Index (see Chapter 5), through:
 - ground-truthing of vegetation communities
 - on-ground assessment of vegetation condition, including structure, composition and tree health.
- improvements to the Biodiversity Condition Index (see Chapter 6), through:
 - addition of biotic indicators representing macroinvertebrates and zooplankton
 - increased spatial resolution of fish surveys within the study area.
- improvements to the Hydrological Stress Index modelling (see Chapter 7), through:
 - the provision of groundwater chemistry, groundwater level data and targeted bathymetry data
 - the incorporation of soil hydraulic conductivity data to better resolve surface–groundwater interactions.
- improvements to the Catchment Disturbance Index (renamed to Landscape Condition Index; see Chapter 8), through:
 - addition of new spatial datasets
 - finer-scale analysis of spatial layers.

The RCI scores for each RCI subregion (subcatchment) within the study area are based on assessments of the key components associated with each river index (Table 1). It is recognised that there are extensive current NSW Government programs in the upper Barwon–Darling region that cover many of the disciplines relevant to the components identified in Table 1. The relevance of these programs to the project were identified as part of a gap analysis and data were consolidated from existing ecological programs. This data gap analysis was used to inform the need for additional data collection. It is

acknowledged that the details of assessment methods and need for additional data were finalised with input from an interagency panel and technical experts.

A condition score is calculated for each of the 6 indexes and then the scores are combined to produce an overall score and grade for each subcatchment (see Figure 3). The details of the methods and results for each of the 6 indexes are discussed in the individual chapters forming this report. Summary results for individual subcatchments are presented in Chapter 2.

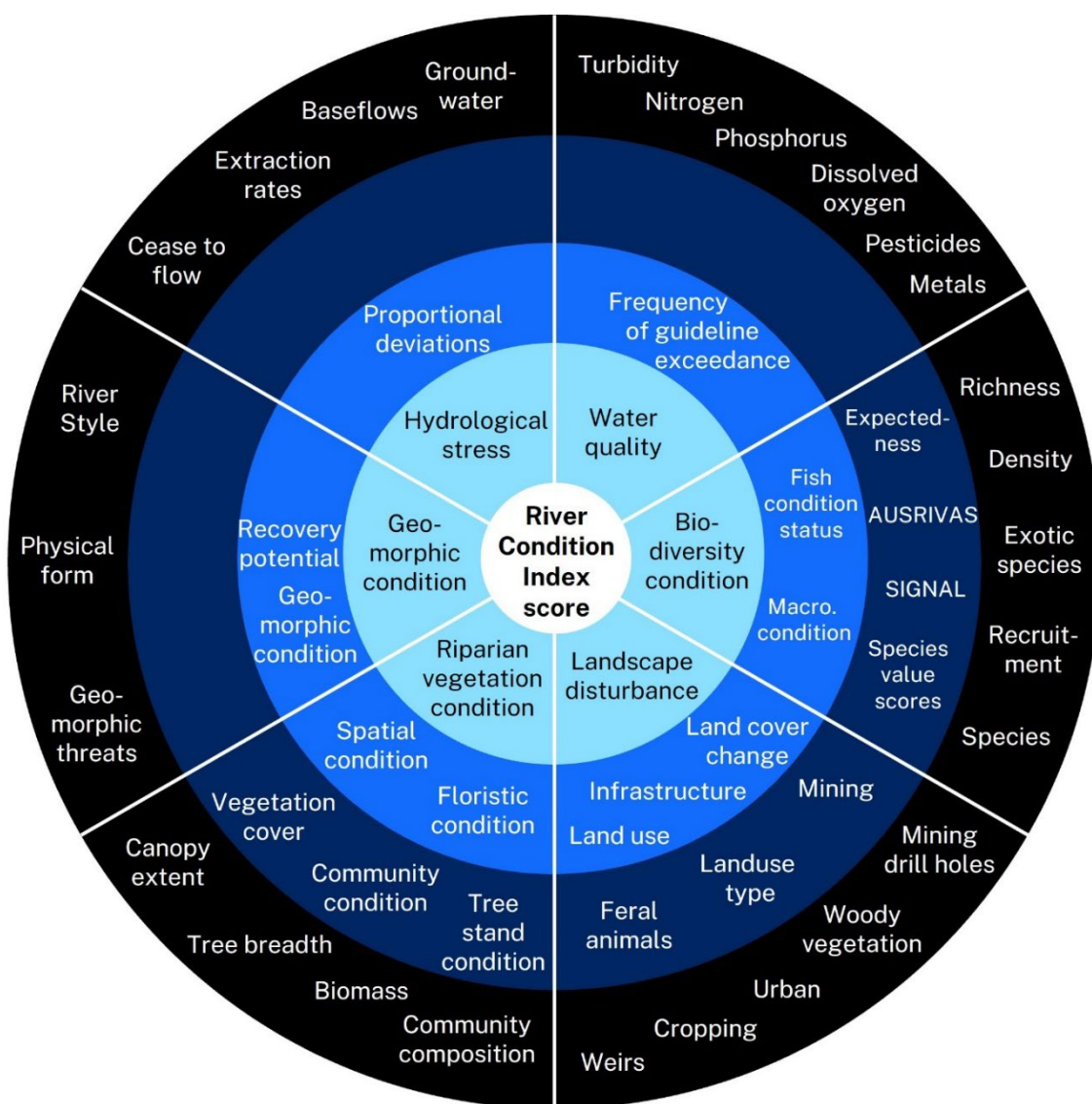


Figure 3 Illustration of River Condition Index score framework

The black band shows the individual metrics that contribute to give a score for sub-indicators groups (dark blue band). These sub-indicators are then combined into broad indicator groups (medium blue band), and (when more than one exists) these are numerically combined to give one overall score for each of the 6 indexes (light blue band), which are then averaged to form the overall River Condition Index score (white). This diagram is for illustrative purposes, not all metrics or indicators are presented in this diagram.

1.4.4 Measurements outside the River Condition Index framework

The RCI framework focuses on reportable indicators of river condition. For example, water quality parameters are assessed against national guideline values, and biodiversity condition is assessed against known indicators (for example, fish condition status and zooplankton index; see Figure 3). These measurements are combined to give overall river health rankings.

The RCI is designed as a tool for analysing river health, but it does not attempt to measure ecosystem processes or biodiversity comprehensively. It also excludes certain parameters for which data were collected as part of the project, such as organic carbon, due to a lack of appropriate guidelines to assess exceedances.

In addition to the updated RCI for the lower Darling Baaka, the project collected data for aspects of the river's condition that focused on reflecting the current condition, function or state of river (Table 1). The project assessed the total number of species present in the region for various taxonomic groups, providing both an assessment of biodiversity and insights into biodiversity condition, which measures community responses to stress. Other analyses, such as fish health assessments, bacteria diversity, waterbird presence, groundwater health, along with additional water quality analyses, contributes invaluable data to better understand the ecological health and functioning of the lower Darling Baaka River. Many of these data are presented in supplementary reports and should be further investigated in terms of understanding river health.

