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MURRAY–DARLING BASIN AUTHORITY

2016–17 basin annual environmental watering priorities

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Accessibility
The Murray–Darling Basin Authority makes its documents and information available in accessible formats. On some occasions the highly technical nature of the document means that we cannot make some sections fully accessible. If you encounter accessibility problems or the document is in a format that you cannot access, please contact us.

Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray–Darling Basin Authority acknowledges and pays respect to the Traditional Owners, and their Nations, of the Murray–Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. The MDBA understands the need for recognition of Traditional Owner knowledge and cultural values in natural resource management associated with the basin.

The approach of Traditional Owners to caring for the natural landscape, including water, can be expressed in the words of Darren Perry (Chair of the Murray Lower Darling Rivers Indigenous Nations)

> *the environment that Aboriginal people know as Country has not been allowed to have a voice in contemporary Australia. Aboriginal First Nations have been listening to Country for many thousands of years and can speak for Country so that others can know what Country needs. Through the Murray Lower Darling Rivers Indigenous Nations and the Northern Basin Aboriginal Nations the voice of Country can be heard by all.*

The use of the terms ‘Aboriginal’ and ‘Indigenous’ reflects usage in different communities within the Murray–Darling Basin.

Contents

Overview of the 2016–17 basin annual environmental watering priorities

The Murray–Darling Basin Authority (MDBA) has basin-wide environmental responsibilities including identifying basin annual environmental watering priorities. The responsibilities of the basin states include identifying annual priorities at the regional scale. This report has been produced principally for holders and managers of environmental water — the Commonwealth Environmental Water Holder (CEWH) and basin states — who will be guided by the basin-wide priorities outlined in this report when they undertake watering in 2016–17. Chapter 8 of the Basin Plan describes their roles and responsibilities in detail.

What are basin annual environmental watering priorities?

The basin annual environmental watering priorities guide the annual planning and prioritisation of environmental watering across the Murray–Darling Basin. They are central to the Basin Plan's objectives of protecting and restoring the basin's rivers, wetlands and floodplains. Annual prioritisation is undertaken to achieve the most effective use of environmental water, promote better basin-scale outcomes, support adaptive management and assist coordination of environmental watering between environmental water holders and managers.

Decisions by environmental water holders on environmental watering in the basin are to be undertaken having regard to the priorities. However, the priorities are not an exhaustive list of all important environmental assets and functions throughout the basin, and they do not preclude other watering priorities identified by environmental water holders and managers at the regional level.

The priorities give effect to the Basin-wide environmental watering strategy (MDBA 2014). The environmental watering strategy quantifies the expected environmental outcomes for the basin's water-dependent ecosystems over the long term and proposes water management strategies and coordinated actions required to achieve them. The priorities represent annual steps to guide environmental watering to meet the long-term outcomes set out in the strategy. For this reason the priorities are best read alongside the environmental watering strategy.

Planning for the priorities

The priorities are prepared as set out in the Basin Plan and the environmental watering strategy. They have regard to the basin states' annual environmental watering priorities and to the outcomes in the strategy. This ensures the priorities take into account both whole-of-basin and regional perspectives.

The priorities have been framed consistent with the statutory *Guidelines for the method to determine priorities for applying environmental water* and forecast seasonal conditions to ensure realistic priorities for the coming water year. These are the fourth annual environmental watering priorities prepared under the Basin Plan. The focus of the priorities has evolved over time to align with the strategy and in response to new knowledge, consistent with adaptive management.

Further changes in the way we set the priorities are expected as we learn more about how species and ecosystems respond to environmental watering in different climatic conditions and as more water is recovered for environmental use under the Basin Plan.

Observations from previous environmental watering

It will take some time for the full benefits of the environmental watering to be realised, because of biological lags and because water recovery and the Basin Plan won't be fully implemented until 2019. Therefore, up to 2019 we aim to maintain ecological conditions; after 2019 we expect to see improved ecological conditions. These targets are set out in more detail in Schedule 7 of the Basin Plan.

Since the Basin Plan came into effect, in 2012, only small volumes of environmental water have been available. Therefore environmental watering undertaken by holders and managers of environmental water has been on a relatively small scale. There has not been the series of wet years required for whole-of-basin watering nor the opportunity to build allocations to the point where the scale and/or duration of larger flow events can be substantially enhanced. This means that, while there have been good responses to environmental watering locally, at the basin scale we are seeing only small improvements and some ongoing decline. For example waterbird abundance continues to be concerning and breeding is insufficient to stop the decline (Figures 6 and 7).

More information will be available in an evaluation report to be published in 2017. Some examples of the outcomes observed to date are listed below.

Monitoring has shown that using environmental water wisely on the back of natural events and normal river operations in the last few years has helped the recovery from drought in some areas. Positive responses were observed between 2013 and 2015 in core wetland vegetation in the Gwydir Wetlands, Macquarie Marshes and lower Lachlan, where environmental water had been provided. The marsh club-rush sedgeland community in the Gwydir Wetlands has recovered from drought and fire in response to environmental water.

Environmental water has been delivered to wetlands and rivers to benefit waterbirds across the basin from 2013 to 2015. Water delivered to the Mallowa Wetlands in northern New South Wales in 2014 provided a refuge for waterbirds in the northern basin. There was an increase in bird breeding in 2014–15 after environmental water was delivered to Yanga National Park. This resulted in eastern great egrets, listed under several international and bilateral treaties, breeding in the area for the first time since 2011. Waterbird breeding was also recorded in Barmah Forest and in the Gingham and Gwydir wetlands in response to environmental water.

The Gingham and Gwydir wetlands were inundated as a result of environmental water delivered from 2014 to 2016 (MDBA 2014a), bringing benefits for waterbirds and native fish, and promoting the growth of low-lying native wetland vegetation species such as water couch. Watering increased the number of waterbirds present within the wetlands and allowed some species to breed. The extended period of wetland inundation was important for nutrient cycling, metabolic processes and stimulating wetland food webs.

Numbers of Murray hardyhead and other small-bodied native fish species increased in Lake Alexandrina in response to environmental water delivered between 2013 and 2015. Increased numbers of congolli, lamprey and common galaxids moved through the barrages from the Lower Lakes into the Coorong and Southern Ocean. Lamprey were also detected moving through the barrages upstream into the River Murray.

Flows from environmental watering in the Mehi River and Carole Creek from 2014 to 2016 provided opportunities for native fish, such as spangled perch and bony bream, in the Barwon–Darling River to disperse during a critical migration period. Flows also allowed the transfer of nutrients and organic matter through the system, and improved water quality (MDBA 2015). Environmental water contributed to improved flows along channels of the lower Gwydir, and contributed to flow regimes that allowed native fish to recruit and survive in the Gwydir system.

Since 2013, coordinated environmental water delivery in the River Murray has provided system-wide events to increase flows across floodplains and along river systems. This has supported increased barrage flows and salt export.

Observations from environmental watering offer important opportunities to improve our understanding of the ecology and how it responds to watering. Environmental watering over successive years, informed by local community involvement and scientific advice provides important opportunities to learn and adjust procedures, consistent with the adaptive management approach of the Basin Plan.

For example many lessons were learnt during in the commissioning of works that support environmental watering at icon sites and these have led to improved procedures and, in some cases, modifications to works.

The Commonwealth Environmental Water Holder has worked closely with the Victorian Environmental Water Holder and local delivery partners to progressively improve environmental watering in the Goulburn River. In the first year (2013), environmental watering supported golden perch breeding but may have also caused minor impacts to river banks and disrupted local fishing events. The 2014 environmental watering was brought forward to October, instead of November, and was delivered as a flow pulse with a gradual recession. This maximised environmental outcomes while minimising unintended consequences – a good example of how experience is leading to better outcomes, through adaptive management. For further information, see the CEWH's report on environmental watering to the MDBA.

More information on the outcomes from environmental watering is contained in the reports published by environmental water managers, see Appendix 1.

Climate context for the 2016–17 priorities

The MDBA is planning in anticipation of dry conditions in 2016–17 but is also prepared for moderate conditions should water availability improve.

In the Basin environmental watering outlook (published on 11 April 2016), the MDBA calculated that most of the basin's catchments could anticipate either a dry or very dry resource availability scenario (or below average antecedent conditions in the case of unregulated catchments) (Appendix 2). Since then, the outlook for eight catchments has become slightly wetter while five have become slightly drier.

The Bureau of Meteorology reported (on 24 May 2016) that the 2015–16 El Niño has ended, and that La Niña is likely to form during winter (June–August). During La Niña, winter–spring rainfall is often above average over eastern Australia.

So while the Murray–Darling Basin is currently experiencing dry conditions, wetter conditions may emerge during 2016–17. Conditions are not expected to tend towards very dry. Accordingly, priorities have been identified for dry conditions and additional priorities have been prepared should conditions become more moderate.

The MDBA's assessment of the climate context is based on:

- analysis of antecedent conditions and surface water availability in Murray–Darling Basin catchments
- the Bureau of Meteorology's climate outlook and El Niño–southern oscillation (ENSO) wrap up
- consultation with environmental water holders and managers.

Reasons for choosing these priorities

The priorities have been prepared following the process set out in the Basin Plan and the Basin-wide environmental watering strategy. In addition to environmental factors, the MDBA must also consider Aboriginal values and uses, and social and economic outcomes. Detail on how the MDBA is working with Aboriginal peoples to incorporate Aboriginal values and uses is described later in this report. A description of how the specific priorities for 2016–17 align with Aboriginal values and uses is included in each of the technical summaries.

The priorities have been chosen because they:

- support achievement of an expected environmental outcome(s) under the Basin-wide environmental watering strategy
- give effect to relevant international agreements (e.g. Ramsar Convention)
- support threatened ecosystems or species listed under national legislation (e.g. *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
- support rare, unique or representative species or habitats at the basin scale (including Basin Plan Schedule 7 targets)
- build on a previous priority to maximise environmental outcomes
- respond to urgent needs for environmental water
- provide multiple outcomes
- complement local or regional priorities.

During the prioritisation process social and economic factors are considered, particularly in relation to any risks associated with the delivery of a priority and whether the priority is practical and feasible. These factors are also considered by water holders when planning implementation. A case study on the how environmental watering can help to deliver improved social and economic outcomes is included in the 'learning and continuous improvement' section.

The basin states also identify environmental watering priorities for each water resource plan area in their state. The MDBA may adopt these priorities, particularly where they have identified priority environmental assets and priority ecosystem functions that have basin-scale significance. The MDBA determines basin-scale significance by applying the test described in the Basin-wide environmental watering strategy. This test involves considering the significance of the environmental benefit if the priority is met; the consequences of not listing the priority; the likelihood of benefit; and any synergies and multiple outcomes. If the MDBA adopts any priorities prepared by the basin states, it will do so by incorporating them into one of the basin priorities (as has been done in the past) or by adding the priority as an addendum.

Priorities for 2016–17

Dry conditions are anticipated to continue in 2016-17 and relatively small volumes of environmental water will be available. The management outcomes sought from environmental watering in dry conditions (Table 4, Appendix 5) are to ensure environmental assets maintain their basic functions and resilience by:

- supporting the survival and viability of threatened species and communities
- maintaining environmental assets and ecosystem functions, including by allowing drying to occur consistent with natural wetting-drying cycles
- maintaining refuges.

The priorities for 2016–17 include overarching and specific priorities that support the achievement of the expected outcomes set out in Basin-wide environmental watering strategy. Each specific priority is addressed in detail in the technical summaries. Implementation of the 2016–17 priorities will require effective use of *all* water, including consumptive water on route to users. Significant environmental benefits, particularly for native fish, can be achieved more efficiently through coordinated water management. The Southern Connected Basin Environmental Watering Committee comprises members from all environmental holders in the southern basin and has a key role to play in facilitating coordinated environmental watering.

Additional priorities have been identified for the possibility that more moderate conditions arise. These are summarised separately below.

Native vegetation

The priority for environmental watering in 2016–17 is to water discrete locations that include threatened vegetation or support other threatened species and communities, including vegetation that is critical waterbird foraging or breeding habitat. The specific priorities are:

- Improve the condition of wetland vegetation communities in the mid-Murrumbidgee wetlands that provide critical habitat for threatened species and communities.
- Improve the health and complexity of waterbird rookery habitat in the northern Narran Lakes system.

Flows that water these vegetation communities will also provide outcomes for native fish and other biota.

Waterbirds

The priority for environmental watering in 2016–17 is to prevent further decline in habitat that supports waterbird breeding across the basin and thereby to help stabilise waterbird populations, albeit at lower levels than are sought over the long term. Environmental watering should be focussed on wetlands that have the greatest potential to support waterbird breeding in the near future.

There are no specific priorities for waterbirds identified for 2016–17 under dry conditions, other than supporting the rookery habitat within the Narran Lakes system (listed under native vegetation). However, there are some specific priorities for identified waterbirds, should more moderate conditions arise.

Native fish

The priority for environmental watering in 2016–17 is to protect drought refuge habitats, to maintain in-stream habitats, and to ensure existing populations of threatened species remain viable. The specific priorities are:

- Contribute to the long-term recovery of silver perch by improving existing populations and enhancing conditions for recruitment and dispersal to and from suitable habitat.
- Support viable populations of threatened native fish by protecting drought refuges and maintaining in-stream habitats and essential functions.
- Maximise opportunities for range expansion and the establishment of new populations of silver perch and other threatened fish, as conditions allow.

Flows and connectivity

The priority for environmental watering in 2016–17 is to provide longitudinal connectivity and variable flow patterns for water quality and ecological benefit — particularly for native fish. The specific priorities are:

- Maintain waterholes in the Lower Balonne Floodplain to provide critical refuge for water-dependent species.
- Protect aquatic habitat conditions in the Coorong and support native fish movement by optimising flows into the Coorong and through the Murray Mouth.

In dry conditions, supporting longitudinal connectivity will be the best outcome that is possible. Although providing lateral connectivity to refuge areas and other priority sites is also important, conditions are unlikely to facilitate widespread lateral connectivity unless structures such as weirs and regulators are used.

Additional priorities for moderate conditions

The forecast for 2016–17 indicates that moderate conditions may arise later in the year. While not certain, if moderate conditions do occur in parts of the basin the management outcomes sought from environmental watering are to maintain ecological health and resilience by:

- enabling growth, reproduction and small-scale recruitment for a diverse range of plants and animals
- promoting low-lying floodplain-river connectivity
- supporting medium-flow river and floodplain functions.

Moderate conditions may provide for small-scale recovery and thereby contribute to meeting the long-term expected outcomes set out in the environmental watering strategy for native vegetation, waterbirds and native fish. Given the condition of the basin's ecology, priorities identified for moderate conditions are additional rather than alternatives to those identified for dry conditions.

In the event moderate conditions arise, the most pressing priorities for the use of environmental water will be to:

- prevent further critical deterioration of Moira grass in Barmah–Millewa Forest, subject to resolving natural resource management issues

- support waterbird populations by watering critical breeding and feeding habitats at the important basin environmental assets for waterbirds, and coordinate watering at ecologically-linked systems, particularly at the Macquarie Marshes and Narran Lakes
- capitalise on opportunities to support waterbird breeding
- contribute to the long-term recovery of threatened species, including silver perch, through range expansion and the establishment of new populations.

Figure 1 shows the locations of the basin-wide priorities.

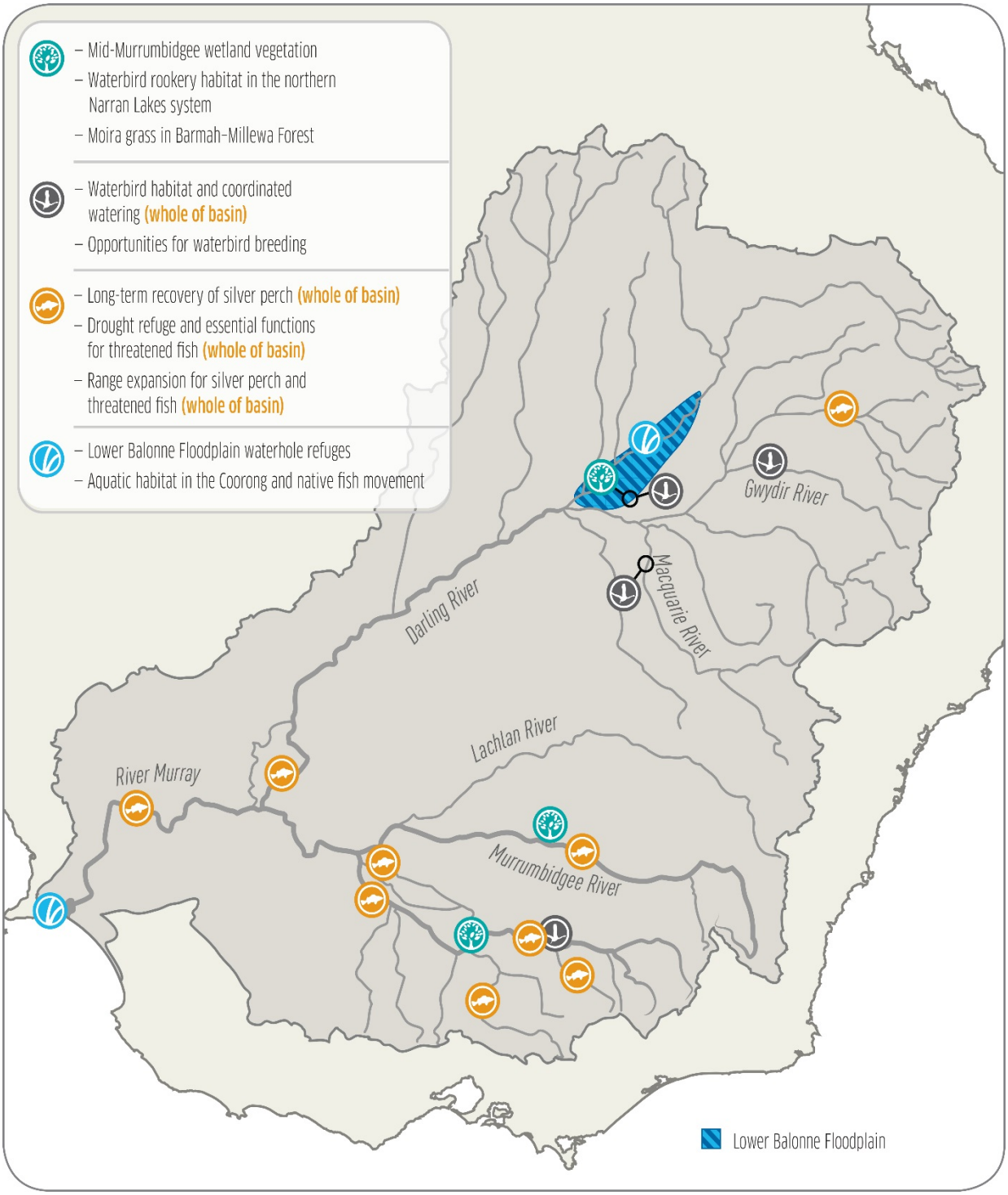

Figure 1: Geographic representation of the 2016–17 priorities in the Murray–Darling Basin

State priorities

The basin states are required to provide the MDBA with annual environmental watering priorities in each water resource plan area by 31 May each year. The MDBA has received annual priorities from Queensland, New South Wales, Victoria and South Australia. These are regional/local priorities. The MDBA had regard for these regional priorities as it finalised the basin-wide priorities.

The MDBA and basin states have different but complementary roles in planning environmental watering. This means that the basin-wide priorities are not an exclusive list — state priorities may be more detailed, at the regional scale.

The 2016–17 annual priorities provided by the basin states generally complement the basin-scale priorities outlined here. This is the result of consultation on the needs and opportunities for environmental watering within the framework provided by the Basin Plan and the Basin-wide environmental watering strategy.

For the coming year there are no state priorities which have been added to the basin-wide priorities. Many regional priorities will support and contribute to the expected outcomes outlined in the Basin-wide environmental watering strategy and the overarching priorities, particularly priorities that support threatened species in dry conditions.

The basin states generally publish their annual priorities on their websites, although some may not be published immediately, see New South Wales, Queensland, Victoria and South Australia.