Also of critical importance is monitoring species of cultural significance to Aboriginal communities. It is suggested that, in the future, cultural indicators are integrated into the RCI framework to provide a more holistic view of river health (see Chapter 9). In incorporating cultural indicators, it is also essential to consider and respect Indigenous Cultural and Intellectual Property rights prior to commencing any work.

Table 1 Summary of river condition indicators incorporated into the 6 indexes used in the Darling Baaka River Health Project. See individual chapters for full details on indexes

Index	Indicator	Sub-indicator or metric	Method			Frequency	Contributes to RCI?
			GIS	Field	Model		
Geomorphic Condition	River Styles	River styles, geomorphic condition and recovery potential	Y	Y	Y	Once	Y
Water Quality	Pollutants	Pesticide/passive samplers + grab	–	Y	–	3-monthly	Y
	Physico-chemistry	Exceedance of guideline values (e.g. pH, dissolved oxygen)	–	Y	–	Monthly	Y
	Organic matter	Total organic carbon Dissolved organic carbon	–	Y	–	Monthly	N
	Nutrients	Exceedance of guidelines (e.g. nitrogen, phosphorus)	–	Y	–	Monthly	Y
	Sediments	Pesticides, benthic carbon, organic matter, nutrients	–	Y	–	Twice	N
Riparian Vegetation Condition	Riparian vegetation condition	Vegetation condition index score and rapid appraisal of riparian condition scores	Y	Y	Y	Once	Y
	Macrophytes	Extent	Y	Y	–	Twice	N
Biodiversity Condition	Macroinvertebrates	Richness, SIGNAL, AUSRIVAS	–	Y	Y	Twice	Y
	Zooplankton	Community scores (e.g. richness)	–	Y	–	Twice	Y
	Bacteria	Functional diversity + indicator species	–	Y	–	Twice	N

Index	Indicator	Sub-indicator or metric	Method			Frequency	Contributes to RCI?
			GIS	Field	Model		
	Groundwater fauna	Groundwater health index	–	Y	–	Twice	N
	Instream vegetation	Presence/absence	–	Y	–	Twice	N
	Fish	Fish condition index	–	Y	–	Twice	Y
	Amphibians/reptiles	Significant species/rarity	–	Y	–	Twice	N
	Algae	Richness, Chlorophyll-a guideline exceedance	–	Y	–	Monthly	Y
	Bird species	Presence/absence, species list/rarity	–	Y	–	5 times	N
Hydrological Stress	Changes to flow	Alterations to flow/water level (e.g. weirs)	Y	–	Y	Desktop	Y
	Extraction rates	Extraction data/licences	Y	–	Y	Desktop	Y
	Groundwater (GW) levels and extraction	Extraction and level change over time	–	Y	Y	Logger/desktop	Y
	Surface water – GW connectivity	Contribution of GW to flow	–	Y	Y	Desktop	Y
Landscape Disturbance	Infrastructure	E.g. number of roads, powerlines	Y	–	Y	Desktop	Y
	Land use	E.g. agriculture, mining, grazing, feral animals	Y	–	Y	Desktop	Y
	Land cover change	Percent change woody and non-woody vegetation	Y	–	Y	Desktop	Y

Table notes: Y = yes; N = no; GIS = geographic information system; River Styles (Fryirs and Brierley 2005); SIGNAL= stream invertebrate grade number average level (Chessman 2003a); AUSRIVAS = Australia River Assessment System (Turak and Johnstone 2004).

1.5 Study area and sampling strategy

1.5.1 Study area

The northern Murray–Darling Basin spans approximately 650,000 km² of inland New South Wales and Queensland. Most of the flow in the Darling Baaka River catchment is generated by rainfall in the wetter headwaters of the main tributaries that drain the western slopes of the Great Dividing Range. The lower Darling Baaka and its major anabranches flow south-west across semi-arid to arid country, joining the Murray River near the town of Wentworth in far western New South Wales. The study area for this project extends between Wilcannia and Wentworth, including the Great Darling Anabranch, generally known as the lower Darling Baaka region (Figure 4).

The lower Darling Baaka region is sparsely populated with several small towns spaced along the river, such as Wilcannia, Menindee and Pooncarie. The dominant land uses on the alluvial floodplains and red soil rangelands are wool production and beef grazing. There are some areas of irrigated cropping, horticulture and viticulture, though most irrigated agriculture occurs upstream in the northern basin along tributaries such as the Macquarie, Namoi, Gwydir and Condamine–Balonne rivers.

The lower Darling Baaka River receives between 200 and 300 mm of rainfall per year, though this is highly variable from year-to-year. Flows in the lower Darling Baaka are highly regulated, with significant upstream extractions reducing flow in major tributaries, numerous in-channel weirs, and water storage associated with the Menindee Lakes Storage Scheme. The highly variable climate sees irregular cycles of flooding and drought, which can influence river health. In times of drought, groundwater can sustain refugial waterholes and support ecosystems, whereas floods can cause large influxes of nutrients, sediments and carbon, which can cause issues with water quality.

1.5.2 Reporting subregions (subcatchments)

The assessment of river health for the lower Darling Baaka River system has been based on the 2023 RCI approach (see section 1.4). The 2023 RCI calculated scores for individual subcatchments across the state, with the lower Darling Baaka region divided into 28 subregions represented by subcatchments (Figure 5). Each subregion incorporates its own mix of habitat types, all of which are interconnected across varying temporal and spatial scales. These subregions have been retained for this project as they provide a high spatial resolution at which to assess variability in river condition and health.