Learning and continuous improvement

Incorporating Aboriginal values and uses

Independent, culturally authoritative and strategic input from Aboriginal people can enhance the outcomes from environmental watering decisions. Aboriginal environmental outcomes are where ecological benefits from environmental watering also support Aboriginal objectives, values and uses. Management of environmental water that encompasses Aboriginal values and uses will enhance wellbeing and cultural resilience. This approach also recognises that Aboriginal peoples' knowledge of Country can inform better water management.

The Basin Plan identifies the Murray Lower Darling Rivers Indigenous Nations and the Northern Basin Aboriginal Nations as key engagement partners in water resource planning. In collaboration with the MDBA, they are developing approaches to integrate Aboriginal values and uses into environmental water planning. Talks have begun on how to integrate this input into the annual environmental watering priorities process to strengthen and improve it over time. This will continue to occur with input into the priorities each year building on the progress already made.

Southern basin — Murray Lower Darling Rivers Indigenous Nations (MLDRIN)

Over the last year, MLDRIN has been working with state governments and the Australian Government to ensure that basin environmental water management is responsive to Traditional Owners' rights and interests. This work includes:

- providing regular advice and undertaking engagement with state governments on the development of water resource plans
- advising and engaging with states on the inclusion of Aboriginal objectives in long-term watering plans
- contributing to decision making about environmental watering through participation in local forums and advisory bodies
- supporting the application of the Aboriginal Waterways Assessment tool as an approach to help Traditional Owners identify watering priorities.

The Murray Lower Darling Rivers Indigenous Nations supports its member Nations to articulate their watering objectives and to have them included in water planning processes. As a first step in the process to integrate Traditional Owners' input into planning for the basin annual environmental watering priorities, MLDRIN members gave feedback on places, species and ecological functions that are in need of watering in the southern-connected system in order to deliver Aboriginal environmental outcomes. Out of this feedback common themes emerged, including the importance of:

- improving habitat and breeding areas for water-dependent species like waterbirds, fish, frogs, turtles and yabbies
- removing barriers to native fish movement to enable breeding and movement throughout the system
- providing drought refuge for water-dependent species during times of low flows
- maintaining connectivity for billabongs, creeks and anabranches that have altered flow regimes due to water resource development
- maintaining the condition of floodplain vegetation.

The key message that underpins these themes is the importance of the environmental health of all native species to Traditional Owners. It is important to remember that, for many Aboriginal people, Country is understood as an interconnected whole. Prioritising particular places or species may not always be compatible with this holistic perspective. This was reflected in feedback that complementary natural resource management measures, like preventing bank slumping, removing and controlling pest species, and revegetation were also of importance to maintain and improve the condition of rivers and floodplains.

Northern basin — Northern Basin Aboriginal Nations (NBAN)

Over the last year NBAN delegates have been working on several large bodies of work in partnership with state governments and the Australian Government that ensure that Traditional Owners' input contributes to northern basin environmental water management. This work includes:

- participating in meetings for the Northern Basin Review, National Cultural Flows Research Committee, Queensland Aboriginal Consultation Working Group and New South Wales Aboriginal Water Initiative workshops
- facilitation of the northern basin Use and Occupancy Mapping, including employing community members as town organisers
- participation in the MDBA's socio-economic surveys conducted in Brewarrina, St George and Dirranbandi (as part of the Northern Basin Review)
- providing advice and undertaking engagement with the Queensland Government on the Queensland Water Resource (Warrego, Paroo, Bulloo and Nebine) Plan 2016 and the Basin Plan's draft Warrego–Paroo–Nebine water resource plan
- reviewing the proposed Warrego–Paroo–Nebine water resource plan put forward for accreditation under the Basin Plan
- endorsement of the pilot Aboriginal Waterways Assessment at Walgett, including input into the publication of the Aboriginal Waterways Assessment program booklet
- ongoing liaison with the National Cultural Flows Research Project on the Gooraman Swamp case study site in New South Wales.

During the 2015–16 water year the MDBA attended a Northern Basin Aboriginal Nations full gathering to start talks on integrating Traditional Owners' input into the priorities process. Talks are continuing on how NBAN can provide input into the 2017–18 priorities, and how the MDBA can identify where environmental watering has provided Aboriginal environmental outcomes. There may be opportunities to use the findings of the work being done through the Aboriginal Waterways Assessment and the Use and Occupancy Mapping in the northern basin for the priorities process.

The MDBA will continue work with NBAN and MLDRIN early in the 2016–17 water year at the joint gathering scheduled to be held in Canberra.

Future improvements

Each year the MDBA improves how the priorities are prepared. This year we have improved how we determine the resource availability scenario (MDBA 2016) and our engagement with Aboriginal people. We have included a case study on the social and economic benefits of environmental watering and increased community participation using an online survey that accompanied the outlook.

We are progressively increasing the objectivity of the process for setting the priorities. This involves developing prioritisation methods that transparently account for ecological condition, biophysical type, relative importance of biodiversity and functional values, and the need for environmental watering.

Environmental water prioritisation has tended to focus at the annual site-based scale. But many population processes operate over longer-term cycles and different locations. Achieving ecological outcomes often relies on cumulative changes over multiple years. The MDBA is examining how to strengthen the contribution that the priorities make to achieving basin outcomes, including whether rolling multi-year priorities can assist.

The MDBA is also working to identify where environmental outcomes may result in complementary social and economic outcomes.

Case study: the mid-Murrumbidgee wetlands

The intent of the 2016–17 mid-Murrumbidgee wetlands priority is to highlight the importance of improving the condition of wetland vegetation communities that provide critical habitat for threatened species and communities. Improved vegetation condition is expected to increase suitable habitat for fish, frogs, birds, turtles and other native animals, as well as providing breeding opportunities for native fish and other aquatic species. It will deliver Aboriginal environmental outcomes in line with the themes identified by members of the Murray Lower Darling Rivers Indigenous Nations. The mid-Murrumbidgee priority also supports the other 2016–17 priority related to silver perch.

The University of Canberra's Regional wellbeing survey has asked questions on the views, values and experiences of environmental watering in the basin. In relation to importance and values of environmental watering for native fish, the responses included:

- 74% of all survey respondents and 67% of New South Wales respondents supported environmental watering to support native fish populations
- 68% of respondents agreed that environmental watering improved fishing conditions, while 64% agreed that environmental watering increased native fish populations, although 54% also agreed that environmental watering increased the spread of pest fish species.

The mid-Murrumbidgee wetlands are an important tourism and recreation destination for Riverina residents and other visitors. The area includes the Murrumbidgee Valley National Park, state forest and private land, with the Gogeldrie Weir and other sites along the Murrumbidgee used for fishing, boating, camping and waterskiing.

The Leeton Bidgee Classic Fishing Competition has been held for the past eight years along a stretch of the Murrumbidgee River that incorporates part of the mid-Murrumbidgee wetlands. The catch and release competition attracts hundreds of anglers and encourages the catch and release of native species such as Murray cod and golden perch and the capture of carp. Proceeds from the event are used to restock the Murrumbidgee River system with native fingerlings.

In March 2016, 22,000 golden perch fingerlings were released into the Murrumbidgee River by the Leeton Angler's Club, while over the past decade 120,000 Murray cod and 98,000 golden perch have been released. Leeton Shire Council regards this as one of their most important tourism events in terms of flow-on benefits for the local economy.

While fishing isn't the main purpose of prioritising environmental watering in the mid-Murrumbidgee, successful implementation of this priority will support the continuing success of the Leeton Bidgee Classic Fishing Competition by providing flows that deliver increased opportunities for native fish to complete critical stages in their life cycles. Environmental water will also provide increased opportunities for people interested in other recreational and tourism activities in the mid-Murrumbidgee wetlands, such as swimming and boating.

Technical summaries of the specific 2016–17 basin annual environmental watering priorities

Native vegetation

Improve the condition of wetland vegetation communities in the mid-Murrumbidgee wetlands that provide critical habitat for threatened species and communities.

Expected benefits

Delivering environmental water to the mid-Murrumbidgee in 2016–17 in accordance with this priority is expected to:

- avoid damage to the health of water-dependent native vegetation communities by providing opportunities for growth and recruitment
- support watering of adjacent low-lying wetlands promoting mobilisation, transport and dispersal of living organisms and non-living material such as sediment, nutrients and organic matter
- discourage terrestrial vegetation from establishing in the wetlands
- support recovery of native vegetation communities from extended periods of drying
- increase habitat for fish, frogs, birds, turtles and other native animals
- create suitable breeding conditions, generate food and provide access to habitat for the silver perch population in the Murrumbidgee River
- maintain and improve the condition of downstream ecosystems.

Why is this a basin watering priority?

Implementing this priority directly supports achieving the expected environmental outcomes for water-dependent native vegetation, specifically for river red gums and non-woody vegetation, identified in the Basin-wide environmental watering strategy (MDBA 2014).

The mid-Murrumbidgee wetlands support rare and threatened animal species including the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (the EPBC Act) listed endangered trout cod, the vulnerable southern bell frog and numerous bird species. The wetlands also support silver perch (EPBC Act listed as critically endangered) and freshwater catfish which are target species of the strategy because of their declining populations across the basin, mainly from reduced river flows and connectivity. The wetlands also support internationally-listed migratory species such as the cattle egret, eastern great egret, glossy ibis, Latham's snipe and the white-bellied sea-eagle (MDBA 2012).

The mid-Murrumbidgee wetlands are a good example of an inland system of river red gum forest interspersed with ancient channels and oxbow lagoons (Wassen, Wolfenden and Spencer 2014), some of which are listed in the Directory of Important Wetlands of Australia (Environment Australia 2001). These wetlands support ecological processes of the middle and lower reaches of the Murrumbidgee River, by providing an important input of carbon and nutrients to the river. They are also important habitat for fish, frogs, birds, turtles and other native animals.

The wetlands between Wagga Wagga and Carrathool (Figure 2) were listed as a basin annual environmental watering priority in 2013–14, 2014–15 and 2015–16. This priority was not

achieved in any of these years because of a combination of low water availability, difficulty coordinating flows (i.e. dam releases with tributarily inflows) and potential for third-party impacts. There have been a few individual watering actions at selected wetlands but at a system level the condition of native vegetation, particularly semi-aquatic vegetation, in the mid-Murrumbidgee wetlands continues to decline because of a lack of inundation. Given the condition of the vegetation, the wetlands may need to be watered in successive years to enable full recovery.

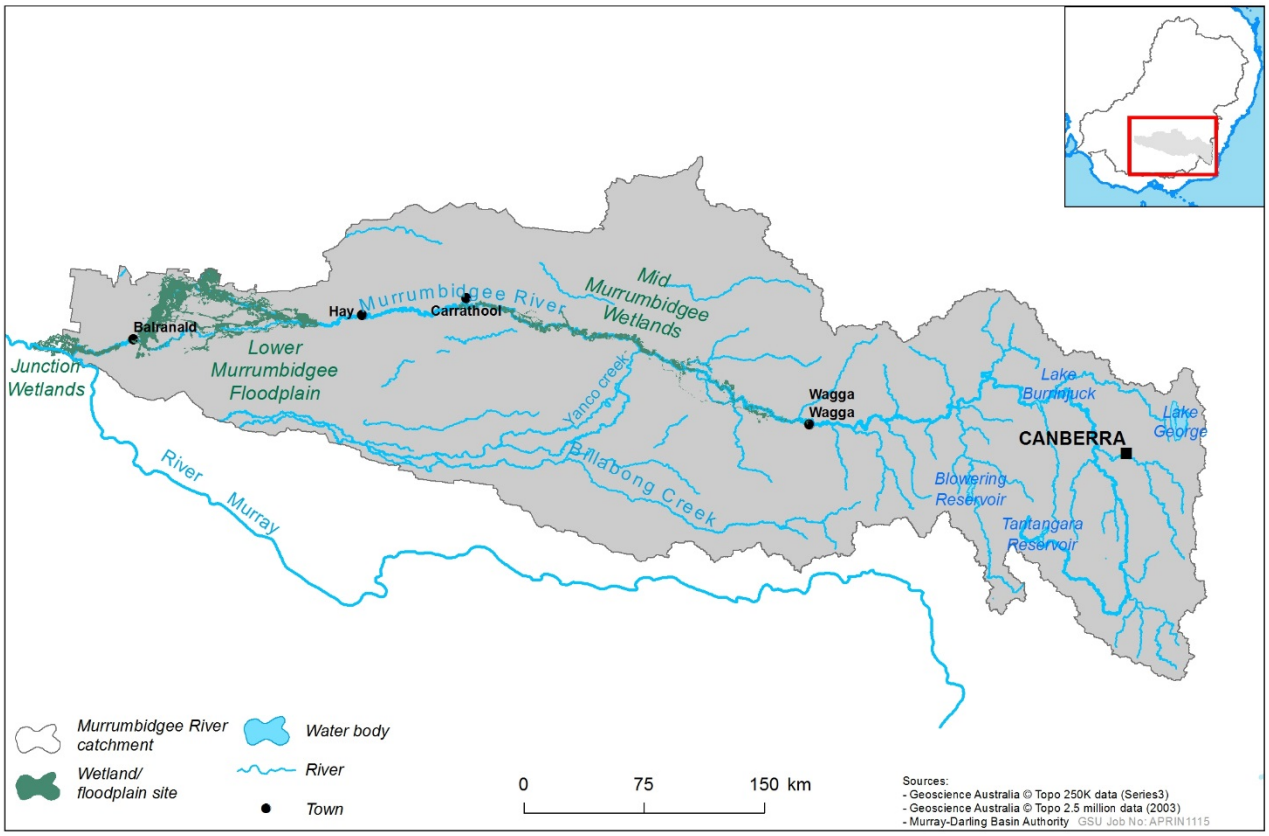

Figure 2: Map of the Murrumbidgee catchment

Implementation

At the time of preparing the priority, the resource availability scenario for 2016–17 is dry for the Murrumbidgee River system, with a potential wetter trend.

Under a dry scenario there are likely to be fewer natural higher flows, which means fewer opportunities to build on a natural flow event to achieve or extend inundation. There will also be reduced water availability, and potentially reduced outlet capacity with lower water levels in Burrinjuck Dam. Should a trigger event not occur in winter or spring (the preferred timing), environmental water managers should consider seeking opportunities later in the season (i.e. autumn) to inundate the mid-Murrumbidgee wetlands. While a flow in autumn may not be ideal, reconnecting the wetlands to the main channel at this time would still be beneficial. If a large natural flow event does not occur, managers should consider building on a smaller natural event or providing a smaller standalone event to help improve conditions of the lower-lying wetlands.

Discussions with environmental water managers suggest that the smaller standalone event is feasible under a dry resource availability scenario.

Should wetter conditions occur (i.e. a moderate to wet scenario) there may be more opportunities to build on larger natural flow events and this will increase the likelihood of achieving this priority. This scenario will also result in increased water availability and greater outlet capacity with higher water levels in Burrinjuck Dam.

There are several constraints to delivering higher managed flows in the Murrumbidgee Valley, such as potential third party impacts. Much work has been undertaken to understand these risks and identify possible mitigation options that could be implemented in the future.

Meeting multiple objectives

In implementing this priority environmental water managers should, where possible, aim to achieve broader outcomes, in particular:

- coordinating flows to the Junction Wetlands
- providing freshes during spring throughout the length of the Murrumbidgee River system to support the implementation of the priorities for silver perch.

The Junction Wetlands are a group of creeks and wetlands on the western side of the Murrumbidgee River at its confluence with the River Murray (Figure 2). Watering of the Junction Wetlands requires concurrent high flows in the Murray (flows of 10,000 ML/day at Barham) and Murrumbidgee (flows of 5,000 ML/day downstream of Balranald weir) rivers (Sinclair Knight Mertz 2011).

The Junction Wetlands, which support a number of rare and threatened species (Sinclair Knight Mertz 2011), have experienced similar conditions to the mid-Murrumbidgee, having undergone a long drying period between 2000 and 2010. While the wetlands and creeks received flows during 2010–12 and smaller selective watering since that time, drying conditions currently prevail and wetland vegetation is in poor health.

The wetland's recovery is expected to take several years. If the River Murray is low and flows are not going to achieve the desired inundation, then water managers should consider directing water to the Lowbidgee floodplain or other assets to maximise outcomes downstream of the mid-Murrumbidgee wetlands.

The mid-Murrumbidgee wetlands priority could also deliver Aboriginal environmental outcomes in line with the themes identified by members of the Murray Lower Darling Rivers Indigenous Nations during discussion in 2016 about integrating Traditional Owners' input into priorities. These include improving habitat and breeding areas for water-dependent species, maintaining connectivity, and maintaining the condition of floodplain vegetation. Complementary social and economic outcomes linked to this priority are outlined in the case study: the mid-Murrumbidgee wetlands.

Improve the health and complexity of waterbird rookery habitat in northern Narran Lakes system.

Expected benefits

Environmental watering of the northern lakes of the Narran Lakes system in 2016–17 in accordance with this priority is expected to:

- improve the health (vigour, structure and floristic diversity) of lignum shrubland used as key breeding habitat by colonial nesting waterbirds
- help maintain the extent of this internationally-recognised habitat
- prime the northern lakes for waterbird breeding when wetter conditions return
- improve habitat conditions for other native water-dependent plant and animal species, some of which have been listed as threatened under state and/or national legislation.

Why is this a basin watering priority?

The Narran Lakes system is a large terminal wetland within the Condamine–Balonne catchment. It lies at the end of the Narran River, which is a distributary of the Balonne River, about 50 km south-west of Lightning Ridge and 50 km east of Brewarrina in north-west New South Wales (Figure 3). The Narran Lakes system covers about 278 km^2 and comprises four distinct structural features — a complex network of river channels (channelised floodplain), floodplain lakes, ephemeral wetlands and a broader floodplain surface (Thoms et al. 2007).

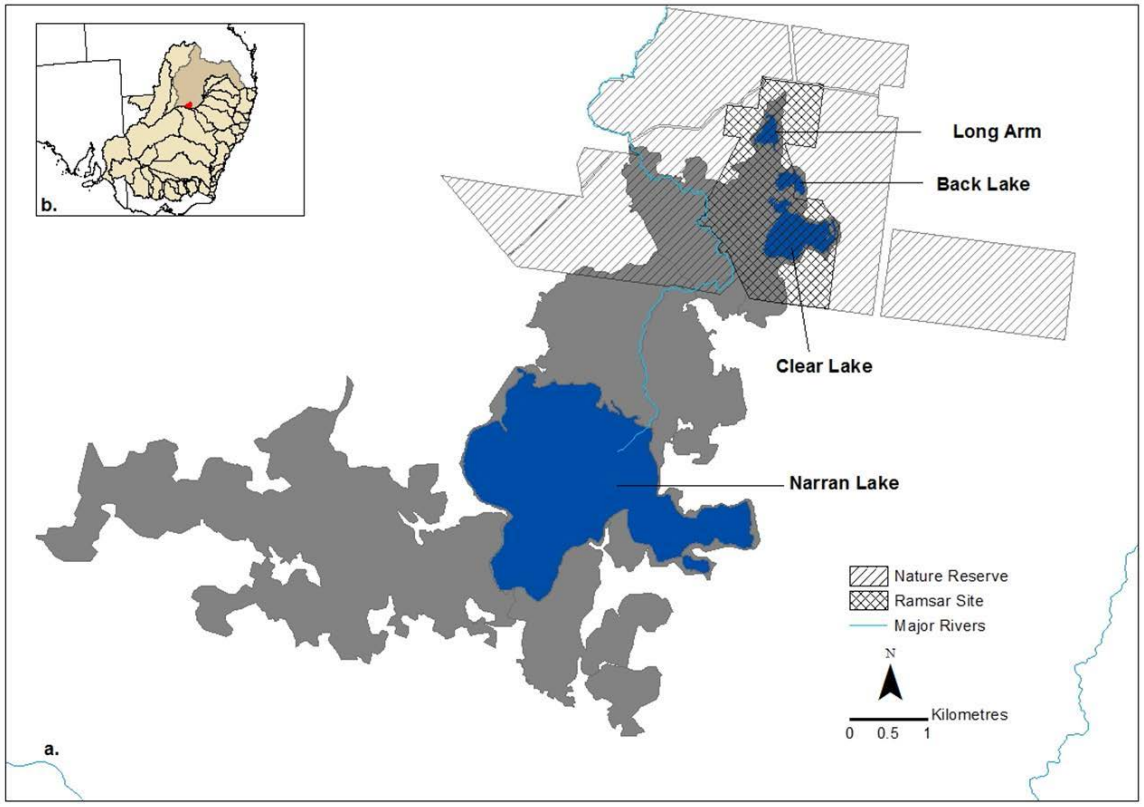

Figure 3: (a) Location of the Narran Lakes system where the Narran River terminates, its lake landforms (Clear Lake, Back Lake, Long Arm and Narran Lake), and the locations of the Narran Lakes Nature Reserve and the Narran Lakes Nature Reserve Ramsar site (b) The lower Condamine–Balonne River catchment of the Murray–Darling Basin (taken from Thomas et al. in prep)

The Narran Lakes system contains four main lakes or water bodies, which are surrounded by a large floodplain. Flows inundating the Narran Lakes system generally fill Clear Lake first and when the lake is at certain levels flows start to fill Back Lake and Long Arm. About 60% of Narran River flows run to the northern lakes while the remaining flows run south to Narran Lake (Thomas et al. in prep).

Work done for the MDBA's Northern Basin Review has characterised the Narran Lakes system into eight hydrological zones (Thomas et al. in prep) (Figure 4) to predict the likely inundated area under a range of inflow volumes measured at the Wilby gauge, about 54 km upstream on the Narran River. This work is improving the information base on the flows needed to maintain and improve the wetland system over time, and has been used to develop this priority.

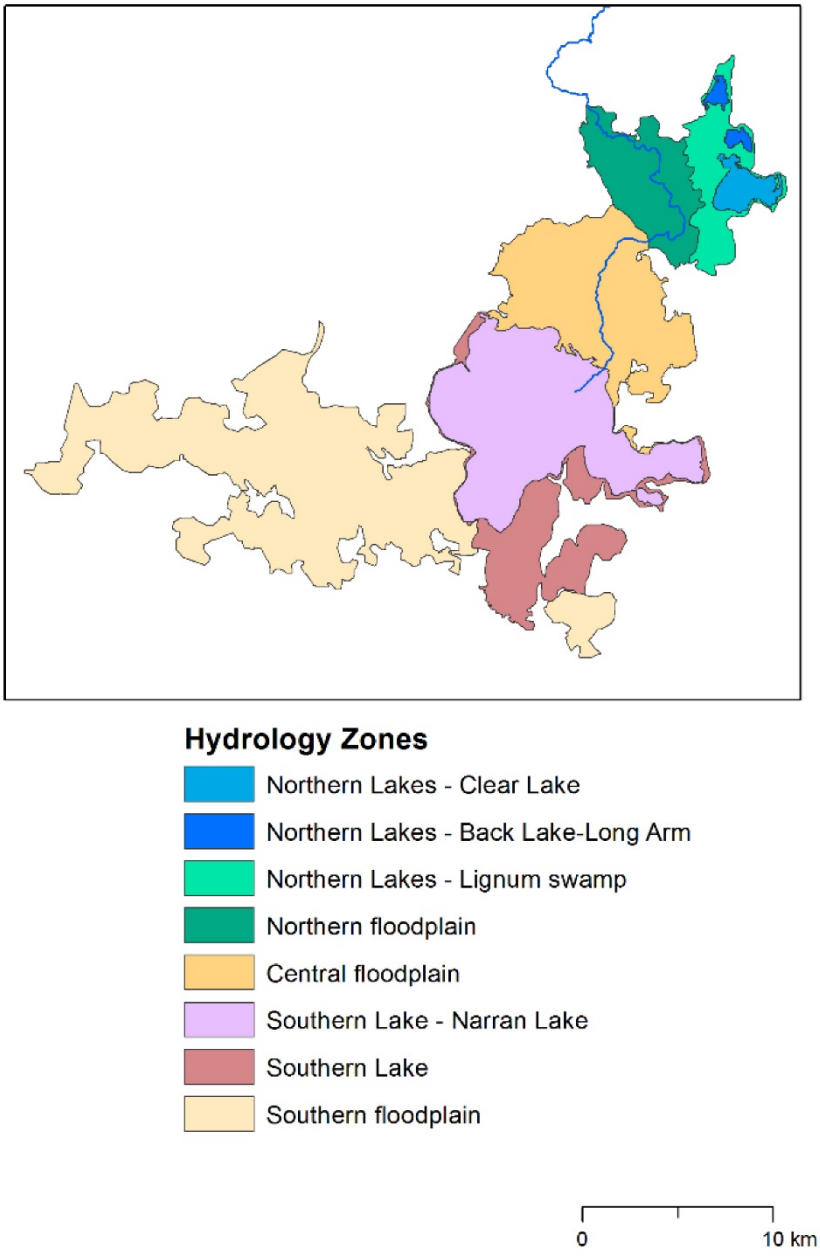

Figure 4: Hydrological zones for the Narran Lakes system (modified from Thomas and Heath 2015)

The Narran Lakes system provides a diversity of important feeding, breeding and rookery habitat for waterbirds, which has been recognised nationally and internationally. The ephemeral and terminal wetland system can provide conditions for large-scale waterbird breeding (Office of Environment and Heritage (NSW) 2011) and has been identified as a particularly important waterbird site within the basin (MDBA 2014). Internationally, this basin-scale priority environmental asset has been recognised as supporting key waterbird breeding (colonial nesters) and foraging (migratory waterbirds and breeding waterbirds) habitat under the Ramsar Convention (Office of Environment and Heritage (NSW) 2011). The Ramsar site is within the Narran Lake Nature Reserve in the northern section of the Narran Lakes system.

The Narran Lakes system is one of the most important sites in the basin for waterbird species richness, number of breeding waterbird species and total number of waterbirds (Porter, Kingsford and Brandis 2015). Narran Lake can retain water for up to two years after flooding (Scott 1997), making the system an important refuge site for waterbirds (Office of Environment and Heritage (NSW) 2011) and other native water-dependent species in drier times.

The relatively small northern lakes part of the Narran Lakes system (which is part of the Narran Lakes Nature Reserve Ramsar site) is particularly important for waterbird breeding because it contains prime nesting vegetation such as vigorous lignum shrubland. This area includes key waterbird rookery sites between Clear Lake and Back Lake.

Vegetation surveys, carried out by the New South Wales Office of Environment and Heritage in late 2015, found floodplain vegetation communities in the northern lakes, including lignum shrubland, contained up to 50% exotic (or invasive native) species, and that there was a reduced number of species and/or reduced structural diversity relative to reference conditions. All vegetation was in moderate condition. The combination of extended dry conditions ─ the northern lakes were last inundated in April–May 2013 ─ and more recently observed browsing pressure, particularly from feral goats, means that the condition of lignum shrubland has further declined.

Maintaining viable waterbird breeding habitat at important sites across the basin is critical. The latest findings of the University of New South Wales' long-term aerial survey of wetland birds in eastern Australia found total waterbird abundance, wetland area, breeding abundance and breeding species richness has continued to decline. The decline in all of these major indices was considerable in 2015, compared to the previous three–five year period, and all four indices were well below long-term averages (Porter, Kingsford and Brandis 2015).

Information from the northern basin review reaffirms earlier work that indicates a 25,000 ML flow over two months at Wilby gauge would inundate the key waterbird rookery habitat being targeted in this priority.

Implementing this priority directly supports achieving the following expected outcomes for water-dependent native vegetation identified in the Basin-wide environmental watering strategy:

- maintain the current extent of extensive lignum shrubland areas within the basin
- by 2024, improve the condition of lignum shrublands.

Implementation

Environmental water in the Lower Balonne is delivered according to rules that control access to unregulated flows. Access rules are complemented by rules in the Queensland resource operations plan that requires the passing of a portion of any inflows into Beardmore Dam during filling periods (termed environmental, stock and domestic releases) and rules that provide a modest reduction in daily extraction limits to certain types of flow events when they have not occurred for specified periods. The 'environmental water' provided under the resource operations plan is essentially the environmental, stock and domestic releases along with the water left in the system (after the access and any flow protection rules are applied). Since water recovery commenced in the Lower Balonne, this existing environmental water is now supplemented by the flows that remain in-stream from the Australian Government's unregulated entitlements.

The Australian Government has significant holdings of unregulated entitlements (un-supplemented water allocations) in the Lower Balonne. As at May 2016 these entitlements totalled around 56 GL in long-term annual average yield. These entitlements contribute to in-stream flows throughout the Lower Balonne distributary system in every unregulated flow event, including along the Narran River. The ongoing 'passive' contribution from these entitlements will provide most of the environmental outcomes in the system.

Additional temporary sources of water and/or active management of flows where appropriate may provide additional capacity to meet this priority.

Extraction remains a risk for environmental watering within the New South Wales managed parts of the catchment which includes the Narran Lakes system.

Coordination between New South Wales, Queensland and Australian Government land and water managers may be needed to support successful implementation of this priority. Coordination would also ensure that another basin annual watering priority for this water year, to maintain riverine waterholes in the Lower Balonne Floodplain, could be implemented in a way that maximises benefits for the Narran Lakes by pre-wetting the system.

Should suitable conditions eventuate during the water year, managers should aim to extend the magnitude and duration of natural flows to sufficiently inundate the northern lakes. Achieving this priority may require interventions that can enable watering.

Prevent further critical deterioration of Moira grass in Barmah–Millewa Forest, subject to resolving natural resource management issues.

Expected benefits

In moderate conditions, delivering environmental water to Barmah–Millewa Moira grass plains in 2016–17 in accordance with this priority is expected to:

- contribute to maintaining the extent and condition of Moira grass by providing an opportunity for growth and recruitment
- provide food and habitat for fish, frogs, birds, turtles and macroinvertebrates
- promote the mobilisation, transport and dispersal of plants and animals, sediment, nutrients and organic matter by delivering water to adjacent low-lying wetlands.

Why is this a basin watering priority?

Barmah–Millewa Forest is located along the River Murray between the towns of Tocumwal, Deniliquin and Echuca (Figure 5). Both forests are listed as internationally significant under the Ramsar Convention, and together are an icon site of The Living Murray program.

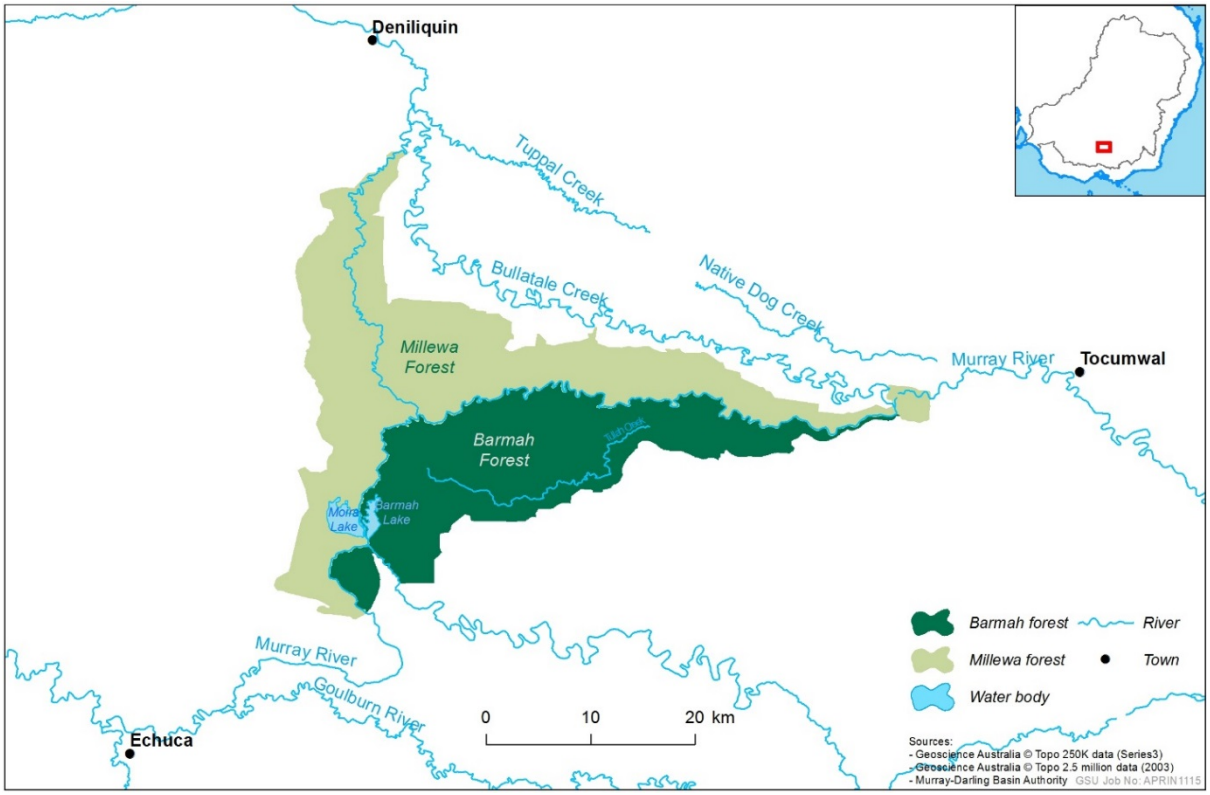

Figure 5: Barmah–Millewa Forest

The floodplain marshes in Barmah–Millewa Forest are recognised as being able to support species listed in bilateral migratory bird agreements with Japan, China and the Republic of Korea as well as the Bonn Convention on Migratory Species.

The forest supports plants and animals listed as threatened under Australian Government and state legislation, and acts as a drought refuge in an otherwise arid to semi-arid region (Colloff et al. 2014; MDBA 2012a).

Moira grass is a rapidly growing, semi-aquatic grass that occurs on wetlands and floodplains. Barmah–Millewa Forest Moira grass plains comprise the largest inland extent of Moira grass in New South Wales and Victoria, and the southern-most extent in Australia (Colloff et al. 2014). The floodplain marshes are one of two critical wetland vegetation categories in the Barmah Forest Ramsar listing (Hale and Butcher 2011).

Around 182 hectares of Moira grass was recorded in the floodplain marshes in Barmah Forest as of early 2014. This is about 12% of the extent at the time of its Ramsar listing in 1982. Only 50.9 hectares (3.5%) of the remaining extent are present as the distinct, continuous monospecific swards that once typified the floodplain marshes, with over half of these present in only one location (Vivian et al. 2015). This decline is considered to indicate a change in ecological character of Barmah Forest (Vivian et al. 2015). The Victorian Auditor-General's Office is undertaking an audit of the management of the 11 Ramsar wetlands in Victoria. The audit, titled 'Meeting Obligations to Protect Ramsar Wetlands', is expected to address the potential change in ecological character of Barmah Forest and is to be tabled in September 2016.

A study by the Murray–Darling Freshwater Research Centre indicates that a persistent and viable seed bank is absent in Barmah Forest. To maintain extensive areas of Moira grass, natural resource managers may need to consider managing the existing stem fragments and rootstock (Durant et al. 2015). This is supported by anecdotal evidence. After a targeted environmental watering in 2013–14 several locations had areas of small dispersed Moira grass plants that were absent before the watering, suggesting viable stolons remain in the sediment (Vivian et al. 2015).

For optimal vegetative growth and flowering, Moira grass requires flooding of at least 0.5 metres from July through to December, followed by a drying period through summer and autumn (Colloff et al. 2014). Improving the condition and range of Moira grass will help potential recruitment and re-establishment, as well as prevent encroachment of species that threaten the range of Moira grass (Mayence et al. 2010).

This priority will contribute to the outcomes outlined in the Basin-wide environmental watering strategy that can be achieved beyond 2019 by maintaining the current extent of non-woody communities near or in wetlands, streams and on low-lying floodplains (MDBA 2014).

Implementation

At the time of preparing this priority, the 2016–17 resource availability scenario for the River Murray is dry. Under this scenario for the River Murray, water delivery could make only a limited contribution towards meeting this priority.

Should the resource availability scenario change to be a moderate scenario water delivery may be able to extend the duration of a natural flooding event. This may allow for environmental watering to be undertaken for longer or for the depth of inundation to align with the optimal conditions for Moira grass growth and flowering.

Any expansion in Moira grass range is likely to take several years because of its depleted range and current condition (Vivian et al. 2015). This will likely be compounded by the depleted viability of its seed bank and ability to disperse. This may increase reliance on resprouting from existing stolons and fragmented rootstock. This means that if environmental watering is to achieve outcomes for Moira grass it will need to occur over a number of years.

There are several constraints that may limit implementation of this priority. There are a number of ongoing natural resource management issues within Barmah Forest, including the presence of feral horses, which need to be resolved to meet this priority. The Goulburn Broken Catchment Management Authority is currently fencing a significant Moira grass-dominated wetland in Barmah Forest to exclude feral animals and is investigating opportunities with research institutes to study feral animal grazing impacts on wetland values.

The findings of the Victorian Auditor-General's Office, and any findings from future studies, are expected to shape future natural resource management decisions within Barmah Forest. Also, high river levels downstream of Yarrawonga Weir can limit access to private property. This restricts the amount of environmental water that can be delivered and when. Any watering decisions to meet this priority will need to consider current constraints and include consultation with relevant stakeholders.

This priority complements the management strategies to achieve connectivity, native fish, waterbird and native vegetation outcomes outlined in the Basin-wide environmental watering strategy, including:

- providing appropriate flow regimes that support the character of water-dependent vegetation on the managed floodplain
- reducing the frequency and length of artificial dry periods
- managing water to the end of a flow event by extending the recession so that a more natural pattern is achieved
- protecting significant waterbird sites
- supporting a network of waterbird sites across the basin
- improving native fish habitat and maintaining drought refuge habitats.

This priority also complements the 2016–17 specific priorities for waterbirds, the protection of threatened native fish species and silver perch. This priority may also deliver Aboriginal environmental outcomes identified by members of the Murray Lower Darling Rivers Indigenous Nations as important to Traditional Owners, including maintaining the condition of native vegetation, improving habitat for water-dependent species, and maintaining connectivity for billabongs, creeks and anabranches.

Waterbirds

Support waterbird populations by watering critical breeding and feeding habitats at the important basin environmental assets for waterbirds, and coordinate watering at ecologically linked systems, particularly at the Macquarie Marshes and Narran Lakes.

Capitalise on opportunities to support waterbird breeding.

Expected benefits

In moderate conditions, delivering environmental water in 2016–17 in accordance with this priority is expected to:

- prevent further decline in waterbird breeding across the basin by supporting critical habitat and providing breeding opportunities at important basin environmental assets for waterbirds
- improve the success of waterbird breeding by ensuring that individual wetlands are managed as part of a broader wetland complex, to lessen the chance of waterbirds leaving breeding sites, as there will be more foraging opportunities in nearby wetlands
- broaden our understanding about how to use environmental water to support, and in exceptional circumstances initiate, waterbird breeding.

Why is this a basin watering priority?

Waterbird breeding

The latest aerial survey of important waterbird sites across the basin, conducted in November 2015, found that the long-term decline in the waterbird population is continuing. Waterbird abundance was the second lowest on record and waterbird breeding the lowest on record (Porter, Kingsford and Brandis 2015; Figures 6 and 7).