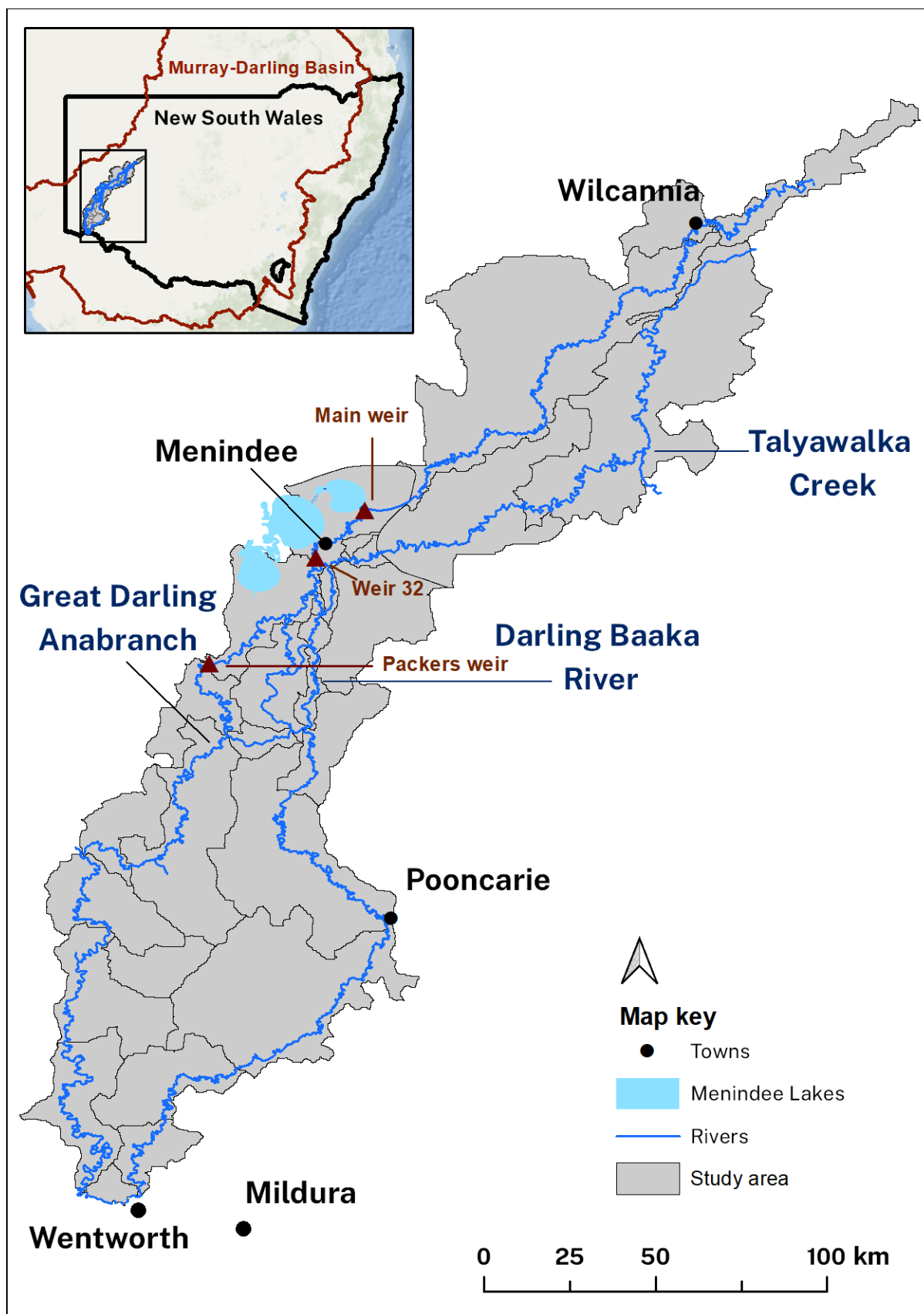


Figure 4 Map showing the Darling Baaka River Health Project study area

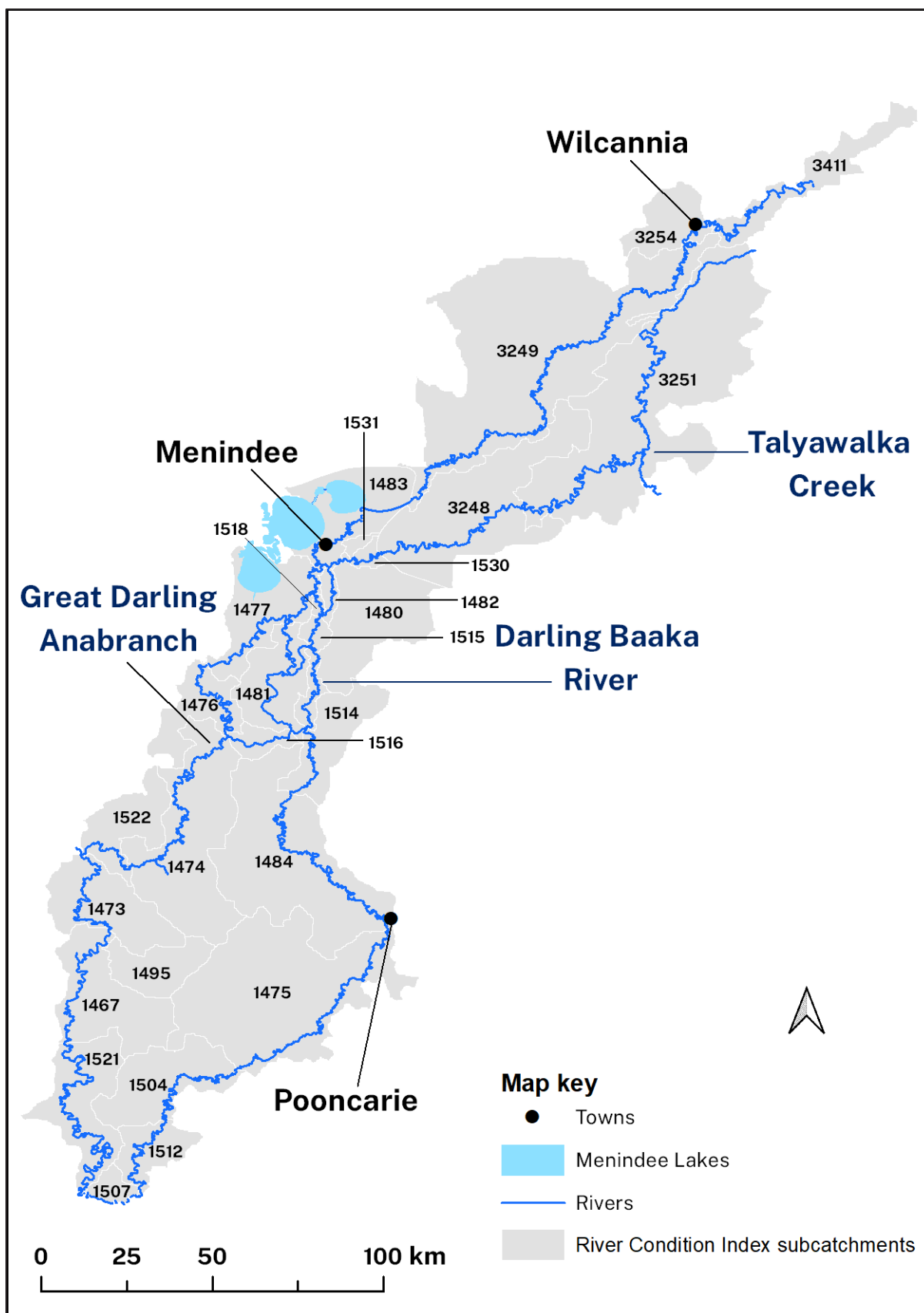


Figure 5 River Condition Index subcatchment numbers and boundaries for the lower Darling Baaka study area. Numbers refer to DPE (2023a) subcatchments and descriptors

1.5.3 Sampling phases and sites

Sampling within the project occurred in 2 distinct phases. Phase 1 (September 2023 to April 2024) focused on water quality monitoring in the river system to address immediate concern as part of the EPA's initial response investigations of the 2023 Darling Baaka fish death event. Phase 2 (April 2024 to March 2025) expanded the sampling effort and study area to fulfil the requirements of the RCI assessment.

Phase 1 (September 2023 to April 2024) comprised routine monthly sampling of water quality (physico-chemical, suspended sediments, chlorophyll, nutrients, biochemical oxygen demand) at 20 sites between Wilcannia and Pooncarie (Figure 6). In addition to routine sampling, 4 smart buoys (automatic samplers) were established, 1 at Wilcannia, 1 at Lake Wetherell, and 2 downstream of the Main Weir in the Menindee weir pool to investigate the dynamics of hypoxia and stratification. The smart buoys sampled water quality at 4 depths in the water column every 30 minutes. Parameters measured were: conductivity, temperature, dissolved oxygen, pH, fluorescent dissolved organic matter, turbidity, chlorophyll-a and phycocyanin.