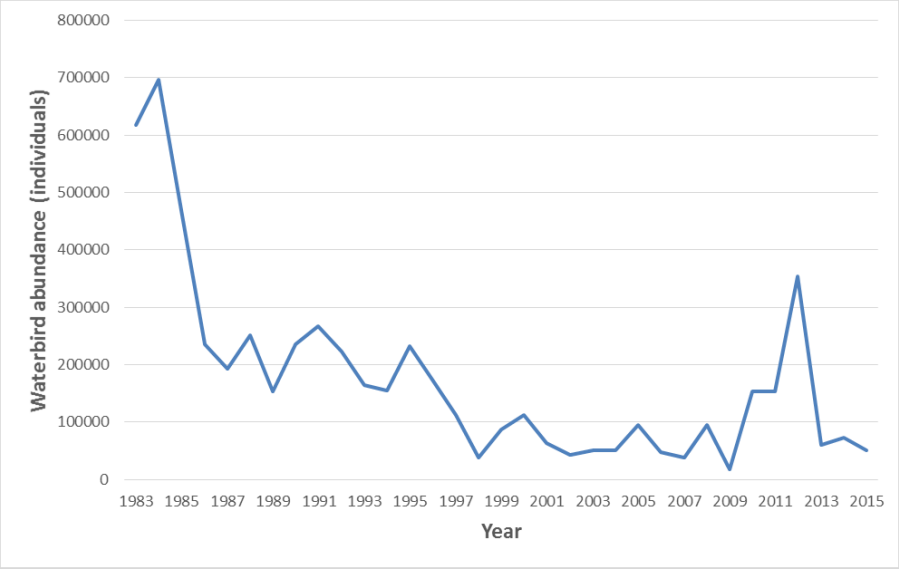

Figure 6: Abundance of all waterbirds in the Murray–Darling Basin (surveyed during annual aerial waterbird surveys of eastern Australia 1983–2015. Survey bands cover about 13.5% of the land area of the Murray–Darling Basin)

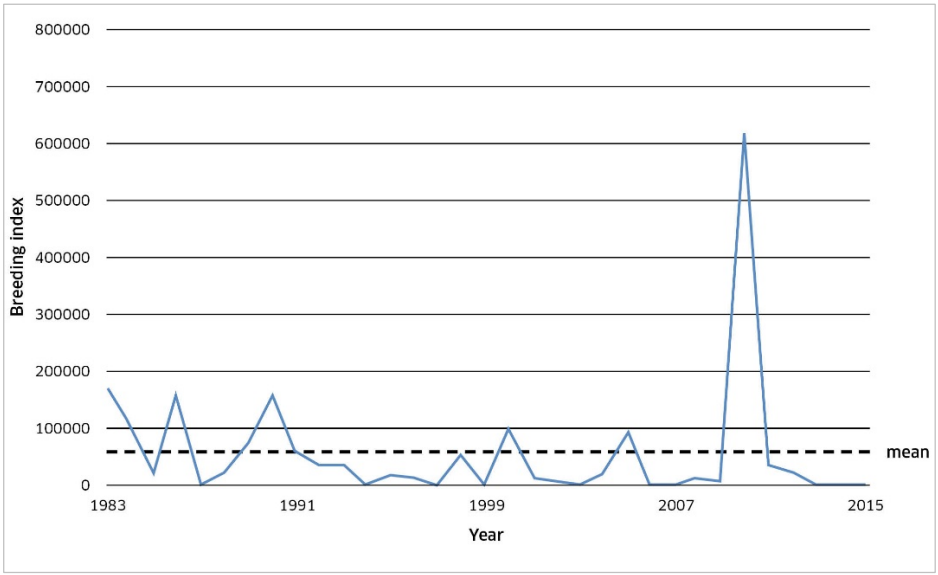

Figure 7: Breeding index of all waterbirds in the Murray–Darling Basin

One of the environmental watering plan's management principles is to apply adaptive management in the planning, prioritisation and use of environmental water (Section 8.40 of the Basin Plan). We need to respond adaptively to this information on the basin's waterbird population, and to the extent possible, use environmental water to address the critical shortage of waterbird breeding.

Over the long term the MDBA expects to see an improvement in waterbird breeding in the order of 30–40% over the baseline scenario (Appendix 2) and a 50% increase in events for colonial nesting waterbirds. These targets apply after 2024 but a significant improvement in waterbird breeding will be needed over the next decade to achieve them.

Supporting waterbird populations by watering critical breeding and feeding habitat, and capitalising on opportunities to support breeding, will address these breeding targets, as well as lead to an overall increase in waterbird abundance. In most circumstances, the preferred management approach is to provide environmental water to support naturally triggered waterbird breeding. In exceptional circumstances, however, it may be appropriate to use environmental water to both initiate and support waterbird breeding (refer O'Connor and Ward 2003).

Coordinated watering at ecologically-linked systems

Many waterbirds are nomadic and can travel large distances between wetlands in the Murray–Darling Basin (Brandis and Bino 2015). Colonial waterbird species in particular congregate for breeding, and when breeding is complete they disperse in small groups. Their movements before, during and after breeding suggest that they forage in wetlands in and next to the breeding site. Given these aspects of waterbird ecology, coordinated management of flows to wetlands has the potential to significantly increase the waterbird population.

As our understanding of the ecology of waterbirds increases, water managers are considering how to manage wetlands in and between catchments to provide improved habitat and foraging opportunities for waterbirds just before and during breeding. This thinking has been most evident in the northern basin, where there is growing evidence that the Narran Lakes (Condamine–Balonne catchment), Macquarie Marshes (Macquarie catchment) and Gwydir wetlands (Gwydir catchment) operate as a linked system (Figure 8).

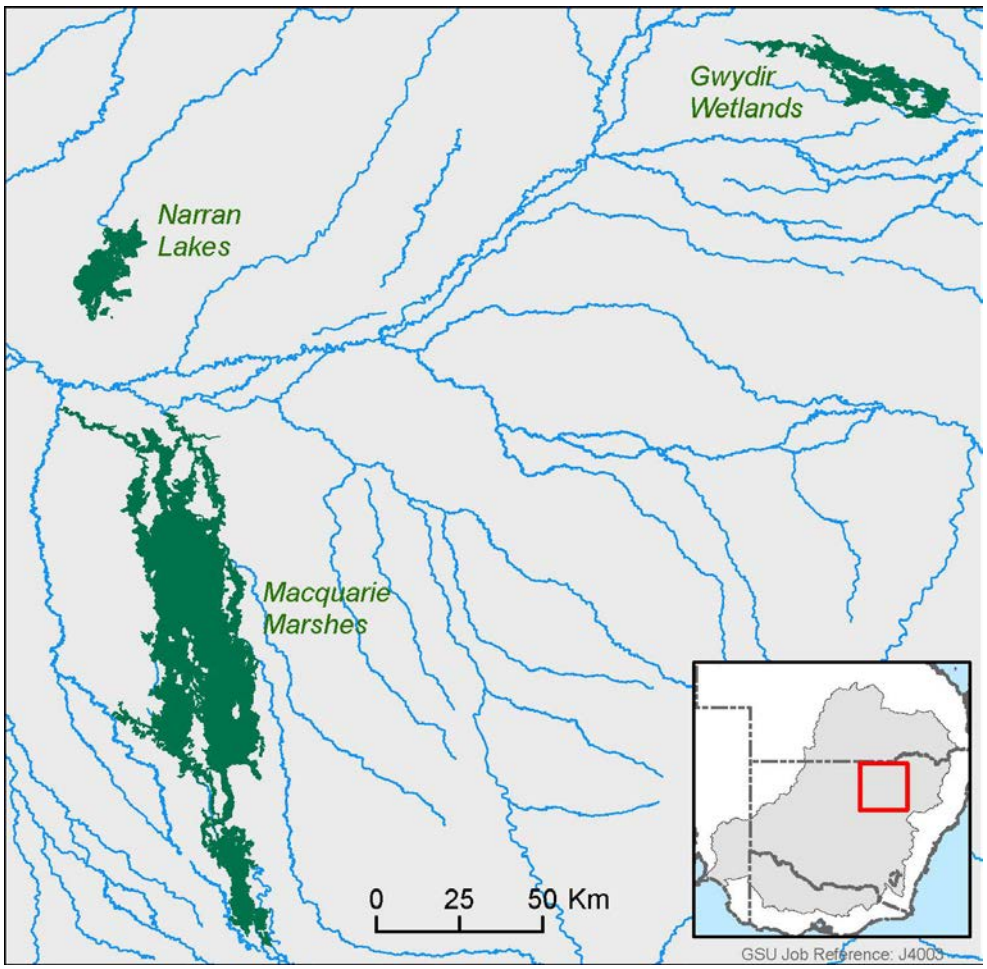

Figure 8: Location map of the Gwydir Wetlands, Narran Lakes and Macquarie Marshes

One role of basin annual environmental watering priorities is to identify priority environmental assets and priority ecosystem functions where the environmental watering during the period will require complex arrangements (Section 8.28b). Two such environmental assets are the Macquarie Marshes and Narran Lakes. They are of basin significance for waterbirds and will benefit from adopting a new management approach, as outlined in this priority.

Implementing this priority directly supports achieving the following expected outcomes for waterbirds identified in the Basin-wide environmental watering strategy:

- breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario
- breeding abundance (nests and broods) for all other functional groups to increase by 30–40% compared to the baseline scenario.

This priority complements the 2016–17 specific priorities for Moira grass in Barmah–Millewa Forest (because the same environmental water may achieve both priorities), and for the waterbird rookery habitat in the northern Narran Lakes system (as improving the condition of rookery habitat will prime the system for future breeding).

Improving habitat and breeding area for waterbirds was one of the themes that members of the Murray Lower Darling Rivers Indigenous Nations identified as needing environmental watering in

the southern basin. Environmental watering in line with this priority would be able to deliver Aboriginal environmental outcomes.

Implementation

Waterbird breeding

Critical breeding and feeding habitats should be a target of environmental watering in 2016–17, where there is enough environmental water. Such situations may emerge where there is held environmental water in storage; where water trading can be used to augment environmental water or protect it on route; or because moderate conditions emerge, providing better conditions to support waterbird breeding at important waterbird sites; or a combination of all three.

Waterbird breeding is not expected to be common during a dry scenario and this priority is mostly appropriate to a moderate scenario. Nonetheless, waterbirds have bred in the Murray–Daring Basin every year since 1983, including during the millennium drought. In 2015–16, waterbirds bred in Barmah–Millewa Forest (Australasian and little bitterns, black swans, little pied cormorants, eastern great egrets, white ibis, straw-necked ibis and royal spoonbills) and the Coorong, Lower Lakes and Murray Mouth (black swans, pied cormorants, straw-necked ibis, spoonbills and white ibis). These breeding events were created or supported by environmental water. It may be feasible to support waterbird breeding at a small number of basin significant sites in 2016–17.

Predicting where waterbird breeding is likely to occur is difficult, as breeding often relies on biological cues, such as local rainfall or particular flows that initiate waterbird breeding (often larger and longer duration flows). In the northern basin, breeding colonies tend to be larger and therefore difficult to start with environmental water alone; while in the southern basin, the colonies tend to be smaller, and environmental watering can initiate and sustain breeding.

We have highlighted important basin environmental assets for waterbirds where there could be sufficient environmental water (Table 1) to support waterbird outcomes in 2016–17. In the southern basin, Barmah–Millewa forest, Gunbower–Koondrook–Perricoota Forest, Lindsay–Walpolla Islands and Chowilla Floodplain have potential in a moderate scenario. In the Murrumbidgee catchment, the Lowbidgee floodplain has potential, if naturally triggered. Other wetlands, such as Fivebough Swamp, may be watered to provide habitat and food for waterbirds.

Breeding habitat can also be provided for in agricultural landscapes. For instance, the endangered Australasian bittern uses rice crops in the New South Wales Riverina for breeding and foraging.

Implementing this priority will not be easy, as using environmental water to encourage waterbirds to breed is proving difficult. For example, in 2014 and 2015 environmental water was provided to support ibis breeding in Murrumbidgil Swamp in the Lachlan, without success. On both occasions the water level was right for ibis breeding, but after promising signs (such as trampling) the birds moved on. The possible reasons for these difficulties are that the birds did not have sufficient bodyweight to breed, or that there was limited foraging opportunity as the surrounding landscape was dry. Further research is needed to determine the most likely reason.

Table 1: Important basin environmental assets for waterbirds and their capacity to support waterbird breeding in 2016–17[1]

Environmental asset	Water resource plan area	Capacity of environmental water to support waterbird outcomes in 2016–17
Currawinya Lakes	Warrego–Paroo–Nebine	Limited (little active management possible, depends on flow event management rules and complementary actions)
Narran lakes	Intersecting streams	Limited (as above)
Cuttaburra channels	Intersecting streams	Limited (as above)
Paroo overflow lakes	Intersecting streams	Limited (as above)
Yantabulla	Intersecting streams	Limited (as above)
Upper Darling River	Barwon–Darling watercourse	Unknown
Gwydir Wetlands	Gwydir	Limited (no proactive watering unless substantial rainfall occurs)
Macquarie Marshes	Macquarie–Castlereagh	Limited (no watering planned)
Booligal Wetlands	Lachlan	Some Support colonial waterbird breeding if naturally triggered
Great Cumbung Swamp	Lachlan	Limited (no watering planned)
Lake Brewster	Lachlan	Limited (no watering planned)
Lake Cowal	Lachlan	Limited (no watering planned)
Fivebough Swamp	Murrumbidgee	Some Provide habitat and food for waterbirds
Lowbidgee floodplain	Murrumbidgee	Some Support colonial waterbird breeding if naturally triggered
Gunbower–Koondrook–Perricoota Forest	NSW Murray and lower Darling	Some Provide suitable habitat for waterbirds (feeding and refuge)
Kerang Wetlands	Victorian Murray	Some current capacity Provide suitable habitat for waterbirds (feeding and refuge) Provide breeding habitat for waterbirds

[1] This table has been prepared in consultation with managers of environmental assets and basin states, including information in the basin states' annual priorities.

Environmental asset	Water resource plan area	Capacity of environmental water to support waterbird outcomes in 2016–17
Menindee lakes	NSW Murray and lower Darling	Unknown
River Murray and Euston Lakes	NSW Murray and lower Darling	Limited
Talywalka system	NSW Murray and lower Darling	Limited
Darling anabranch	NSW Murray and Lower Darling	Limited
Lindsay–Walpolla Islands and Chowilla Floodplain	NSW Murray and lower Darling/ Victorian Murray/ SA River Murray	Some Provide breeding habitat for waterbirds
Barmah–Millewa Forest	NSW Murray and lower Darling/ Victorian Murray	Some Initiate and sustain a targeted waterbird breeding event (colonial species and bitterns)
Kiewa River	Victorian Murray	Limited (unregulated system)
Corop Wetlands	Northern Victoria	Limited (not managed with environmental water)
Winton Wetlands	Northern Victoria	Limited (unregulated system)
Waranga basin	Northern Victoria	Limited (not managed with environmental water)
Noora evaporation basin	South Australian Murray Region	Limited
Pyap Lagoon	South Australian River Murray	Limited
Hattah Lakes	Wimmera–mallee	Some
Lake Albacutya	Wimmera–mallee	Limited (unregulated system)
Lake Buloke	Wimmera–mallee	Limited (unregulated system)
Lake Hindmarsh	Wimmera–mallee	Limited (unregulated system)
Coorong, Lower Lakes and Murray Mouth	SA River Murray/ SA Murray region/ eastern Mount Lofty Ranges	Limited

The Basin wide environmental watering strategy advocates water management strategies for waterbirds, including:

- creating and maintaining lateral connectivity, by increasing bankfull and, where possible, overbank events, extending flow duration, and protecting flow peaks by limiting extraction
- supporting breeding events by responding to natural cues and ensuring that environmental water is provided at seasonally-appropriate times.

Additionally, there are a range of strategies that could facilitate outcomes, including:

- providing additional water to breeding locations to support enough foraging habitat for successful breeding
- prioritising sites that had some inundation in 2015–16. As waterbirds tend to take about a year to respond to conditions, sites that were inundated in 2015–16 may provide the best opportunities for waterbirds
- hold environmental water as a contingency to support waterbird breeding, noting this may mean forgoing other opportunities
- providing larger, long-duration flows for successful breeding, where possible
- being ready to purchase water in cases where more water is needed to sustain a breeding event, so that if this response is needed it can be implemented rapidly.

The appropriateness of these strategies is for environmental water holders and managers to decide, and should be considered within and across catchments.

Coordinated watering at ecologically-linked systems

The northern basin contains three significant colonial waterbird breeding sites; the Narran Lakes, Gwydir Wetlands, and Macquarie Marshes. They provide some of the most important breeding habitat for large-scale colonial waterbird breeding within the Murray–Darling Basin (Bino et al. 2014).

The three wetlands are not linked hydrologically, as they are fed by different rivers/catchments and varying climatic systems. However their geographical proximity and potential to support major waterbird breeding events suggests a strong ecological connection.

As mentioned in the Basin environmental watering outlook for 2016–17, the MDBA commissioned analysis of the data on waterbird breeding at these wetlands for evidence of a regional population (Brandis and Bino 2016; Figure 9). The analysis found that when considering the population structure of total waterbird breeding abundance, strong support was given to the existence of two sub-populations: the Macquarie Marshes and Narran Lakes as one, and the Gwydir Wetlands as the second (Brandis and Bino 2016).

Breeding events occurred in the Macquarie Marshes and Narran Lakes concurrently more often than they occurred at the Gwydir Wetlands and Macquarie Marshes. However, the analysis found some co-occurrence when the Gwydir Wetlands and Narran Lakes were paired (especially for large waders). These results indicate there is some relationship between the three sites and that they may be operating collectively to support a regional waterbird population. There is merit in managing the wetlands of Narran Lakes and the Macquarie Marshes, and to a lesser degree, the Gwydir Wetlands collectively to improve breeding opportunities and to support a sustainable waterbird population. For the complete analysis, see Brandis and Bino 2016.

The finding that there is a regional population operating between the Narran Lakes and Macquarie Marshes, and for some waterbird functional groups, involving the Gwydir Wetlands, is relevant to how these systems are managed, including for environmental watering.

Narran Lakes and the Macquarie Marshes are about 70 km apart, which means that waterbirds are able to fly between the sites, when breeding or when foraging. When planning for waterbird outcomes, it may be advisable to:

- treat the Macquarie Marshes and Narran Lakes as a linked wetland complex, especially when considering the ideal frequency of breeding events or examining management triggers, such as maximum dry period between inundation of these wetlands
- note that there needs to be a certain number of breeding events across both sites to maintain and/or improve the regional population. If there are no events at any of these sites, a management response becomes a high priority. Waterbird breeding was last recorded at Narran Lakes in 2012, and in the Macquarie Marshes in 2011 (Figure 9)
- create pre-breeding habitat requirements in the lead up the breeding event. Before laying eggs, waterbirds need time to build up body condition (Briggs and Thornton 1998)
- use linked wetlands as a contributor to food resources during breeding. Food availability is a key driver of successful waterbird breeding; adequate food is needed throughout the breeding event to support both adult and juvenile birds.

The MDBA notes that these findings require further discussion with site managers to better understand the implications for management. Also, further research is needed on waterbird movement, the quality of nesting habitat and the supply of food resources before and during breeding.

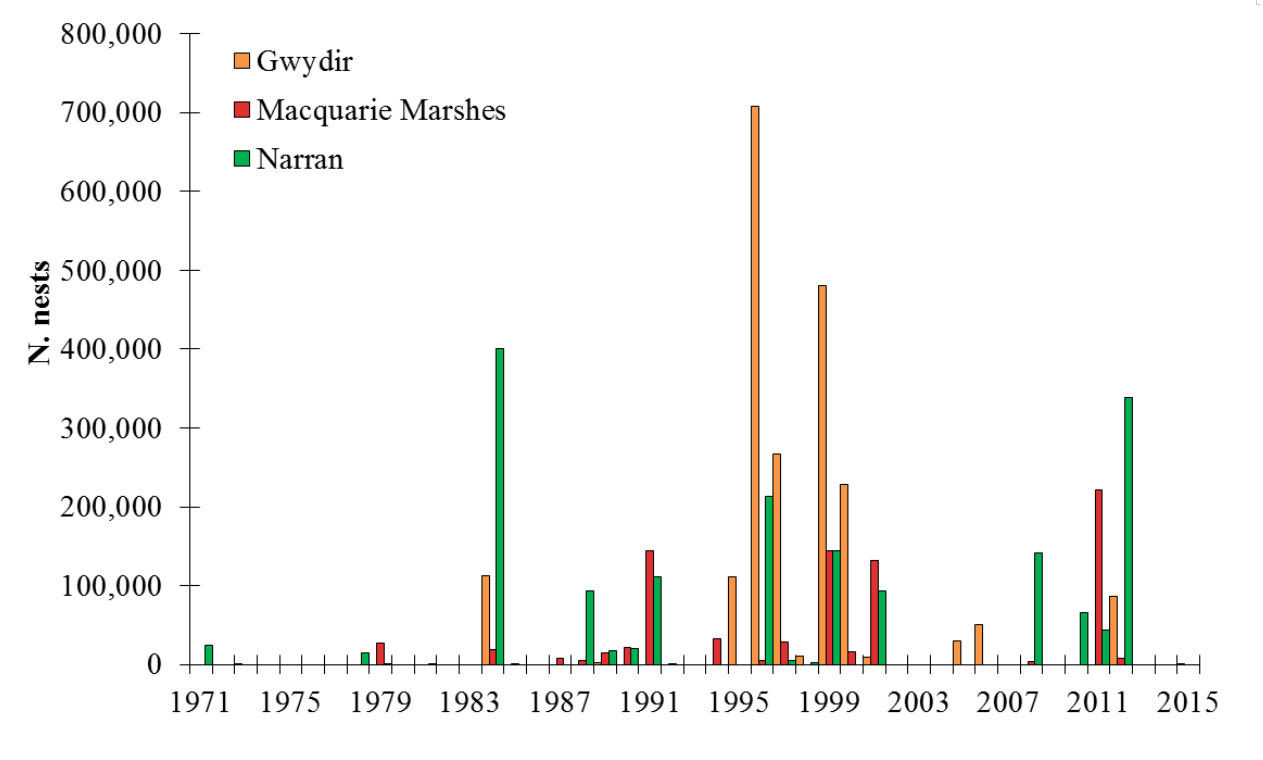

Figure 9: Records of breeding 1971–2015 (top y-axis: ln(y+1), bottom y-axis: y) for Gwydir Wetlands, Macquarie Marshes and Narran Lakes.