Phase 2 (April 2024 to March 2025) expanded the Phase 1 sampling strategy to align with monitoring required under the RCI framework. Parameters were expanded to include data for biological, geomorphological and spatial analysis as well as hydrological modelling (Table 1). Sites were expanded to include 35 river sites (Figure 7) and 18 groundwater sites (Figure 8) sampled from Wilcannia to Wentworth. Two additional smart buoys were deployed, both on the Anabranche, and one of the two smart buoys from the weir pool was moved to Pooncarie.

A total of 41 sites were sampled for water quality during Phases 1 and 2 of the project, with data only from Phase 2 sites included in this report (Figure 6; Figure 7; Table 2). A total of six smart buoys were deployed in the study period (Table 3) and 19 dissolved oxygen loggers were deployed throughout the study area in Phase 2 of sampling. Additionally, the sampling strategy was expanded in April 2024 to include all 6 RCI indexes, including biological, geomorphological and spatial analysis as well as hydrological modelling.

Sites for Phase 2 were specifically chosen to align with historic biological data allowing comparisons over time, as well as aligning with known data gaps and existing monitoring programs. While 6 sites sampled under Phase 1 were no longer sampled in Phase 2, the later phase has a larger number of sites spread across the entire study area, including the Great Darling Anabranche (see Figure 6 and Figure 7). In addition, 18 groundwater sampling sites were selected for this study (Figure 8).

Sample sites were selected according to the following criteria:

- sufficient site density to describe longitudinal processes (minimum one site per subcatchment on the Darling Baaka River and Great Darling Anabranche, where flow permitted)
- historical data availability for either water quality or biological indicators
- sites contain adequate representation of key habitat components

- site access (that is, adjacent to passable roads and/or crossings)
- access has been granted by landholders.

All 35 surface water sites for Phase 2 sampling were monitored monthly, with pesticides sampled in the water at 15 sites on 2 occasions and in the sediment on 2 occasions. Water chemistry from groundwater was sampled at 18 sites on 2 occasions, and data loggers installed at these bores. Data loggers measure water level, electrical conductivity and temperature every hour. Water quality analyses have been undertaken by the project team as well as various collaborators (Appendix B). Full details of water quality sampling are presented in Chapter 4.

Biological sampling was conducted at 31 sites on 2 occasions, one site (site S32) was only sampled once due to access issues (Figure 7). On these sampling occasions, macroinvertebrate, fish, zooplankton, algae, bacteria, riparian vegetation and environmental DNA (eDNA) were surveyed (see Chapter 6 for full details). Two sampling campaigns used drone surveys to monitor macrophyte extent at 3 regions within the river. Additionally, 54 sites had vegetation condition assessed (see Chapter 5 for full details). Additional algae samples were collected at 3 sites (sites B1–B3), as well as the 32 routine sampling sites.

Full details of methods and surveys conducted for each RCI index are presented in Chapters 3 to 8 of this report.

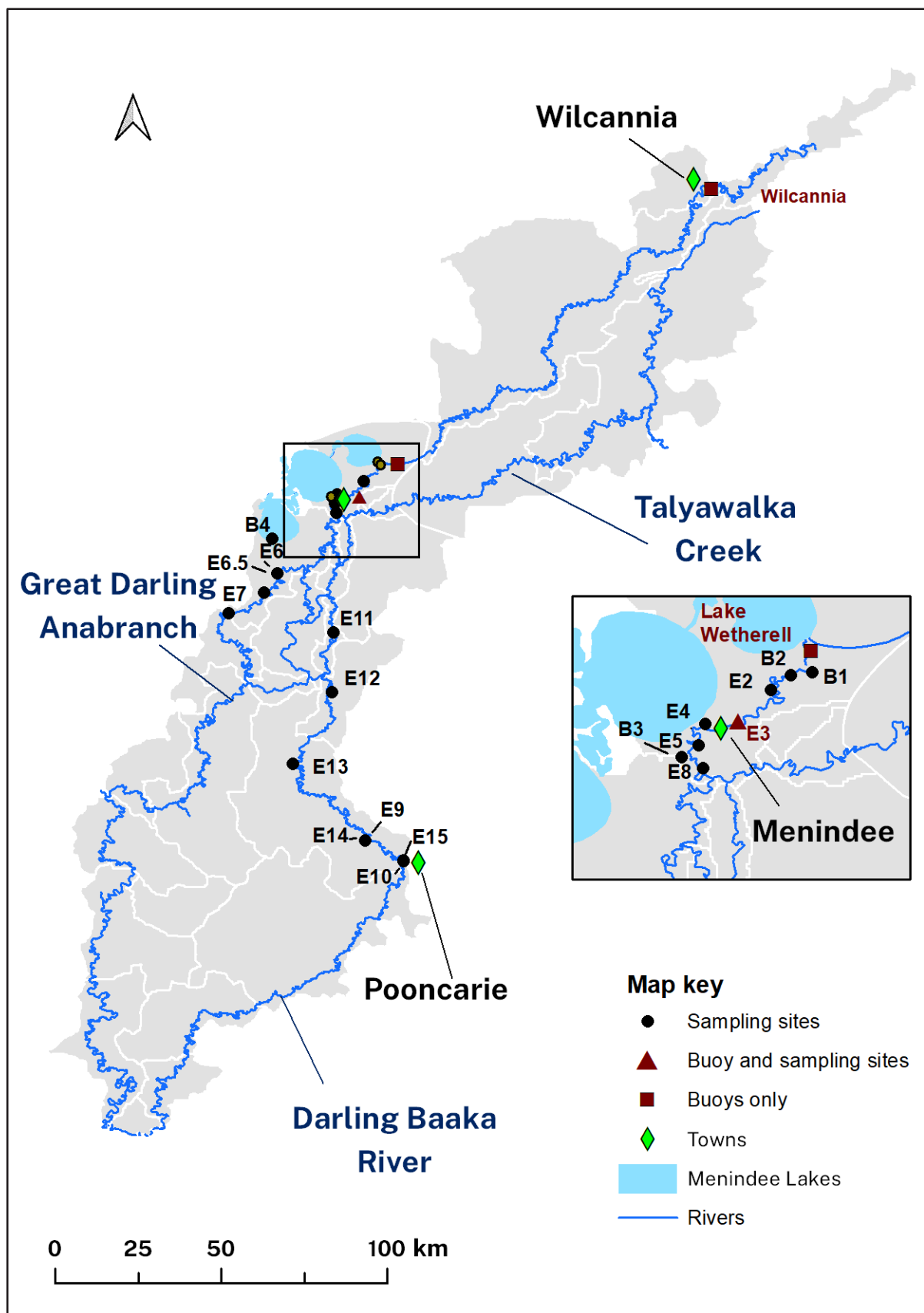


Figure 6 Phase 1 sampling sites (September 2023 to April 2024) on the lower Darling Baaka River

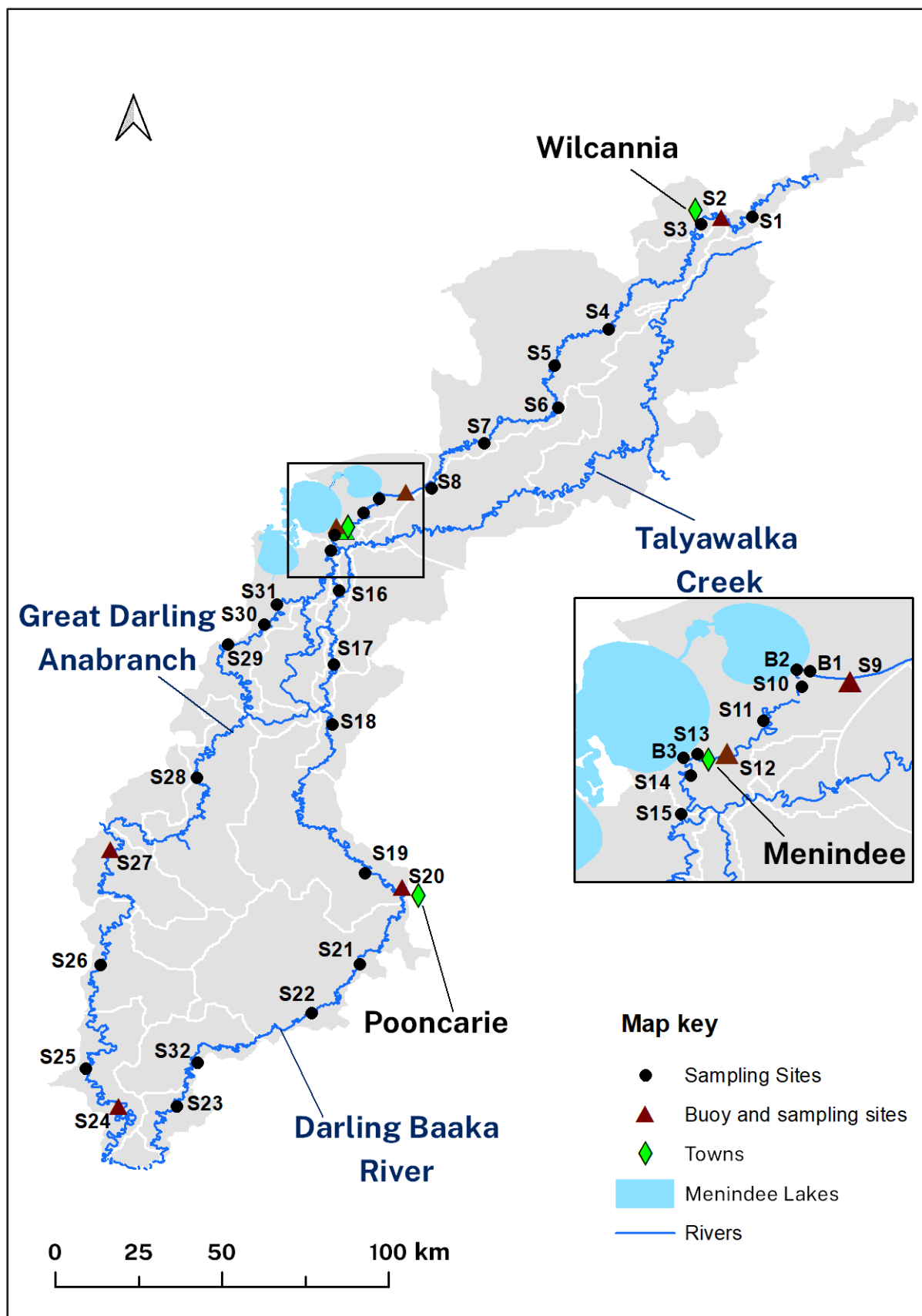


Figure 7 Phase 2 surface water (river) sampling sites (April 2024 to March 2025) on the lower Darling Baaka River

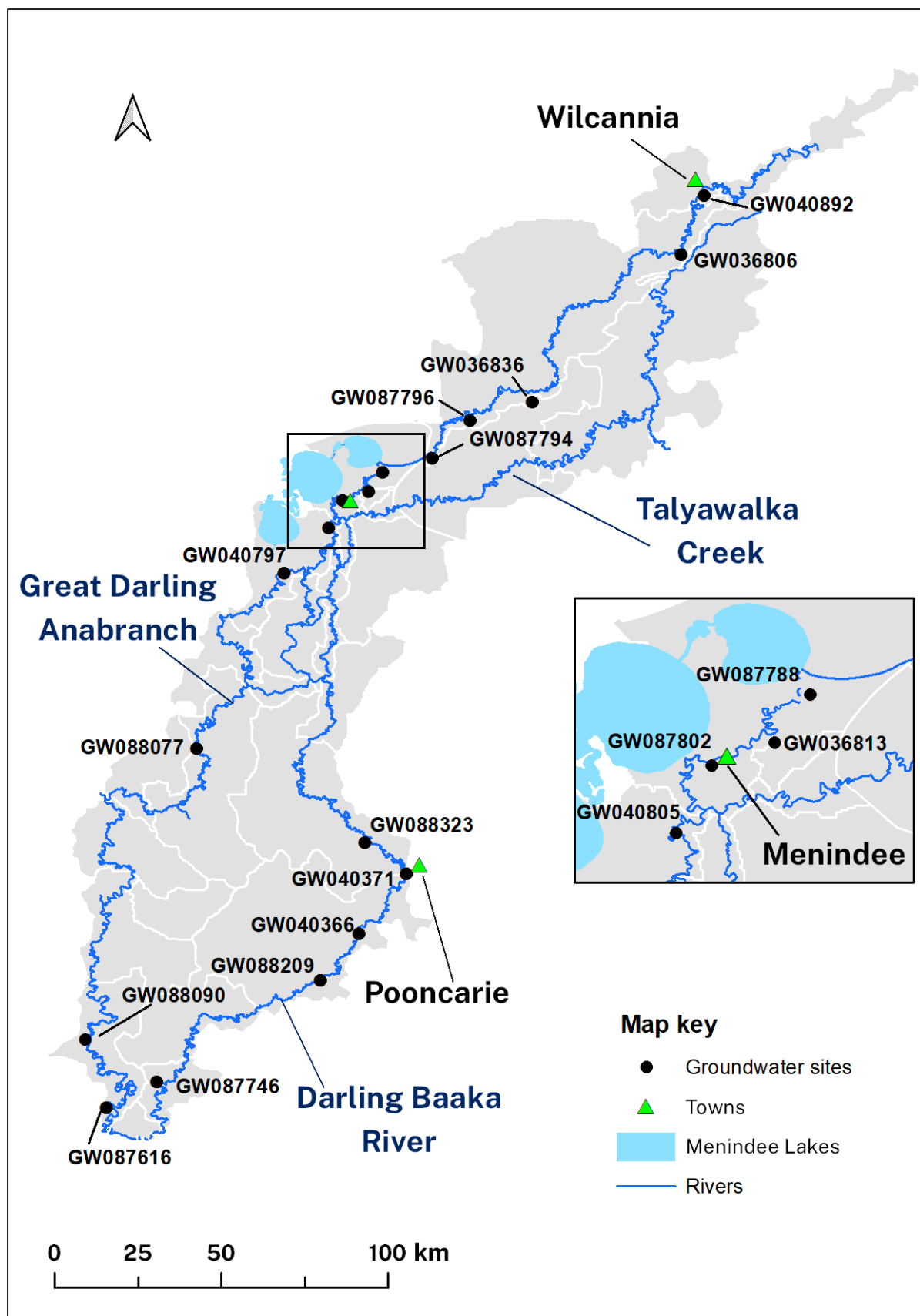


Figure 8 Phase 2 groundwater sampling sites on the lower Darling Baaka River

Table 2 Study area subcatchments and associated water quality (Phase 1 and 2) and biological sample (Phase 2 only) sites