Native fish

Contribute to the long-term recovery of silver perch by improving existing populations and enhancing conditions for recruitment and dispersal to and from suitable habitat.

Support viable populations of threatened native fish by protecting drought refuges and maintaining in-stream habitats and essential functions.

Maximise opportunities for range expansion and the establishment of new populations of silver perch and other threatened fish, as conditions allow.

Expected benefits

Under dry conditions, managing and delivering environmental water in accordance with the 2016–17 priority is expected to:

- support the recovery of silver perch in the mid-River Murray region
- boost silver perch numbers in tributaries and anabranches in the lower and mid-Murray
- maintain viable populations of silver perch more broadly across the basin
- maintain important refuge habitats to increase the resilience of threatened fish populations and prevent major population loss
- maintain in-stream habitat to sustain and promote recovery of threatened species
- increase successful recruitment of threatened species by mitigating unnaturally large and rapid variations in depth and discharge
- limit catastrophic fish losses in the lower Darling River.

Additional benefits under more moderate conditions in 2016–17 include:

- support the recovery of silver perch across the Murray–Darling Basin
- improve recruitment outcomes for threatened fish populations
- increase the area occupied by threatened species by expanding existing populations and the establishment of new populations.

Why is this a basin watering priority?

Native fish play an important role in freshwater ecosystems and are a vital part of food webs — both as a consumer and as a source of food for other animals. Native fish are also highly valued by people. Fish have totemic and cultural values for Aboriginal communities and are a valuable economic and social resource for the Murray–Darling Basin, particularly recreational fishing. All of these values depend upon healthy native fish populations.

Silver perch is a highly mobile species endemic to the basin, recruiting and dispersing over hundreds to thousands of interconnected river kilometres. It was once a common recreational species and widely distributed but severe declines led, in 2013, to the species being listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth). Coordinated, multi-jurisdictional cooperation is needed to manage flows across the large spatial scales to which this species responds.

Actions that benefit silver perch are also likely to benefit other native fish species with similar life-history requirements, such as golden perch. The MDBA listed silver perch as a basin environmental watering priority in 2015–16, noting that actions over several years would be

needed to achieve significant outcomes. Managing and delivering environmental water in 2016–17 will continue to contribute to the recovery of silver perch in the Murray–Darling Basin.

More broadly, the conservation status of native freshwater fish in the Murray–Darling Basin is of concern, with almost half the species listed under national, state or territory threatened species legislation. Many of these threatened fish are priority species in the Basin-wide environmental watering strategy (MDBA 2014).

In the long term, the environmental watering strategy expects to achieve a diverse native fish community with sustainable populations occupying a greater proportion of their historic distribution than they do now. Current basin populations are vital source stocks that must be sustained if species are to have a long-term future in the basin.

In 2016–17, this priority will contribute to improved recruitment and distribution for a number of threatened fish listed in the strategy, including silver perch. It will help to ensure another key objective of the environmental watering strategy is met — 'no loss of native species currently present within the basin'. This priority will also directly contribute to achieving other strategy objectives of improved population structure of key species and, under moderate conditions, expanded distributions of key species in the northern and southern basin.

Improving conditions for native fish was also one of the strongest themes to emerge from feedback from members of the Murray Lower Darling Rivers Indigenous Nations on the places, species and ecological functions that need watering in the southern basin. Environmental watering in line with this priority could deliver Aboriginal environmental outcomes, particularly in relation to improving habitat, breeding and movement of native fish.

Improved water management is a key action that will contribute to the recovery of threatened native fish species. Effective management of all water has a major role in the recovery of these species. Environmental water is particularly important in supplying water to sustain remnant habitats and allowing fish to feed and to breed. It can also be used to reconnect isolated populations and increase the area that threatened species occupy, reducing the risk of extinction.

Positive outcomes can be achieved for silver perch and other threatened fish in 2016–17 under dry to moderate conditions. Under dry conditions, the focus will be on actions that protect drought refuges and in-stream habitats by providing in-channel flow variability and maintaining river connectivity. Flows can also help ensure that essential functions for populations can be met, such as providing food and some breeding opportunities (particularly for short-lived species), as well as allowing localised dispersal.

Should conditions improve, there will be opportunities to achieve more significant outcomes for silver perch and other threatened fish in addition to those identified for dry conditions.

Moderate conditions can enable multiple actions to be taken for a greater range of species and sites, including providing suitable flow conditions for expanding species' range and establishing new populations.

These native fish priorities also complement the 2016–17 specific priorities for waterholes in the Lower Balonne Floodplain, the Coorong and Murray Mouth, and the mid-Murrumbidgee Wetlands.

Implementation in dry conditions

Actions in 2016–17 for silver perch are to:

- enhance drought refuges and in-stream habitats to maintain viable populations
- maximise recruitment and dispersal of the mid-Murray population
- maintain and improve existing populations throughout the basin
- improve hydrodynamic diversity in the lower Murray.

Actions in 2016–17 for threatened fish more broadly are to:

- enhance drought refuges and in-stream habitats to maintain viable populations
- increase successful recruitment of threatened species by mitigating unnaturally large or rapid variations in water depth
- minimise adverse impacts on fish communities in the lower Darling River from critically low water levels.

Enhance drought refuges and in-stream habitats to maintain viable silver perch and threatened fish populations

The long-term survival of native fish species depends on fish being able to access suitable refuge sites during dry times. Refuge sites with surviving populations are the key sources for recolonising waterways when conditions and connectivity improve. Ideally, refuge sites form a network across the landscape and maintain good water quality during dry phases. Where dry phases span multiple years, flows that connect and replenish are needed to maintain suitable water quality and habitat, particularly aquatic and emergent vegetation.

Connection between the main stem of the River Murray with tributaries and off-channel habitats, such as lakes, billabongs and lagoons, provides conditions important in the life-cycle of small and large-bodied threatened fish species. Changes to the natural flows have led to regular periods of low flows and disconnection of these habitats, causing spawning and recruitment failures for many species. Connectivity is needed between refuges, and between main river channels and off-channel systems to maintain a range of habitats, and for native fish to disperse and recolonise.

For silver perch, a key action under dry conditions is to support survival of a recent conservation stocking in the Namoi. Around 50,000 silver perch were introduced into the Namoi River in 2016 between Gunnedah and Narrabri. This is the first event in a five-year program to re-establish this species within its former range in this region.

To increase the potential of silver perch to establish a self-sustaining population in this region, suitable flow regimes, including those that protect and maintain refuge pools, are needed. Water management should aim to provide enough water supply and flow regimes to maximise survival, growth and future recruitment needs of this population. These flow regimes are also likely to benefit other aquatic communities and values.

For other threatened fish, actions under dry conditions focus on securing water supply to protect and maintain key populations at discrete sites. Short-lived species are particularly vulnerable because of their short lifespans and need for regular (in some cases annual) spawning and recruitment. They remain a high priority for environmental watering actions in 2016–17.

Examples where flows can maintain drought refuges and suitable in-stream habitats for threatened species are:

- olive perchlet in the Lake Brewster region of the Lachlan catchment, where environmental water can help maintain habitat, particularly macrophyte persistence
- northern basin olive perchlet populations, including those in the Border Rivers, Bogan River, and the recently detected population in the Gwydir Valley
- purple-spotted gudgeon populations in the Border Rivers and the lower Murray, particularly to provide suitable conditions for macrophytes and to ensure that refuges are available during dry conditions
- key Murray hardyhead sites in South Australia, Victoria and New South Wales
- anabranch and tributary habitats in the lower Murray, such as the Lindsay–Mullaroo system, where flows that connect to the main stem of the Murray will benefit freshwater catfish
- freshwater catfish habitats in the lower Gwydir Valley to improve maintenance, recruitment and distribution of new populations.

Maximising recruitment and dispersal of the mid-Murray silver perch population

The uninterrupted, flowing-water habitats between Yarrawonga Weir (on Lake Mulwala) and Euston Weir support the largest self-sustaining populations of silver perch in the Murray–Darling Basin (Figure 10).

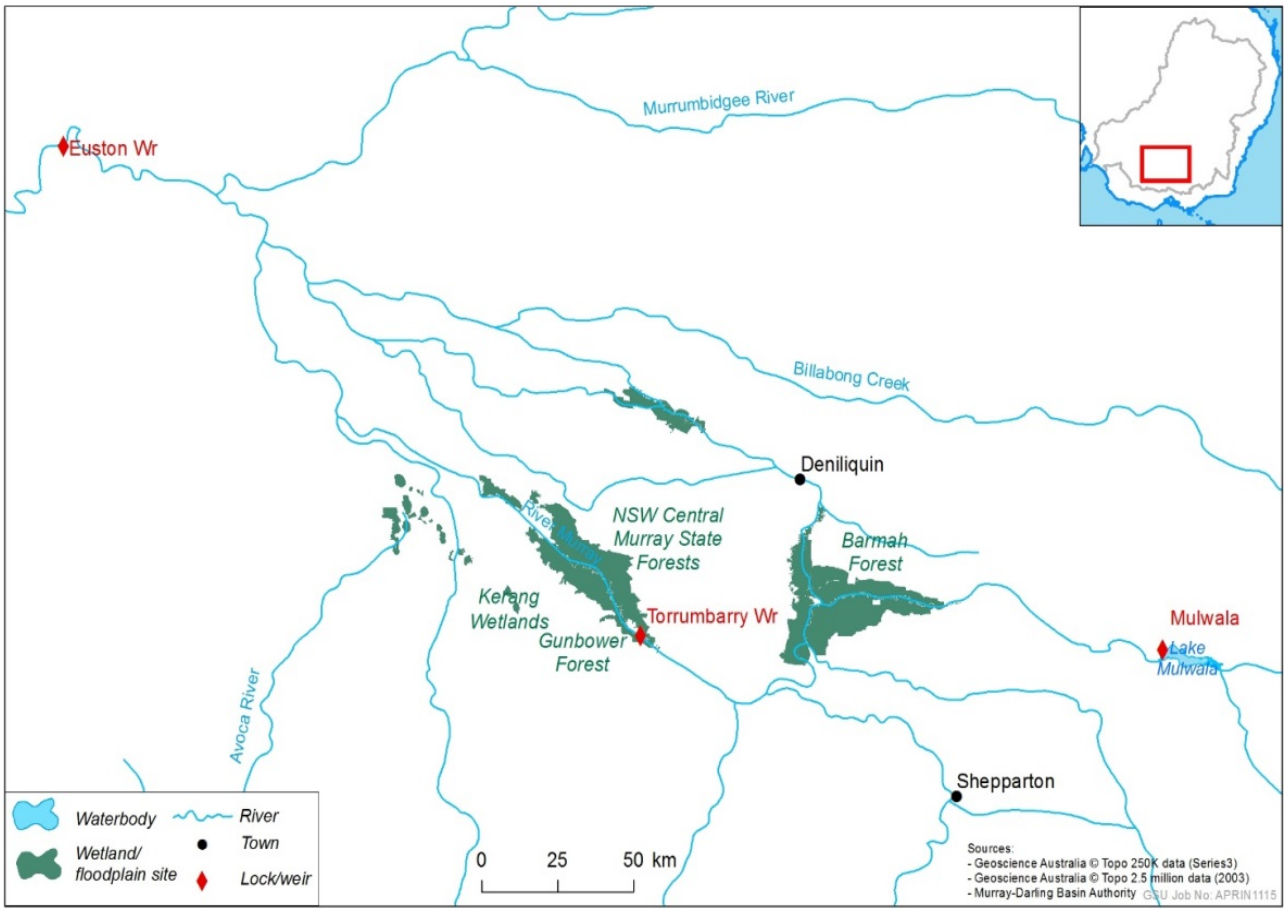

Figure 10: The mid-Murray region

Silver perch populations in the mid-Murray main channel can contribute to broader population recovery in connected tributaries and anabranches and into the lower Murray. Therefore, maximising silver perch populations in the mid-Murray region remains a focus for the recovery of this species in the Murray–Darling Basin.

Environmental water, consumptive water, unregulated and managed water in the southern-connected system all need to be coordinated across jurisdictions so that population dynamics and abundance of silver perch are improved in the mid-Murray region. Passive drift of eggs and larvae and active movement and dispersal of both adults and juveniles are essential flow-driven population dynamics in this system.

Silver perch in the mid-Murray need annual in-channel flow rises in spring/early summer (from October into January). Ideally in-channel flows should reach bankfull, or at least >70% bankfull, with some variation in depth (e.g. a rise of 0.15 metres).This annual in-channel flow:

- triggers adult movement and stimulates spawning
- promotes the dispersal and recruitment of drifting eggs and larvae resulting from spawning events
- triggers mass juvenile migrations of silver perch

These actions can be implemented under dry conditions by using environmental water in conjunction with water on route to consumptive uses.

Environmental watering in 2014–15 and 2015–16 in the River Murray provided suitable flow triggers for silver perch. Monitoring detected silver perch spawning responses from both events and a strong class of year-old silver perch from the 2014–15 watering, are now present in the mid-Murray region. Fisheries scientists undertaking monitoring and research in Barmah Forest and Edward–Wakool detected these young perch in 2016 and observed large numbers of silver perch migrating through the Torrumbarry fishway.

Silver perch populations in the mid-Murray main channel can contribute to broader population recovery by enhancing dispersal into connected tributaries and anabranches (and their subsequent return to the main channel). Flows that provide connectivity and migratory cues to attract silver perch, particularly juveniles, into these rivers can boost local population numbers and benefit silver perch populations at the basin scale. Even small daily variations in flow (e.g. a change in river height of 8–15 cm) can trigger juvenile migrations.

Flows within perennial and intermittent tributaries and anabranches are important to improve growth, condition and survival of young silver perch and any resident adult fish. Flows can stimulate food production (productivity) and allow access throughout the year to productive and complex habitat (i.e. submerged snags and healthy aquatic and riparian vegetation). In particular systems, maintaining sufficient water levels in winter is crucial for silver perch to survive. Connectivity and flow variability will also ensure maturing silver perch can return to the main channel system for breeding when conditions improve.

Rivers permanently connected to the mid-Murray offer the greatest opportunities under dry conditions for silver perch to boost tributary and anabranch populations. The Little Murray, Edward–Wakool and the Goulburn are river systems where fish from the mid-Murray population could re-colonise and expand the current range of silver perch.

Gunbower Creek is another opportunity in future years that could contribute similar outcomes for silver perch when fishways are completed in 2018. Rivers intermittently connected to the mid-Murray (e.g. Victorian tributaries like the Campaspe River) also provide opportunities for recolonisation and boosting silver perch numbers in tributaries. Such opportunities may arise under dry conditions but connection to intermittently connected systems is more likely under moderate conditions.

The Little Murray–Lake Boga region also provides an opportunity to enhance silver perch outcomes. Lake Boga currently supports good numbers of silver perch that can be sustained by maintaining adequate water levels in the 2016–17 year. Over time, with the anticipated completion of fishways and changes to operations, the Little Murray can become a flowing anabranch connected to the Murray. These systems can all be linked with flows that connect Lake Boga to the mid-Murray (via the Little Murray), potentially allowing this region to function as a key nursery habitat for mid-Murray silver perch into the future.

Maintain and improve existing populations of silver perch throughout the basin

Silver perch occur in many parts of the basin, the mid-Murray population being the largest. However, these populations are now separated from each other by barriers and other impacts of river regulation. The long-term aim is to allow more populations in the basin to reconnect under suitable conditions. In the interim, actions that maintain and improve existing populations should focus on timing of flows which support silver perch growth, spawning and recruitment, and minimise adverse conditions.

Environmental watering should focus on the following attributes:

- recruitment, productivity and connectivity
- hydrodynamic diversity
- flow integrity.

Flows that create suitable breeding conditions, generate food, and provide access to habitat will support populations in the Murrumbidgee River, the lower Murray (downstream of Euston), the Lachlan, the Border Rivers and the Barwon–Darling. Similarly, uninterrupted stretches of flowing-water habitat throughout the Darling River could be prioritised for silver perch in times where sufficient water is available.

The mid-Murray population used to connect with the Murrumbidgee River. However, in-stream barriers limit upstream migration of silver perch into the Murrumbidgee and prevent the Murrumbidgee population from interacting with the mid-Murray population. This could be rectified by reinstating fish passage, allowing silver perch from the mid-Murray to disperse into the lower Murrumbidgee and boost populations within this system. In the meantime, actions that maintain and improve the current Murrumbidgee population are needed.

Improve hydrodynamic diversity in the lower Murray

Weir pools have created still water habitat within sections of the River Murray that used to flow. This reduction in hydrodynamic diversity has had negative impacts on the diversity and distribution of fish and other aquatic life. Areas of fast-flowing, slow-flowing and still water habitats need to occur across local to landscape scales to maintain sufficient hydrodynamic diversity. Actions to reinstate hydrodynamic diversity by creating greater extent and duration of a

mix of slow-flowing and fast-flowing habitats will benefit silver perch as well as threatened fish like Murray cod and recreational species like golden perch.

One key strategy will be to provide flows at the right time coupled with manipulation of River Murray weir pools. A combination of high flows and weir drawdown is likely to provide a mix of habitats, which in turn will encourage silver perch to spawn and disperse. Minimising impacts to fish passage along the channel, and between the floodplain and the main channel, while undertaking these actions will improve the outcomes.

Further outcomes could be achieved by ensuring the flow integrity of in-channel pulses during spring. Retaining spring pulses in-channel and allowing them to pass downstream (i.e. flow integrity) will allow flow cues to be retained throughout large sections of the Basin. This will increase the extent to which spawning, and dispersal of eggs and larvae, will occur.

For example, the Lock 10 to Lock 6 stretch of the lower Murray is a series of ponded water bodies with low flow variability and significant diversions into Lake Victoria. A side effect of this water management process is for flow pulses originating in the upper or mid-Murray to be 'dampened' or regulated, leading to the loss of biological cues for fish (to migrate or spawn). Preserving flow pulses (rising and falling water levels) through this stretch of the River Murray will support silver perch (and golden perch) by providing spawning cues, movement pathways and improved in-channel productivity. There would also be significant benefits to other species including Murray cod, freshwater catfish and small-bodied species.

Increase successful recruitment of threatened species by mitigating unnaturally large or rapid variations in water depths

River regulation in the southern basin has reversed or inverted natural flow seasonality; in some reaches downstream of weirs, waterways are almost dry in winter. Across the whole basin, highly variable water supply is also typical in many anabranches, creeks and rivers that supply water to people (Mallen-Cooper et al. 2013).

Unnaturally large or rapid variations in discharge and water depth can lead to poor recruitment of native fish. In these situations, young and adult fish compete for food, habitat and protection from predators. In creeks and tributaries with reduced winter flows, fewer fish survive to adulthood and body condition of mature fish deteriorates, reducing breeding and recruitment potential.

Nesting and substrate spawning species such as Murray cod, trout cod, river blackfish, Macquarie perch, southern purple-spotted gudgeon and freshwater catfish are particularly vulnerable to extreme water variations. Very large or rapid drops in water levels around the breeding season can: reduce the number of available spawning sites; hinder nest selection and preparation; interrupt courtship or spawning; cause nest abandonment, and affect egg survival (for example see Sharpe and Stuart 2015; Tonkin et al. 2015). For species that spawn only once each year, this means that an entire breeding season can be lost.

Water management can be modified in systems affected by altered winter flows or extreme water variations to significantly improve outcomes for native fish without affecting consumptive users (Mallen-Cooper et al. 2013; Sharpe and Stuart 2015). Improved management of both environmental water and water on route to consumptive uses can benefit native fish. In regulated systems in the southern Basin, mitigating unnaturally low flows by ensuring that suitable base flows are retained for winter will also improve outcomes for native fish. In unregulated systems,

arrangements that minimise unnatural variation will also benefit many different threatened species.

Specific examples where providing water to minimise extreme water fluctuations will improve outcomes for threatened species are:

- ensuring suitable winter base flows and minimising water fluctuations in the Goulburn, Gunbower Creek and the Loddon–Pyramid system will benefit species like Murray cod
- the provision of more natural, slower rates of recession to periods of high in-channel flows caused by rain rejections to protect in-stream habitat in the Edward–Wakool system
- the Billabong–Yanco–Colombo system where fluctuating water levels can be severe during the breeding season of trout cod (October–December). Flows will also increase connectivity to the Murrumbidgee River
- mitigating extreme water fluctuations affecting freshwater catfish habitat, particularly refuges, including in the Border Rivers and the Namoi valley
- southern purple-spotted gudgeon populations in the Border Rivers, including systems such as Tenterfield Creek, Severn River and Dumaresq River, and the lower Murray in South Australia

Minimise adverse impacts on fish communities in the lower Darling River from critically low water levels

The lower Darling River is a system of basin significance for threatened and recreational species in the basin. The lower Darling River provides vital habitat for native fish, including key threatened species and major recreational species such as Murray cod and golden perch. In particular, this system is an important source population of golden perch for the wider basin (Zampatti et al. 2015).

The lower Darling River is experiencing an unprecedented period of low flow, turning the channel into a series of isolated pools from Weir 32 to Burtundy. The system is under severe stress and there is limited capacity to implement short-term actions because of low water availability. Catastrophic losses of fish populations in this system will have long-term and wide-ranging effects.

In 2016–17, and beyond if conditions continue to decline, this system needs careful management to sustain native fish populations while addressing the needs of all water users.

Despite small inflows to Menindee from the northern Darling catchment in late March 2016, stratification, low dissolved oxygen levels and high salinity persist below 2–3 metres depth. There remains a very high risk of major fish kills in the lower Darling River in 2016–17 because of the very low water levels and deteriorating water quality. Management options need to be carefully considered as there is the potential to exacerbate poor water quality and cause severe fish kills. Small flows are a particularly high risk in hot weather.

The MDBA notes that severe water shortages in the lower Darling give managers very few options to alleviate stresses in this system. However, to minimise risks to native fish, water managers should consider the following matters when making decisions in 2016–17:

- Ideally, small magnitude/duration replenishment flows should be avoided in hot weather until a large flow has passed through the system. However, given current low water

availability, smaller releases may be the only option. If used, they should be accompanied by an understanding that fish deaths would be expected.

- Should conditions improve, any summer and autumn releases from Lake Wetherell should be a minimum of 2,000 ML/day, for a period of three weeks. This will result in a rapid mixing of layered pools with fresh water and provide connectivity with upstream pools, allowing fish to escape the poor conditions at the flow front. Flows will need to be carefully managed with consideration of temperature, salinity and dissolved oxygen levels, particularly at the flow front.
- Smaller magnitude releases (minimum of 500 ML/day for 10 days) can be considered during cooler months (winter and spring–early summer of 2016–17). However, some level of fish mortality should still be expected and planned for.
- Releases should be monitored to observe the scale of any fish kills and to assess responses of the fish community.

At the time of writing there was insufficient water in storage at Menindee to provide the recommended flow relief to the lower Darling River. In the absence of significant inflows to Menindee Lakes, there are few management options that mitigate the environmental risk. Saving fish to transfer to alternate habitats may be risky given the current stresses fish are experiencing and that appropriate habitat to relocate fish to may be several hundred kilometres away.

Given the importance of the lower Darling River for native fish species, management actions to protect and improve these populations over the longer term are needed. Mechanisms to restore unregulated flows passing through the upper Darling will be important, particularly to align with critical times downstream in the lower Darling. This will allow small-to-medium sized flows to reach Menindee. At a minimum, this will help preserve a refuge habitat in Lake Wetherell and provide enough water to support human needs and the fish communities downstream of Menindee through maintenance and replenishment flows.

Implementation in moderate conditions

In addition to actions identified for dry conditions, moderate conditions will allow greater outcomes to be achieved by increasing the number of species that can be supported and the range of locations where these can be achieved. Actions in moderate conditions in 2016–17 for silver perch and threatened fish are to:

- provide suitable flow conditions to expand the range of silver perch and to establish new populations
- provide suitable flow conditions for other threatened species to expand their range and to establish new populations.

Provide suitable flow conditions to expand the range of silver perch and to establish new populations

Supporting range expansion of silver perch may be possible for some locations under dry conditions. However, moderate conditions provide greater opportunities for expanding the range of silver perch and establishing new populations.

Dispersal of silver perch into rivers intermittently connected with the mid-Murray (including Victorian tributaries such as the Campaspe, Goulburn, Loddon–Pyramid systems) will be an important action to improve silver perch in this region. Intermittent connections may allow dispersal into some of these habitats under dry conditions but are likely to achieve more

substantial dispersal under moderate conditions. Flows that provide connectivity and migratory cues to attract silver perch, particularly juveniles, into these rivers can boost local population numbers and ultimately benefit silver perch populations at the basin scale.

In some locations very low numbers of silver perch and barriers to fish passage limit the ability of flow-related actions to expand the range of populations. In these cases, using conservation stocks may be considered, particularly to re-populate areas where habitat rehabilitation has occurred.

Environmental water can support the return of silver perch in regions where populations are being re-established through conservation stocks. Conservation stockings will benefit from flow regimes that provide conditions that support the maintenance, condition and recruitment of fish. The program to re-establish silver perch in the Namoi River (already identified under actions in dry conditions) can be further enhanced under moderate conditions.

Provide suitable flow conditions for other threatened species to expand their range and to establish new populations

Should moderate conditions arise in 2016–17, managers can further contribute to protecting threatened species by providing suitable conditions for threatened native fish populations to expand their current range. The supply and management of environmental water will be important in preparing sites for new fish populations. This includes creating suitable habitat, and securing their long-term future. Many sites and species are potential candidates to expand their range or to establish new populations. Managers are encouraged to work with threatened species recovery agencies/managers to assist in the long-term establishment of new populations.

An example of how supply and management of environmental water is important in preparing sites for new fish populations is the recent success in recovering small populations of Murray hardyhead in South Australia (e.g. Berri evaporation basin) and Victoria (Brickworks Billabong). Environmental water delivery to discrete sites has played a critical role alongside complementary measures to help recover this species.

Support for Murray hardyhead under moderate conditions should focus on increasing the area this species occupies through establishing new populations. One goal is to establish a relocated population in western New South Wales. This goal has been identified by the multi-jurisdictional Murray hardyhead recovery team, who have identified suitable sites on the River Murray floodplain in western New South Wales, as well as in northern Victoria and South Australia (Ellis and Kavanaugh 2014). Watering actions should be considered alongside other measures required to prepare and manage the sites (e.g. removal of carp to promote development of macrophyte and plankton communities).

Flows and connectivity

Maintain waterholes in the Lower Balonne Floodplain to provide critical refuge for water-dependent species.

Expected benefits

Delivering environmental water to maintain the viability of waterhole refuges in the Lower Balonne Floodplain in 2016–17 in accordance with this priority is expected to:

- ensure protection of critical refuge habitat for native fish, native birds, frogs, turtles and macroinvertebrates during prolonged periods of low to no flows
- ensure water quantity and quality in refuge waterholes is maintained at levels that support water-dependent species
- assist water-dependent species to recolonise the river and move about the floodplain when higher flows arrive.

Why is this a basin watering priority?

The Lower Balonne Floodplain consists of the channels, waterholes and floodplains of the Balonne River, and its distributary network of channels, downstream of St George, Queensland to the confluence with the Barwon River in New South Wales (Figure 11). The floodplain includes the Culgoa, Ballandool, Birrie, Bokhara and Narran rivers, and the Narran Lakes Nature Reserve, which is listed on the Ramsar Convention. The reserve is capable of supporting waterbird species listed in the Japan–Australia Migratory Bird Agreement, China–Australia Migratory Bird Agreement and Republic of Korea–Australia Migratory Bird Agreement.

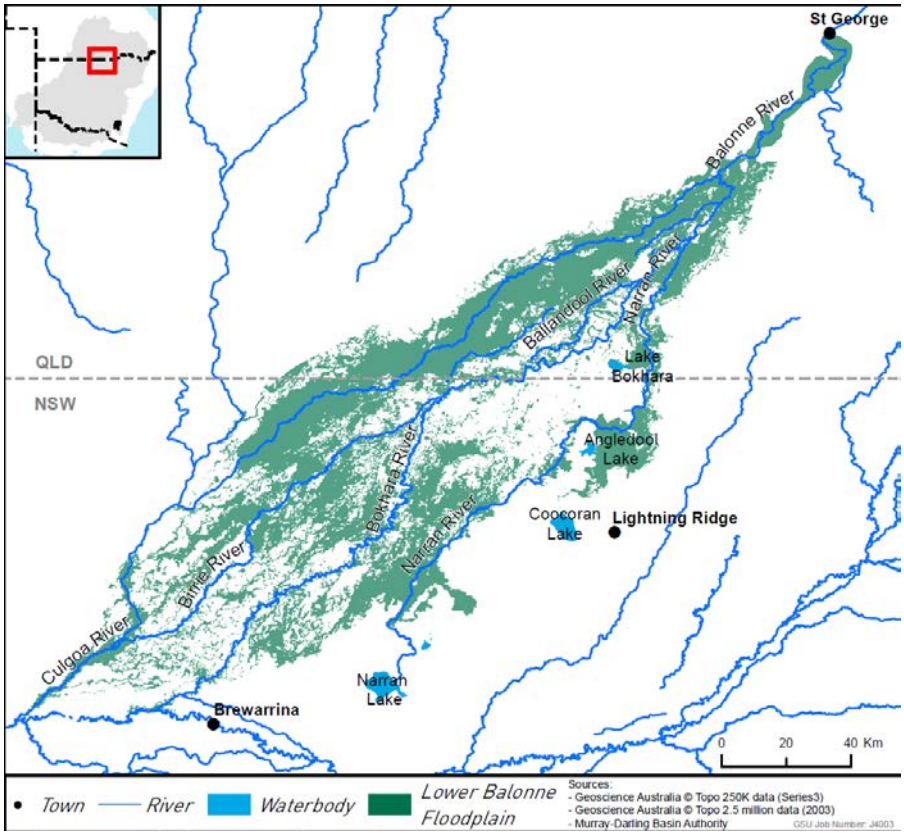

Figure 11: The Lower Balonne Floodplain

The Lower Balonne Floodplain supports several water-dependent species listed as endangered or vulnerable under Australian Government and state legislation and contains the largest number of wetlands in the Murray–Darling Basin (CSIRO 2008).

Dryland rivers naturally fluctuate between episodic flooding and dry spells that turn the river into a network of waterholes. These waterholes serve an important ecological function by providing refuge habitat for water-dependent species like fish, waterbirds and macroinvertebrates. They also help water-dependent species recover and disperse after prolonged dry spells (Bunn et al. 2006; Sheldon et al. 2010; Webb et al. 2012).

Water resource development has increased the intensity and frequency of dry spells to the point where these periods are longer than the time that waterholes persist (Department of Science, Information Technology and Innovation 2015; MDBA in prep; Webb et al. 2012). Given these changes to the flow regime, waterhole refuges are likely to be more important for the ecosystem than under 'without development' conditions. This is because in-channel freshes and overbank flooding occur less often, reducing opportunities for recruitment, growth and migration for many water-dependent species (MDBA in prep). Changes to the natural pattern of waterhole formation, as a result of development and a changing climate, also threaten the ability of waterholes to act as refuges (Reid et al. in press).

Several factors determine whether a waterhole can act as a refuge: how long the waterhole persists; the quantity and quality of water and available food in the waterhole; and connectivity between waterholes (Department of Science, Information Technology and Innovation 2015). Numerous studies have found that maintaining a mosaic of refugial waterholes will help maintain the biodiversity of water-dependent species (Arthington et al. 2005; Marshall et al. 2006; Sheldon et al. 2010; Webb et al. 2012), and enable them to recolonise rivers and floodplains when flows return. It may also decrease the likelihood of waterholes experiencing simultaneous catastrophic events which would cause regional extinction (MDBA in prep).

The MDBA is preparing an updated assessment of the environmental water requirements for the Condamine–Balonne river system as a part of the Northern Basin Review. This priority reflects the site-specific flow indicators for drought refugia in the Lower Balonne Floodplain detailed in the updated assessment.

This priority will contribute to the quantified environmental outcomes, outlined in the Basin-wide environmental watering strategy, by keeping base flows at least 60% of the natural level (including cease-to-flow events not exceeding natural levels, where possible), improving the structure, and increasing the movement of key native fish species (MDBA 2014).

Implementation

As most rivers of the Lower Balonne Floodplain are unregulated there is a limited capacity to manage flows. Environmental water is provided to the Lower Balonne Floodplain in Queensland and northern New South Wales using a rules-based approach. This approach depends on stream flow, the type of water entitlement and conditions, and the rules in the resource operations plan for the Condamine–Balonne system around environmental, stock and domestic releases. Depending on antecedent conditions modest additional flow protection measures for low flows, medium flows and flows that previously would have filled Narran Lakes may also be triggered.

The Commonwealth Environmental Water Holder has significant un-supplemented water allocation entitlements in the Lower Balonne. This means that there will now be less take, or

more flow, during all unregulated (water harvesting) flow events, and this will increase low flows throughout the system in small flow events in the range that could reach or almost reach the end of the distributary channels and refill waterholes.

There is a limited capacity to purchase water on the temporary market to assist in meeting this priority due to the relatively small market. Purchasing water from private storages is another strategy but there are issues, related to the potential water quality impacts of these releases on waterways, which still need to be resolved. This issue is currently being addressed in a joint Australian Government and Queensland project to monitor water quality in storages and the lower Balonne system and to develop a code of practice for store and release options.

The Department of Science, Information Technology and Innovation (2015) study into waterhole persistence found that the Culgoa and Narran rivers have few waterholes that retain water for one year or longer without inflows. The study also found that water resource development poses a risk to refugial waterhole persistence relative to 'pre-development' conditions.

This priority focusses on the need to minimise periods without flow lasting longer than one year in the Lower Balonne. The threshold of concern for modelled waterholes is 350 days for the Narran Culgoa rivers. Modelling undertaken in the Department of Science, Information Technology and Innovation 2015 study shows that about two-thirds of the waterholes in the Culgoa and Narran rivers will go dry after one year without inflows.

Of the 27 waterholes assessed, eight were identified as being refuge waterholes — four each in the Culgoa and Narran systems (Figure 12). Refuge waterholes provide persistent refuge under extended no-flow conditions.

The antecedent conditions in the Condamine–Balonne catchment, which includes analysis of rainfall, runoff and root zone soil moisture, is below average to average, as set out in Appendix 2. For the Lower Balonne Floodplain waterhole refuges to remain viable habitat for water-dependent species, periods of no flow should ideally be less than one year and not exceed one and a half years. This should preferably be assessed on the basis of a flow-through event occurring for the Narran, Culgoa, Birrie and Bokhara river channels. At a minimum a flow through both the Narran and Culgoa river channels is required to top-up the refuge waterholes.

Environmental water delivery to achieve this priority may require coordination between Queensland and New South Wales water managers, and the Commonwealth Environmental Water Holder. Water managers will need to ensure that enough water is delivered to both reach and fill the refuge waterholes. Should the rules-based approach used in Queensland and New South Wales limit water managers' ability to meet this priority the updated assessment of environmental water requirements for the Condamine–Balonne system should be considered in any upcoming rules reviews.

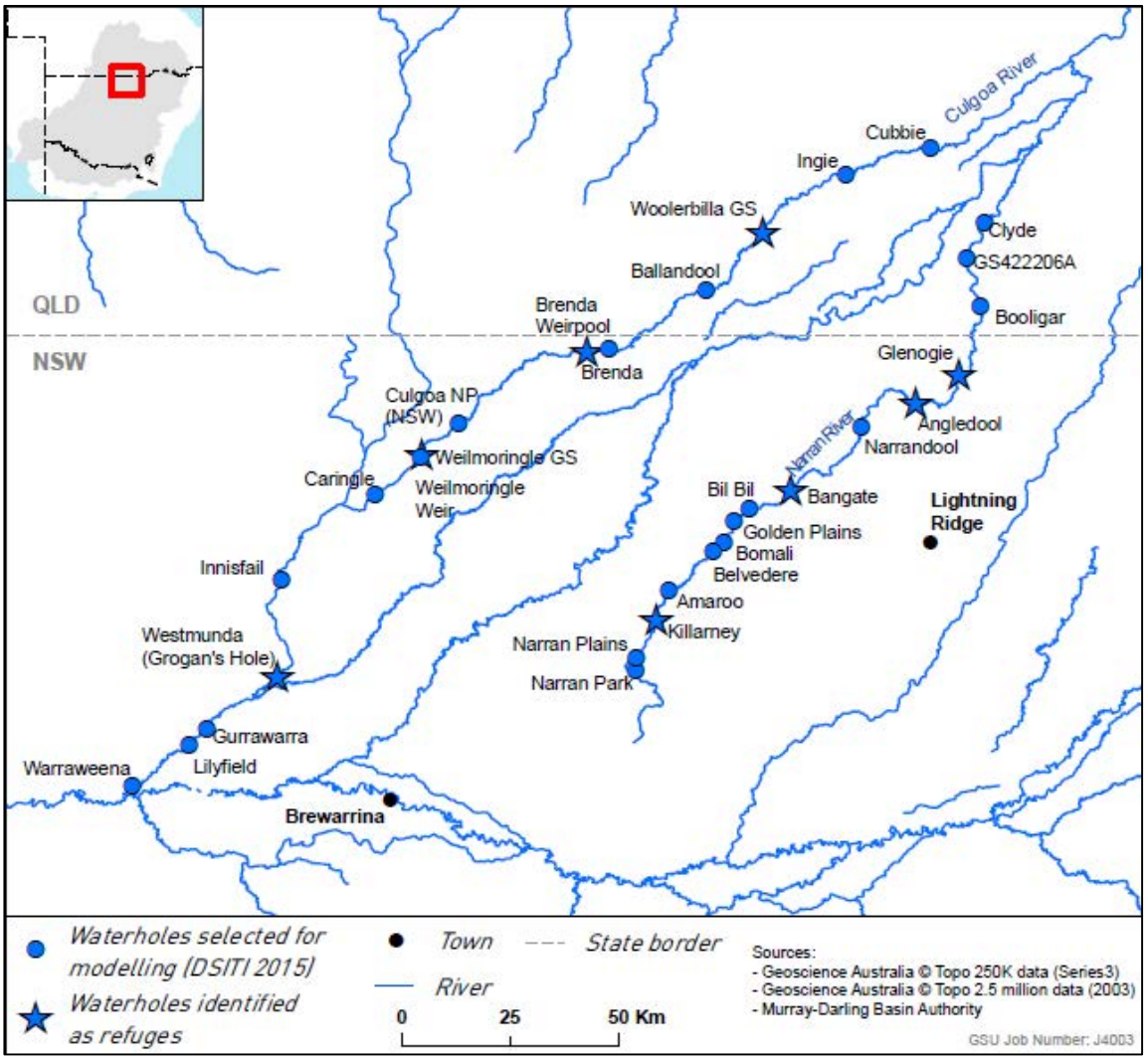

Figure 12: The waterholes selected for modelling on the Culgoa and Narran rivers in the Department of Science, Information Technology and Innovation 2015 study. Waterholes marked with a star were identified as refuge waterholes.