Subcatchment name	Subcatchment number	Sample site code Phase 1	Sample site code Phase 2	Latitude	Longitude	Groundwater bore number (latitude and longitudes do not apply to these bores)	Smart buoy number
Darling Baaka River subcatchments							
Lower Paroo	3411	n.a.	S1	-31.559	143.511	-	-
Lake Woytchugga	3254	n.a.	S2	-31.553	143.401	-	Smart buoy 4
		n.a.	S3	-31.579	143.373	GW040892	-
Wilcannia Downstream	3249	n.a.	S4	-31.864	143.123	GW036806	-
		n.a.	S5	-31.961	142.976	-	-
		n.a.	S6	-32.076	142.986	GW036836	-
		n.a.	S7	-32.170	142.786	GW087796	-
		n.a.	S8	-32.293	142.644	GW087794	-
Lake Wetherell	1483	n.a.	S9	-32.317	142.556	-	Smart buoy 3
		n.a.	S10	-32.321	142.503	GW087788	-
		E2	S11	-32.358	142.461	GW036813	-
		E3	S12	-32.397	142.421	GW088209	Smart buoy 1
		E4	S13	-32.395	142.390	GW087802	-
		E5	S14	-32.418	142.383	-	-
		E8	n.a.	-32.444	142.388	-	-
		B1	B1	-32.313	142.508	-	-
		B2	B2	-32.305	142.500	-	-

Subcatchment name	Subcatchment number	Sample site code Phase 1	Sample site code Phase 2	Latitude	Longitude	Groundwater bore number (latitude and longitudes do not apply to these bores)	Smart buoy number
		B3	B3	-32.400	142.374	-	-
Downstream Weir 32	1518	n.a.	S16	-32.568	142.395	-	-
Lower Yampoola Creek	1515	n.a.	S17	-32.769	142.380	-	-
		E10		-33.387	142.570	-	-
Cuthero Creek	1514	E12	S18	-32.931	142.376	-	-
Upstream Pooncarie	1484	E14	S19	-33.333	142.465	GW088323	-
		E15	S20	-33.387	142.569	GW040371	Smart buoy 2
		E13		-33.123	142.269	-	-
Downstream Pooncarie	1475	n.a.	S21	-33.579	142.451	GW040366	-
		n.a.	S22	-33.711	142.320	-	-
Palinyewah	1504	n.a.	S32	-33.844	142.012	-	-
Lower Darling	1512	n.a.	S23	-33.962	141.957	GW087746	-
Murray–Darling confluence	1507	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Great Darling Anabranch subcatchments							
Cawndilla	1477	n.a.	S15	-32.460	142.370	GW040805	-
		E6.5	S30	-32.660	142.192	-	
		E6	S31	-32.607	142.227	GW040797	-
		B4		-32.528	142.220	-	-

Subcatchment name	Subcatchment number	Sample site code Phase 1	Sample site code Phase 2	Latitude	Longitude	Groundwater bore number (latitude and longitudes do not apply to these bores)	Smart buoy number
		E9		-33.332	142.465	-	-
Lower Redbank Creek	1476	E7	S29	-32.716	142.095	-	-
Anabranh North Lakes	1474	n.a.	S28	-33.075	142.010	GW088077	-
Coonalhugga Creek	1481	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Popio	1522	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Anabranh Offtake	1516	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Anabranh North	1473	n.a.	S27	-33.269	141.792	-	Smart buoy 6
Lake Milkengay	1495	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Warrawenia Lake	1467	n.a.	S26	-33.581	141.750	-	-
Lower Anabranh	1521	n.a.	S24	-34.027	141.814	GW087616	-
		n.a.	S25	-33.862	141.711	GW088090	Smart buoy 5
Talyawalka Creek subcatchments							
Upper Talyawalka Creek	3251	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Middle Talyawalka Creek	3248	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lower Three Mile Creek	1531	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lower Talyawalka Creek	1530	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Yampoola Creek	1480	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Charlie Stones Creek	1482	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Note: n.a. indicates no sampling sites were established in these subcatchments, primarily due to lack of flowing water or access. Groundwater data loggers, measuring water level, temperature and electrical conductivity were deployed in all bores.

Table 3 Smart buoy locations and codes

Location	Barkandji name	Site	Deployed	Longitude	Latitude
Wilcannia upstream	Kindji Yupparra	S2	8/12/2023	-31.5662	143.4049
Lake Wetherell		S9	6/12/2023	-32.3122	142.5551
Menindee weir pool	Baaka Marli	S12	11/10/2023	-32.3971	142.4199
Pooncarie	Parnty Kira	S20	13/6/2024	-33.3855	142.5672
Great Darling Anabranh		S24	16/6/2024	-34.0317	141.8156
Woodlands		S27	18/12/2025	-33.2692	141.7920

1.6 Technical report structure and overview

This technical report summarises all the data collected as part of the project. The data were collected in accordance with the Phase 1 sampling (September 2023 to April 2024) and Phase 2 sampling (April 2024 to March 2025). Additional data were collected by the department's Darling Baaka River health team in response to the 2023 flooding and associated fish kills at Menindee from April to August 2023. These data have been included in analysis of water quality.

This technical report comprises the following chapters:

- Chapter 1: Summary and project overview
- Chapter 2: River Condition Index report card summaries
- Chapter 3: Geomorphic condition
- Chapter 4: Water quality
- Chapter 5: Riparian vegetation condition
- Chapter 6: Biodiversity condition
- Chapter 7: Hydrological stress
- Chapter 8: Landscape disturbance
- Chapter 9: Value of the project and recommendations
- Chapter 10: References

Supplementary reports from key collaborators are referred to throughout and are also published on the Environment and Heritage website. The supplementary report details are:

- Davis S and Korbek KL (2025) *eDNA monitoring of waterbirds for the Darling Baaka River Health Project*, final report for NSW DCCEEW, Macquarie University, Sydney.
- DCCEEW EPS (2025) *Lower Darling Baaka system pesticide monitoring: insights from surface water, sediment and groundwater sampling and use of passive samplers*, Department of Climate Change, Energy, the Environment and Water, NSW Government.