This priority aligns with the approaches to achieve connectivity, native fish, waterbird and native vegetation outcomes outlined in the Basin-wide environmental watering strategy by:

- improving native fish habitat and maintaining drought refuge habitats
- supporting waterbird abundance and diversity through protecting drought refuges
- maintaining the extent of vegetation that closely fringes or occurs within main river corridors.

This priority complements the 2016–17 specific priority on the protection of threatened native fish, and the delivery of the 2016–17 specific priorities for waterbirds by priming the Narran River system for potential inflows.

Protect aquatic habitat conditions in the Coorong and support native fish movement by optimising flows into the Coorong and through the Murray Mouth.

Expected benefits

Managing and delivering water in the Coorong, Lower Lakes and through the Murray Mouth in 2016–17 in accordance with this priority is expected to:

- provide connectivity between the River Murray, the Lower Lakes, the Coorong estuary and through the Murray Mouth to the Southern Ocean
- improve habitat conditions and maintain a salinity gradient in the Coorong for the native estuarine fish and to limit further loss of threatened *Ruppia tuberosa*[2]
- maintain seasonal flow cues for migratory (diadromous) fish movement
- support estuarine macroinvertebrates (key food source) and productivity
- improve water quality in the Lower Lakes and export salt out of the Murray–Darling Basin system
- provide the Coorong with resilience to withstand future dry years.

Why is this a basin watering priority?

The Coorong and Lakes Alexandrina and Albert comprise one of Australia's largest wetland systems totalling 142,500 hectares (Figure 13) and are listed under the Ramsar Convention. The Coorong, Lower Lakes and Murray Mouth meet eight of the nine criteria listed in the Ramsar Convention and contain 23 Ramsar wetland types. The area contains important feeding habitat for international migratory waterbirds, provides for the export of salt and sediment through the Murray Mouth and allows for native fish movement between marine, estuarine and freshwater environments.

Figure 13: Coorong, Lower Lakes and Murray Mouth, South Australia

[2] Dry conditions do not provide appropriate conditions for *Ruppia tuberosa* recruitment.

Hydrological connectivity between freshwater, estuarine and marine environments facilitates native fish movement and migration which sustains native fish populations and enables fish to complete lifecycles in different aquatic environments. Connectivity is particularly important for diadromous fish, such as congolli, common galaxias, short-headed lamprey and pouched lamprey. Water flow out of the Murray Mouth is needed to export salt from the basin. It also allows tidal exchange through the Murray Mouth to flush water through the length of the Coorong to maintain salinity levels in the South Lagoon (MDBA 2012b).

The salinity of the Coorong generally increases with distance from the Murray Mouth, but varies over time. This is largely in response to freshwater inflows from the River Murray through the Lower Lakes and barrages. It is also influenced by seawater flowing back through the Murray Mouth and into the Coorong.

An assessment in 2009 showed some benefits of flows from the Upper South East Drainage Scheme to the South Lagoon, however the contributions are small compared to the River Murray inflows which are the main driver in maintaining water quality in the Coorong (Lester and Fairweather 2009). Ensuring this salinity gradient exists (i.e. a gradual change from freshwater to hyper-saline water within the Coorong) along the length of the Coorong is vital to maintain a diverse and healthy estuary and support the broader ecology of the Coorong. The salinity gradient is also important to sustain native fish populations (Elliott and Whitfield 2011), distribution, species richness and spawning and recruitment success (Zampatti et al. 2010; Bice et al. 2012).

In recent years, resource conditions have become increasingly dry, with a downward trend in the total volume of water arriving in South Australia and subsequently to the Lower Lakes, Murray Mouth and Coorong, ranging from 15,217 GL in 2010–11 to 2,446 GL in 2015–16 (to 16 June 2016).

During spring 2015 the Lower Lakes (see Figure 14) were managed to levels higher than the levels stipulated in Environmental Water Requirements (MDBA 2014; MDBA 2014b) and Full Supply Level. These higher lake levels have been similarly prioritised over recent years to:

- achieve ecological outcomes in the Lower Lakes, which are still in recovery following the unprecedented low lake levels that occurred during the millennium drought
- to reduce the risk of levels falling below the minimum level of 0.40 m AHD described in the Basin Plan objectives.

Monitoring in the Coorong shows that salinity has increased in 2015–16, consistent with expectations and the inverse relationship between flows over the barrages and salinity levels in the South Lagoon. In 2016 salinity in the Coorong could exceed the Basin-wide environmental watering strategy's quantified ecological outcomes of 100 grams per litre 95% of the time (MDBA 2014b).

Salinity levels, water depth and turbidity in the Coorong drives the distribution and health of *Ruppia tuberosa* (Carruthers et al. 1999). The important plant species provides abundant food resources for local and migratory waterbirds (Paton et al. 2001; Nicol 2005; Whipp 2010) and habitat for native fish and macroinvertebrates (Paton and Rogers, 2009). This makes it a key indicator species for the health of the Coorong (Lamontagne et al. 2012; MDBA 2012b). Low water levels and high salinity levels due to reduced freshwater inflows in the past few years has

greatly reduced the distribution and abundance of *Ruppia tuberosa* in the South Lagoon (Paton and Rogers 2009; Lamontagne et al. 2012). It is important to *minimise the extent and duration that salinities exceed the tolerance of chironomids, Ruppia tuberosa, native fish and migratory waterbirds.*

Achieving the expected benefits of this priority and the quantified environmental outcomes in the strategy requires the appropriate climate conditions and environmental water planning, management and delivery over multiple years. Therefore, this priority builds on priorities the MDBA has listed since 2013–14 and will contribute to achieving many of the quantified environmental outcomes in the strategy (MDBA 2014), for example:

- salinity in the Coorong remains below 100 grams per litre 95% of the time
- maintaining water levels in the Lower Lakes above 0.4 metres Australian Height Datum (AHD) for 95% of the time, as far as practicable, to allow for barrage releases
- a sustained and adequate population of *Ruppia tuberosa* in the South Lagoon of the Coorong by ensuring *Ruppia tuberosa* occurs in at least 80% of sites across at least a 50 km extent by 2019
- detection in nine out of 10 years of bi-directional seasonal movements of diadromous species through the barrages and fishways in 2019–24 compared to 2014–19.

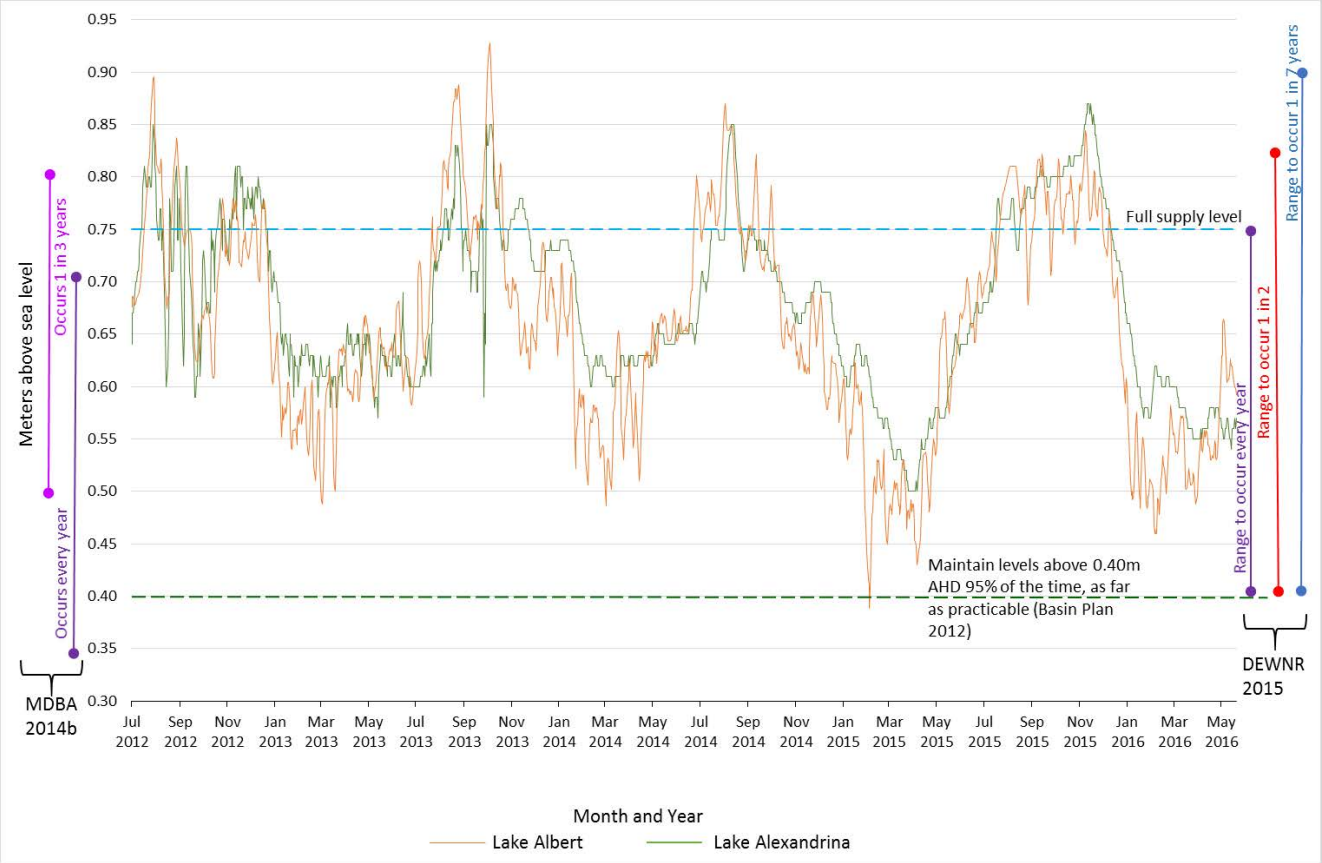

Figure 14: Water levels in Lake Alexandrina and Lake Albert from July 2012 to May 2016 (five-day rolling averages) from Milang and Meningie. This also includes the water level ranges needed to deliver the environmental water requirements to achieve icon site ecological target levels approved by basin and Australian Government ministers (MDBA 2014b). The ranges needed to deliver the environmental water requirements to achieve the desired hydrological regime (DEWNR 2015) are also included. This Figure also indicates the quantified ecological outcome for the minimum lake level in the strategy (MDBA 2014) and the Full Supply Level of Lake Alexandrina.

Implementation

Water reform

In response to the millennium drought the Australian Government prompted water reform and investment to provide a robust and flexible framework to plan for and manage extreme dry conditions by balancing environmental, social and economic values in the Murray–Darling Basin. In addition to basin-wide measures (establishing the MDBA, the Water Act, the Commonwealth Environmental Water Holder and the Basin Plan) some specific measures that focussed on the Coorong, Lower Lakes and Murray Mouth included:

- investing up to $200 million over 10 years into the Coorong, Lower Lakes and Murray Mouth Recovery Project, as part of South Australia's Murray Futures program funded by the Australian Government's Water for the Future initiative (note: the full initiative funded up to $610 million included riverine recovery projects upstream)
- establishing a Drought Emergency Framework for Lakes Alexandrina and Albert to guide decision making about the Lower Lakes during extreme drought.

The South Australian Government is developing the Lower Lakes water level policy and barrage operating strategy (water level operating strategy) to establish a decision-making framework based on best available information, to maintain the site's ecological character and identify environmental and water security risks. It will consolidate knowledge of management practices, fill knowledge gaps and document operating policies and procedures for the Lower Lakes. The water level operating strategy is being developed with partner government agencies and in consultation with local communities.

Australian Government water reform and the South Australian Government's water level operating strategy supports environmental benefits in the Coorong, Lower Lakes and Murray Mouth being achieved in drier years and reduces the chance that the catastrophic events that took place in the Coorong, Lower Lakes and Murray Mouth during the millennium drought will be repeated.

Variable lake levels

The importance of increased availability of environmental water for outcomes for the Coorong, Lower Lakes and Murray Mouth has been well recognised within the Basin Plan 2012 and the environmental watering strategy (MDBA 2014). There is an increasing recognition of the significance of having complementary and seasonally appropriate operating strategies to maximise priority environmental outcomes.

The environmental water requirements for the Coorong, Lower Lakes and Murray Mouth were approved by ministers from each of the basin states and the Australian Government, recommends the water levels in Lakes Alexandrina and Albert to fluctuate between 0.7 m AHD and 0.35 m AHD every year and between 0.8 m AHD and 0.5 m AHD once every three years (MDBA 2014b).

The South Australian River Murray long-term environmental watering plan describes similar lake levels to deliver the environmental water requirements to achieve the desired hydrological regime (South Australian Department of Environment, Water and Natural Resources (DEWNR) 2015), these are:

- 0.4 m AHD to 0.75 m AHD every year,

- 0.4 m AHD to 0.83 m AHD to occur every one in two years
- 0.4 m AHD to 0.9 m AHD to occur one in seven years
- with maximum lake levels in December to February and minimum lake levels in March to May
- peak barrage flows in October to December.

Since 2011, lake levels have been managed in the higher water level range, although it was not possible to meet the timing and duration consistent with the environmental water requirements sought from these lake levels. Figure 14 indicates that there is capacity to increase flows to the Coorong within lake level operational goals. Managing the Lower Lakes to optimise additional flow to the Coorong in dry and moderate conditions will:

- lower salinity levels in the North Lagoon
- connect freshwater and estuarine environments
- facilitate bi-directional connectivity
- improve estuarine productivity
- create foraging habitats around the Coorong on the exposed shorelines
- allow upstream and downstream fish movement
- export salt out of the Lower Lakes into the Southern Ocean
- improve extent and condition of fringing vegetation around the Lower Lakes (Roberts and Marston 2011; MDBA 2014b).

It is recommended that water is delivered and managed in the Lower Lakes and Coorong in a way that optimises additional flow to the Coorong, in line with the environmental water requirements and the quantified environmental outcome in the strategy (MDBA 2014) to maintain lake levels above 0.4 metres AHD for 95% of the time (as far as practicable).

Water availability

The resource availability scenario for the southern basin in 2016–17 is dry to moderate (Table 2, Appendix 2). This priority can be implemented in all resource availability scenarios, but to a limited extent in a very dry scenario. If conditions become very dry for an extended period environmental water managers and planners should consider the drought emergency framework for Lakes Alexandrina and Albert.

The resource availability scenario and local rainfall conditions change quickly. By monitoring dam volumes and communicating regularly, river operators, environmental water managers and planners will be best positioned to respond to changing conditions and maximise opportunities in line with the priority in a timely way.

Environmental water holders and managers should consider using environmental water, consumptive water, unregulated and managed water in the southern-connected system to achieve the environmental benefits of this priority. This priority may be complemented by other 2016–17 specific priorities in the southern-connected system.

Environmental watering decisions to meet this priority will need to include consultation with relevant stakeholders to manage third party impacts. This may be done through formal processes. For example, in April 2016 the Commonwealth Environmental Water Holder entered into a partnership with the Ngarrindjeri Regional Authority to formalise their input into water planning and delivery in the region.

This priority has the potential to deliver Aboriginal environmental outcomes in line with the themes identified by members of the Murray Lower Darling Rivers Indigenous Nations during discussions in 2016 about integrating Traditional Owners' input into priorities. During these talks Traditional Owners identified removing barriers to native fish movement and maintaining connectivity as themes important to them.

Implementing this priority complements the following water management strategies outlined in the Basin-wide environmental watering strategy (MDBA 2014):

- augmenting and coordinating tributary flows in regulated parts of the basin (particularly those which naturally contribute large flows downstream) to help meet downstream environmental outcomes
- watering requirements that support recruitment events and improve condition, including requirements for drying periods
- maintaining a salinity gradient in the estuary, while ensuring that the spatial extent of the gradient varies
- considering the spawning and recruitment outcomes for all native fish species, especially where flow affects critical parts of their life-cycles (such as movement and dispersal).

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Appendix 1 Reports on outcomes of environmental watering

Department of the Environment (Australian Government)
Improved outcomes for native fish, birds, frogs and habitat from environmental watering: 2014-15 Outcomes Snapshot

Commonwealth Environmental Water Office (Australian Government)
Environmental outcomes report 2012-13

Murray–Darling Basin Authority (Australian Government)
The Living Murray – 2014-15 Environmental Watering Report

Office of Environment and Heritage (NSW)
Environmental water use in New South Wales: Outcomes 2014-15

Victorian Environmental Water Holder
Reflections – environmental watering in Victoria 2014-15

South Australian Department of Environment, Water and Natural Resources
River restoration and environmental water

Appendix 2 Seasonal conditions

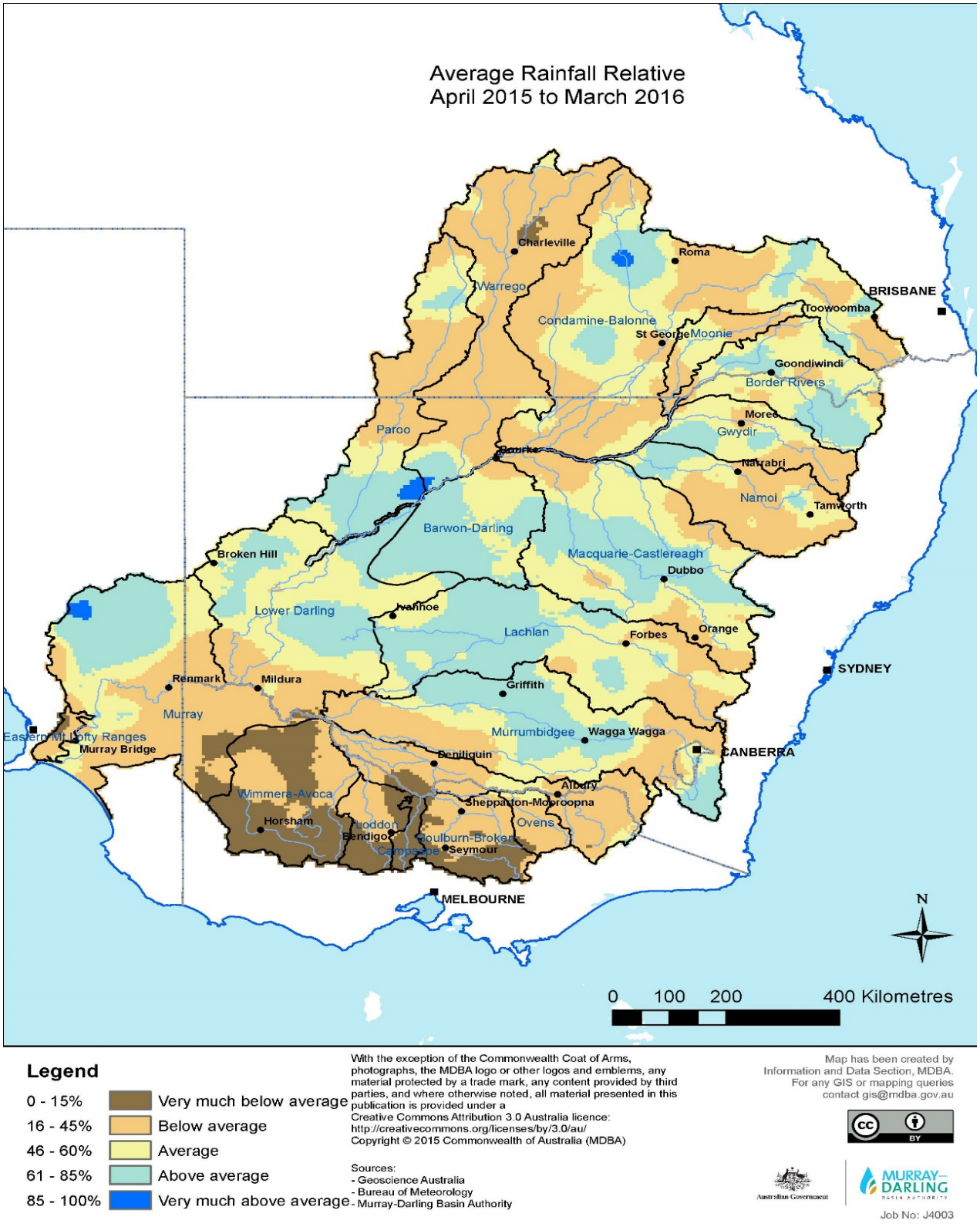

Figure 15: Annual average rainfall for 2015–16 (relative to the historical record) in the Murray–Darling Basin