- Hose GC, Dabovic J and Korbel K (2025) *Application of the Groundwater Health Index (GHI) as water monitoring tool: benchmarking and assessing groundwater ecosystems within the Darling-Baaka catchment*, report for NSW DCCEEW, Macquarie University, Sydney.
- Thiem JD and Stocks JR (2025) *Darling Baaka River Health Project: fish technical report*, NSW Department of Primary Industries and Regional Development, NSW Government.
- Seymour J, Siboni N, and Korbel K (2025) *Microbiological characterisation of the Darling Baaka River System*, report for NSW DCCEEW, University of Technology Sydney.
- Mitrovic S, Rogers T, Luong H, King J, Kobayashi Y, Walton J, Seymour J, Korbel K (2025) *The Darling Baaka River Health Project: phytoplankton as indicators*, University of Technology Sydney.
- WaterNSW (2025b) *Darling Baaka River Health Monitoring Program hydrological modelling report*, report for NSW DCCEEW, Water NSW.

Appendix A: River Condition Index assessment details

Table 4 provides a description of conceptual model components and threatening processes, which were used for the RCI assessment process. Indicators of threatening processes and river health are given for each component with potential indicators for consideration in the Project given.

Table 4 (a to f) Description of conceptual model components used in the River Condition Index assessment

Table 4a **Climate: The lower Darling Baaka system experiences a hot desert climate, with high inter-annual variability in rainfall. Major flooding occurs on approximately decadal return intervals, interspersed with extended drought periods**

Component	Detail	Threatening processes	Indicators/resources
- Solar - Temperature - Rainfall	–	Climate change.	- BOM weather data - Weather stations

Table 4b **Landscape: The Darling Baaka system comprises a complex network of drainage features across its floodplain including river channels, anabranch channels, distributary channels/flood runners, billabongs, wetlands and ephemeral lakes. These features are interconnected during floods and become increasingly isolated during low flow periods and some dry completely during extended drought**

Component	Detail	Threatening processes	Potential Indicators
Geomorphology	Quaternary alluvial complex of river and lake sediments with associated aeolian landforms. Geomorphic evolution of the floodplain gives rise to the different habitats represented on the Darling-Barka floodplain (see below).	- Interference of natural flow patterns across the floodplain due to agriculture and grazing activities (i.e. artificial banks/ levees/tracks) - Knickpoint erosion and gullying - Waterhole sedimentation	- LiDAR - GIS analysis of geomorphic features in relation to primary risks (e.g. agricultural drainage, earthworks, flow diversion etc.) - Flow path and stream power mapping to identify potential erosion hotspots

Component	Detail	Threatening processes	Potential Indicators
		- and infilling due to elevated sediment loads, which reduces waterhole depth and persistence time - Climate change impacts	Waterhole bathymetry and sedimentation rates
Soils	Grey clay and white sand in channels, lake beds and beaches. Brown clays on swamps, merging to red sands and some texture contrast soils on sandplains. Lunettes of white or pale yellow sand alternating with layers of pale brown pelleted clay.	- Disturbance due to agriculture (grazing, cropping, etc.) - Dryland salinity - Changes in soil C,N,P due to fertiliser application - Formation of potential acid sulfate soils (PASS) in lakes due to changes in inundation regimes arising from regulation - Climate change impacts	- Soil C,N,P contents - Extent of PASS in lakes - Acidification of waterways draining ASS on the floodplain

Table 4c Hydrology: Ecology and river health in the Darling Baaka system are underpinned by hydrological processes which are controlled by interactions between climate and landscape factors

Component	Detail	Threatening processes	Potential Indicators
Surface water	Surface water hydrology of Darling Baaka system is driven by climatic cycles (major flooding and extended drought) that occur over multiple year and decadal cycles (e.g. ENSO, IPO etc.).	- Disruption to flows and water levels, including reduced channel-floodplain connectivity due to weirs and water regulation - Truncation of inflows due to	- Deviation of river flows from expected normal - Deviation of water level variation in lakes from expected normal range - Streamflow as a proportion of modelled/estimated upstream

Component	Detail	Threatening processes	Potential Indicators
	Inundation of floodplain habitats is limited to large floods occurring over decadal return intervals.	water extractions upstream of study area • Artificial releases of water from water storage structures • Overall drying trend over the last 40 years • Increase in the frequency of extreme events due to climate change	extractions as a measure of extraction-induced hydrological stress • Waterhole levels and persistence
Groundwater	Deep and shallow aquifers. Linkage between surface water and groundwater recharge. Relationships between GW and floodplain habitats (including GW inputs to river channels).	• Acidification of groundwater due to ASS • Reduction in recharge due to anthropogenic changes to floodplain surface water hydrology • Climate change impacts (recharge, evaporation, etc.).	• Deviation of shallow groundwater levels from expected normal range across floodplain • Physicochemical water quality of groundwater • eDNA indicators of biological connectivity • Groundwater health indicators

Table 4d Floodplain habitats: Functional zones within the lower Darling Baaka system are made up of unique mosaics of distinct habitats that have evolved in response to interactions between climate, landscape and hydrological factors

Components	Description	Threatening processes	Potential Indicators
• River channels • Lakes • Flood runners • Wetlands • Billabongs • Floodplain vegetation communities • Groundwater	Floodplain habitats evolve in response to interactions between climate, landscape and hydrological drivers. The ecological integrity of the greater Darling Baaka is dependent on the function of individual habitats and their interaction with adjacent habitats.	• Vegetation clearing • Feral animal and weed species • Changes to hydrology • Climate change.	• GIS analysis of habitats and threatening processes • Ground-truthing of mapped habitats • ID and survey of key habitats within each function zone

Table 4e Organic matter and microbial metabolism: Aquatic food webs and key environmental risks (blackwater, harmful algal blooms [HABs], hypoxia) are dependent on the interactions between organic matter and the microbial community of the Darling Baaka River

Components	Description	Threatening processes	Potential Indicators
Detrital organic matter (allochthonous OM)	Inputs of detrital OM from the floodplain to waterways during floods supports aquatic foodweb.	• Bushfire on floodplain • Drought cycles/climate change • Changes to floodplain vegetation composition due to agriculture and hydrological alterations • Changes to floodplain hydrology impacting delivery of detrital OM to waterways	• GIS analysis of floodplain vegetation communities • Isotopic signatures of floodplain OM • Isotopic signatures of riverine OM

Components	Description	Threatening processes	Potential Indicators
Internally produced organic matter (autochthonous OM)	Primary production by aquatic plants supports foodweb outside of peak flood times. Main sources include: • pelagic microalgae and cyanobacteria (phytoplankton) • benthic microalgae and rooted macrophytes	• Phytoplankton blooms due to a combination of reduced flows and nutrient inputs • Changes in microbial community composition due to anthropogenic changes in N:P loadings to waterways	• Algal ID and toxins • Biovolume • Chlorophyll, phycocyanin • eDNA • Nutrients (N, P, Fe) • Turbidity/light • Seston isotopic signature
Cyanobacteria	Phytoplankton include N-fixing cyanobacteria (also known as blue green algae) including potentially toxic species. Ability to fix atmospheric nitrogen (N) allows cyanobacteria to outcompete other phytoplankton species in N-limited waters.	• Shift in phytoplankton composition in favour of potentially harmful cyanobacteria • Production of phyto-toxins cause fish kills, stock poisoning, skin disorders etc.	• As for autochthonous OM above • Community observations
Microalgae	–	–	–
Mixotrophic and heterotrophic microbes	Bacterial metabolism dominates in light-limited portions of the water column and contributes to hypoxia.	• Increased respiration due to OM inputs (↓ oxygen, ↑ CO₂ + methane) • Shift in microbial community composition in favour of potentially toxic bacteria	• Genetic profiles • eDNA • Light/dark BOD • Bacterial indicator species
Oxygen metabolism	Dissolved oxygen (DO) concentrations vary in aquatic waterways due to a combination of	• Increased diel variation in DO concentrations due to eutrophication	• Temporal and spatial variation in DO concentrations (loggers, surveys etc.

Components	Description	Threatening processes	Potential Indicators
	physical and biological processes.	• DO stratification due to alterations in hydrology and eutrophication • Hypoxia due to blackwater inputs during floods • Hypoxia due to concentration of fish biomass in river channels and weir pools • Changes to river flows by extractions and regulation. • Climate change	• Sediment and water column BOD • Ecosystem metabolism models for key reaches (e.g. Menindee weir pool) • Greenhouse gas fluxes

Table 4f Higher food web: Higher orders of the Darling Baaka system food web have evolved to live in an extremely variable environment, experiencing extended drought and infrequent flooding

Component	Detail	Threatening processes	Potential Indicators
Invertebrates	Include: • molluscs, • yabbies, • zooplankton	• Hypoxia • Disruption of habitat requirements due to flow regulation	• Species richness • Biomass • eDNA • SIGNAL, AUSRIVAS
Fish	Include: • species composition, distribution as a function of time and space • habitat requirements (breeding, nursery, feeding, migration passage, refugia etc.)	• Disruption of fish passage • Hypoxia • HABs • Disruption of habitat requirements due to flow regulation • Pest species	• GIS analysis of waterway connectivity • eDNA • Flow

Component	Detail	Threatening processes	Potential Indicators
Amphibians	Species composition, distribution as a function of time and space. Habitat requirements (breeding, nursery, feeding, migration passage, refugia etc.).	• Disruption of habitat requirements due to flow regulation • Drying • Pest species	• Species richness • Biomass • eDNA
Reptiles	Species composition, distribution as a function of time and space., Habitat requirements (breeding, nursery, feeding, migration passage, refugia etc.).	• Disruption of habitat requirements due to flow regulation • Pest species	• Species richness • Biomass • eDNA
Birds	Species composition, distribution as a function of time and space. Habitat requirements (breeding, nursery, feeding, migration passage, refugia etc.).	• Disruption of habitat requirements due to flow regulation • Pest species	• Species richness • Biomass • eDNA

Appendix B: Key collaborators

Table 5 Key collaborators for each indicator

Indicator type	Data collected 2025 RCI	Collaborating agency
Fish	FCI (Richness, abundance, recruitment, nativeness, health)	- Department of Primary Industries and Regional Development – Fisheries - DCCEEW Water Group – Surface Water Science
Macroinvertebrates	- SIGNAL2 - POET - AUSRIVAS	Macquarie University
Zooplankton	Community health score (richness, reproductive state, sensitive taxa)	DCCEEW Water, Wetland and Coastal Science Branch
Bacteria	Diversity	University of Technology, Sydney
Algae	- Richness and abundance - Presence of toxin producers	- University of Technology, Sydney - WaterNSW
Waterbirds	Species richness (eDNA)	Macquarie University
Macrophytes	Recovery since flood (% cover)	DCCEEW Water, Wetland and Coastal Science Branch
Pesticides	Presence and concentration	- DCCEEW Environment Protection Science - University of Queensland
Groundwater	- Water quality - eDNA - Microbial activity	- Macquarie University - DCCEEW Water Group – Surface Water Science
Hydrology	Hydrological modelling	WaterNSW
Riparian vegetation	- Ground truthing - Assessment of riparian condition	- DCCEEW Water, Wetland and Coastal Science Branch - DCCEEW Water Group - Surface Water Science
Geomorphology	River Styles	DCCEEW Water Group – Surface Water Science

Table 6 **Expert panel members**

Name	Collaborating agency
Professor Lucy Marshall	University of Sydney
Ass. Professor Tim Ralph	Macquarie University
Luke Driscoll	CEO Barkandji Prescribed Body Corporate
Ass. Professor Luke Moseley	University of Adelaide
Dr Sarah Mika	University of New England
Professor Lee Baumgartner	Charles Sturt University
Dr Martin Mallen-Cooper	Charles Sturt University
Dr Angus Ferguson	DCCEEW
Dr Kathryn Korbel	DCCEEW
Dr Tracey Macdonald	DCCEEW
Jessica Bournier	DCCEEW

Abbreviations

AHP:	Analytic Hierarchy Process
ARI:	annual recurrent interval
BCI:	Biodiversity Condition Index
Cd:	cadmium
Cu:	copper
DBH:	diameter at breast height
DEM:	digital elevation model
DIN:	dissolved inorganic nitrogen
DOC:	dissolved organic carbon
EC:	electrical conductivity
EPA:	NSW Environmental Protection Authority
Fe:	iron
GCI:	Geomorphic Condition Index
GHI:	groundwater health index
GIS:	geographic information system
Hg:	mercury
HSI:	Hydrological Stress Index
IBRA:	Interim Biogeographic Regionalisation of Australia
LDI:	Landscape Disturbance Index
LiDAR:	light detection and ranging
LOR:	limit of reporting
MCI:	macroinvertebrate condition indicator
NDVI:	Normalised Difference Vegetation Index
NH ₄ ⁺ :	ammonia
NO _x :	nitrate/nitrites
NSW:	New South Wales
OCSE:	Office of the Chief Scientist and Engineer
Pb:	lead
PCT:	plant community type
POET:	Plecoptera, Odonata, Ephemeroptera and Trichoptera

RARC: rapid appraisal of riparian condition
RCI: River Condition Index
SLATS: Statewide Landcover and Tree Survey
SRP: soluble reactive phosphorus
TN: total nitrogen
TP: total phosphorous
UTS: University of Technology Sydney
WQI: Water Quality Index
ZCCS: zooplankton community condition score
Zn: zinc
zOTUs: zero-radius operation taxonomic unit

Units of measure

FNU: formazin nephelometric units
FRU: relative fluorescent units
kW: kilowatt
m³: cubic metres
mg/L: milligrams per litre
ML/day: megalitres per day
NTU: nephelometric turbidity units
ppb: parts per billion
QSU: quinine sulphate units
µg/L: micrograms per litre
µS/cm: microsiemens per centimetre
µm: micrometre
% v/v: percent by volume

More information

- [Darling Baaka River Health Program – Smartbuoy locations](#)
- [Making Data FAIR: Findable, Accessible, Interoperable, and Reusable – Australian Research Data Commons webpage](#)