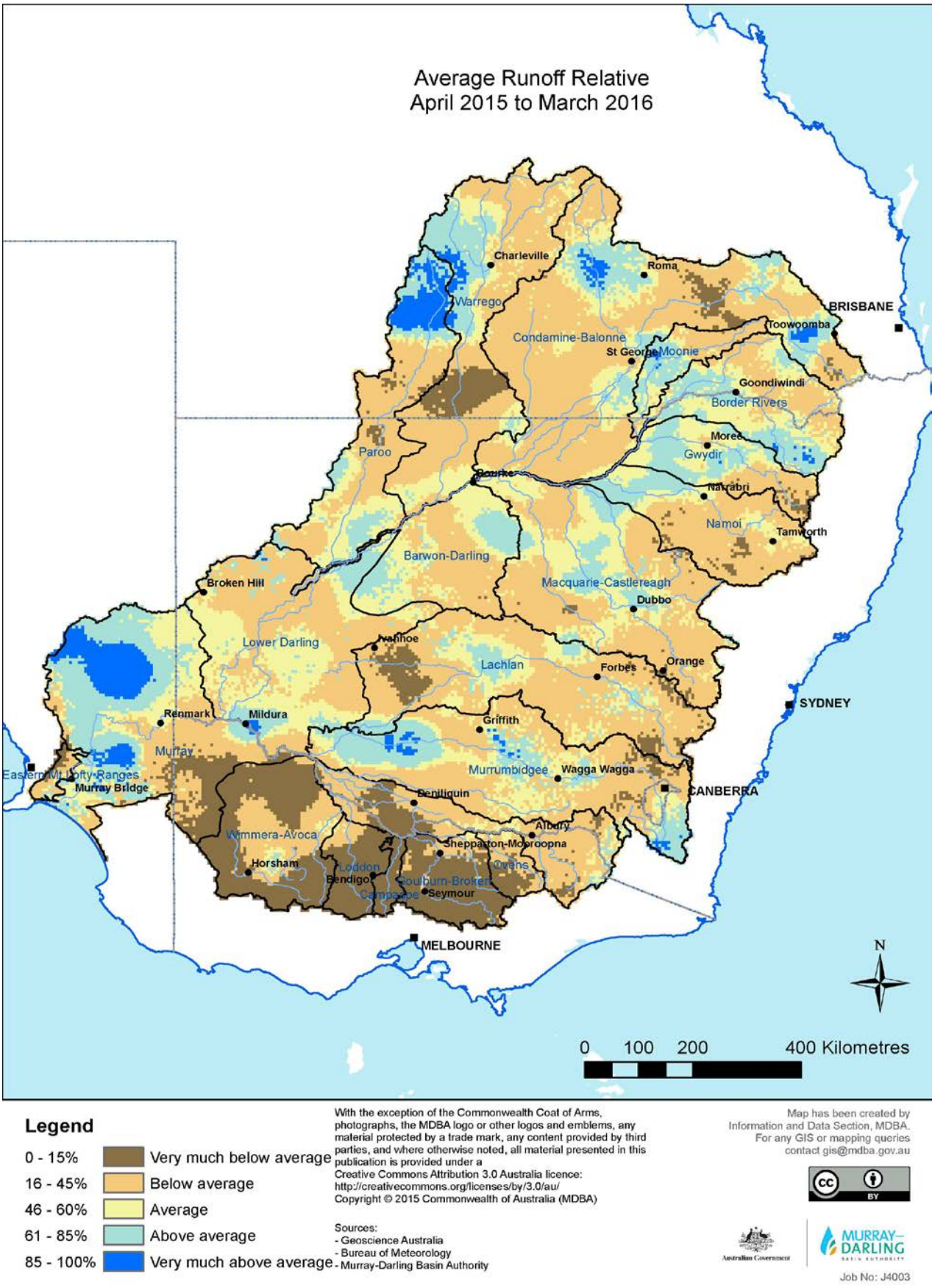

Figure 16: Annual average runoff for 2015–16 (relative to the historical record) in the Murray–Darling Basin

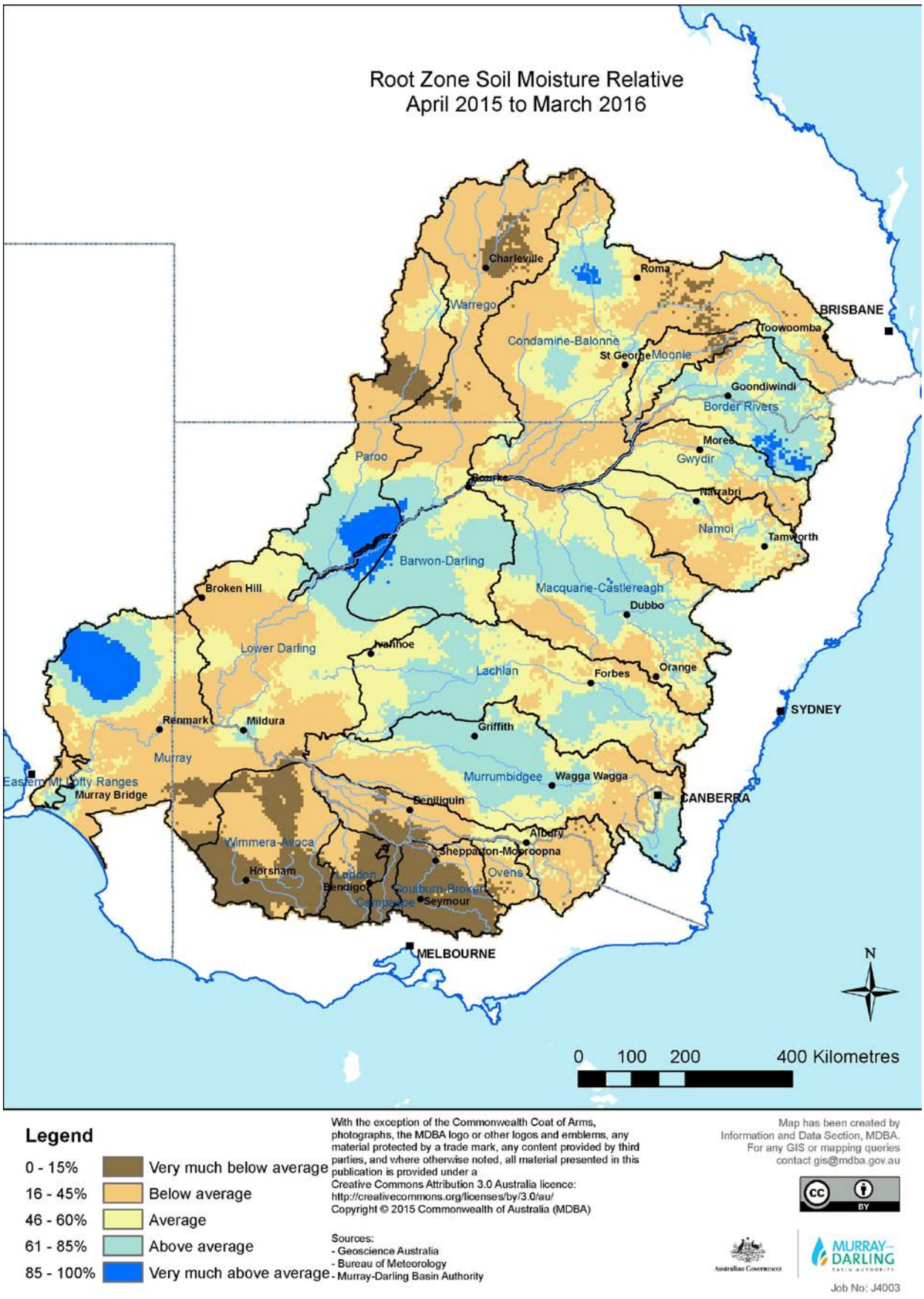

Figure 17: Annual average root zone soil moisture for 2015–16 (relative to the historical record) in the Murray–Darling Basin

Table 2: Resource availability scenarios for the catchments of the Murray–Darling Basin for April 2015-March 2016

Catchments	Antecedent conditions — environmental watering plan percentiles				Surface water availability[1]	Resource availability scenario — environmental watering plan percentiles
	Runoff 2015–16	Root zone soil moisture 2015–16	Precipitation 2015–16	Antecedent percentile range	Surface water percentile	
Regulated catchments						
Border Rivers	46-60	61-85	46-60	46-60 to 61-85	61-85	wet
Gwydir	46-60	16-45	46-60	16-45 to 46-60	16-45	dry
Namoi	16-45	0-15	16-45	0-15 to 16-45	16-45	very dry to dry
Macquarie–Castlereagh	16-45	46-60	46-60	16-45 to 46-60	0-15	very dry to dry
Lachlan	16-45	46-60	46-60	16-45 to 46-60	16-45	dry
Murrumbidgee	46-60	16-45	46-60	16-45 to 46-60	16-45	dry
Lower Darling	16-45	46-60	46-60	16-45 to 46-60	0-15	very dry to dry
Murray	46-60	0-15	16-45	0-15 to 46-60	16-45	very dry to dry
Loddon	0-15	46-60	0-15	0-15 to 46-60	16-45	very dry to dry
Campaspe	0-15	46-60	0-15	0-15 to 46-60	0-15	very dry to dry
Goulburn–Broken	0-15	61-85	16-45	0-15 to 61-85	16-45	very dry to moderate
Wimmera-Avoca	16-45	46-60	0-15	0-15 to 46-60	n/a[2]	very much below average to average (very dry to moderate)
Unregulated catchments[3]						
Moonie	46-60	16-45	16-45	16-45 to 46-60	n/a	below average to average (dry to moderate)
Barwon–Darling[4]	46-60	46-60	61-85	46-60 to 61-85	n/a	average (moderate)
Condamine–Balonne	16-45	16-45	46-60	16-45 to 46-60	n/a	below average to average (dry to moderate)
Paroo	46-60	0-15	46-60	0-15 to 46-60	n/a	very much below average to average (very dry to moderate)
Warrego	16-45	0-15	16-45	0-15 to 16-45	n/a	very much below average to below average (very dry to dry)
Ovens	16-45	16-45	16-45	16-45	n/a	below average (dry)
Eastern Mt Lofty Ranges	16-45	61-85	16-45	16-45 to 61-85	n/a	below average to above average (dry to wet)

1 Based on the most up-to-date data available at the time of writing.
2 Only antecedent conditions have been applied to determine this catchment's resource availability scenario due to insufficient relevant long-term data for surface water availability.
3 Only antecedent conditions can be applied to determine the catchment Resource Availability Scenario in unregulated system given the absence of public water storages. Note that alternate indicators for surface water availability in unregulated catchments will be investigated for future applications of the resource availability determination method.
4 There is some uncertainty in the resource availability scenario outlook for this catchment, and so we have been conservative. Given this uncertainty the applicability of the resource availability scenario determination method for this catchment will be further investigated to inform future Basin environmental watering outlooks.

Appendix 3 Snapshot of water volumes in major public storages across the basin

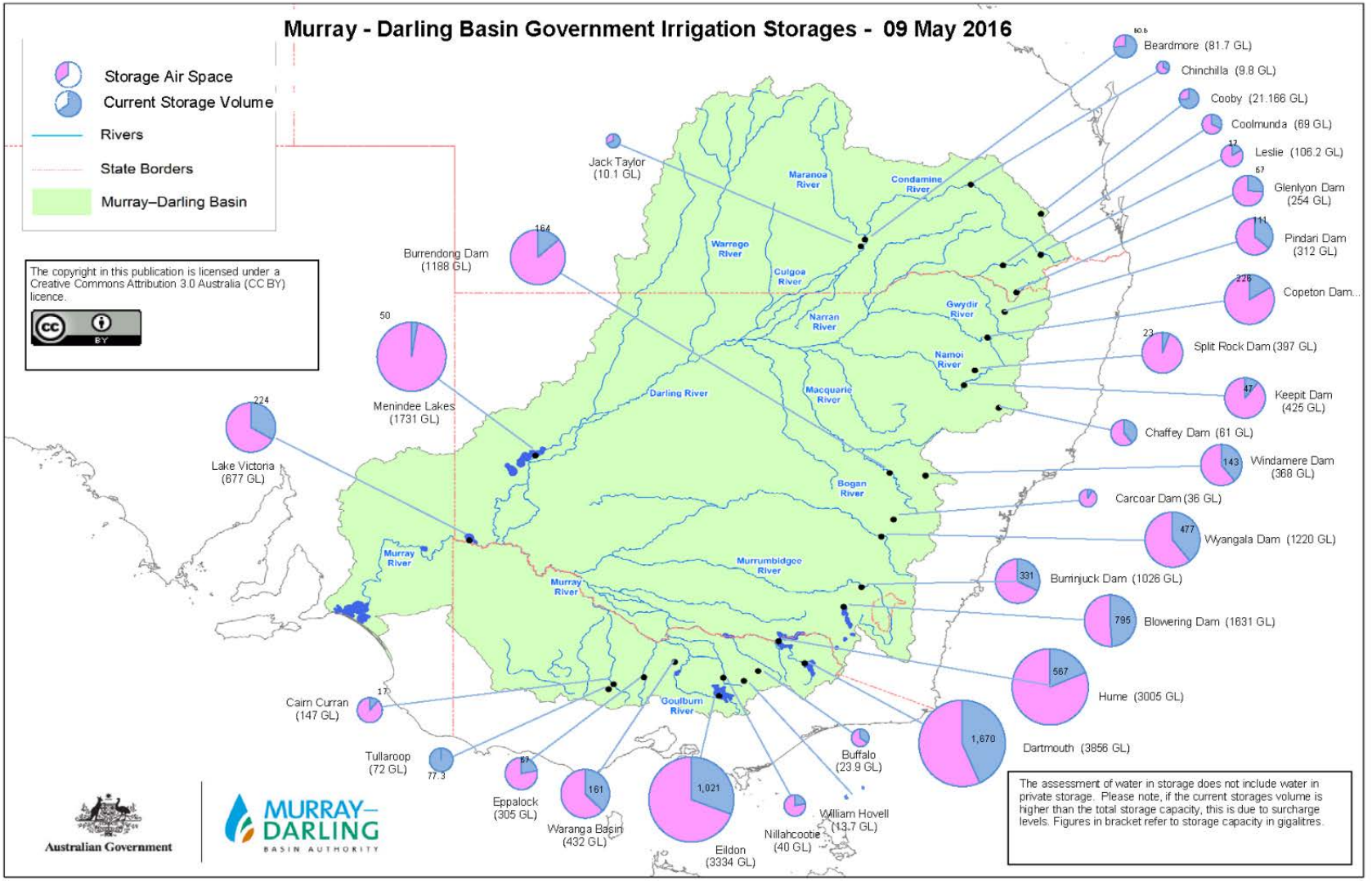

Figure 18: Water volumes in major Murray–Darling Basin public storages as at 9 May 2016 (www.mdba.gov.au)

Appendix 4 Summary of expected environmental outcomes from the Basin-wide environmental watering strategy

With the additional water available for environmental watering under the Basin Plan, assisted by the Basin-wide environmental watering strategy, we expect to achieve:

River flows and connectivity

Maintained base flows:

- at about 60% of natural levels
- Improved overall flow:
  - 10% more into the Barwon–Darling
  - 30% more into the River Murray
  - 30–40% more to the Murray Mouth (and it open to the sea 90% of the time)

Maintained connectivity in areas where it is relatively unaffected:

- between rivers and floodplains in the Paroo, Moonie, Nebine, Warrego and Ovens

Improved connectivity with bank-full and/or low floodplain flows:

- by 30–60% in the Murray, Murrumbidgee, Goulburn and Condamine–Balonne
- by 10–20% in remaining catchments

Maintain the Lower Lakes above sea level

Vegetation

Maintenance of the current extent of:

- about 360,000 ha of river red gum; 409,000 ha of black box; 310,000 ha of coolibah forest and woodlands; and existing large communities of lignum
- non-woody communities near or in wetlands, streams and on low-lying floodplains

Maintained condition of lowland floodplain forests and woodlands of:

- river red gum
- black box
- coolibah

Improved condition of:

- southern river red gum

Waterbirds

Maintained current species diversity of:

- all current Basin waterbirds
- current migratory shorebirds at the Coorong

Increased abundance:

- 20–25% increase in waterbirds by 2024

Improved breeding:

- up to 50% more breeding events for colonial nesting waterbird species
- a 30–40% increase in nests and broods for other waterbirds

Fish

Improved distribution:

- of key short- and long-lived fish species across the Basin

Improved breeding success for:

- short-lived species (every 1–2 years)
- long-lived species in at least 8/10 years at 80% of key sites
- mulloway in at least 5 out of 10 years

Improved populations of:

- short-lived species (numbers at pre-2007 levels)
- long-lived species (with a spread of age classes represented)
- Murray cod and golden perch (10–15% more mature fish at key sites)

Improved movement:

- more native fish using fish passages

Figure 19: Summary of expected environmental outcomes from the Basin-wide environmental watering strategy

Appendix 5 Extracts from 'Guidelines for the method to determine priorities for applying environmental water'

Table 3: Matrix for determining the resource availability Scenario

Surface water availability (percentile)	Antecedent conditions (percentile)				
	0–15	16–45	46–60	61–85	86–100
0–15	very dry	very dry	dry	dry	n/a
16–45	very dry	dry	dry	moderate	wet
46–60	dry	dry	moderate	wet	wet
61–85	dry	moderate	wet	wet	very wet
86–100	n/a	moderate	wet	very wet	very wet

Note: n/a means that it is improbable that this combination will arise and so no resource availability scenario is specified.

Table 4: Management outcomes for each resource Availability scenario

	Resource availability scenario				
	Very dry	Dry	Moderate	Wet	Very wet
Management outcomes	Avoid irretrievable loss of or damage to, environmental assets: Avoid critical loss of species, communities, and ecosystems. Maintain critical refuges. Avoid irretrievable damage or catastrophic events. Allow drying to occur, where appropriate, but relieve severe unnaturally prolonged dry periods.	Ensure environmental assets maintain their basic functions and resilience: Support the survival and viability of threatened species and communities. Maintain environmental assets and ecosystem functions, including by allowing drying to occur consistent with natural wetting-drying cycles. Maintain refuges.	Maintain ecological health and resilience: Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna. Promote low-lying floodplain-river connectivity. Support medium-flow river and floodplain functions.	Improve the health and resilience of water-dependent ecosystems: Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna. Promote higher floodplain-river connectivity. Support high-flow river and floodplain functions.	Improve the health and resilience of water-dependent ecosystems: Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna. Promote higher floodplain-river connectivity. Support high-flow river and floodplain functions.

Note: More than one resource Availability scenario could apply at one time (for example, between different water resource plan areas across the Basin).

Appendix 6 Principles to be applied to determine priorities.

Principle 1 Consistency with principles of ecologically sustainable development and international agreements

Principle 2 Consistency with objectives

Principle 3 Flexibility and responsiveness

Principle 4 Condition of environmental assets and ecosystem functions

Principle 5 Likely effectiveness and related matters

Principle 6 Risks and related matters

Principle 7 Robust and transparent decisions

Appendix 7 Scientific names of plants and animals mentioned in this report

Australasian bittern	*Botaurus poiciloptilus*
black swan	*Cygnus atratus*
bony bream	*Nematalosa erebi*
carp	*Cyprinus carpio*
cattle egret	*Ardea ibis*
common galaxias	*Galaxias maculatus*
congolli	*Pseudaphritis urvillii*
chironomids	Chironomidae (family)
eastern great egret	*Ardea modesta*
freshwater catfish	*Tandanus tandanus*
glossy ibis	*Plegadis falcinellus*
goat (feral)	*Capra hircus*
golden perch	*Macquaria ambigua ambigua*
horse (feral)	*Equus caballus*
Latham's snipe	*Gallinago hardwickii*
lignum	*Muehlenbeckia florulenta*
little bittern	*Ixobrychus minutus*
little pied cormorant	*Microcarbo melanoleucos*
Macquarie perch	*Macquaria australasica*
marsh club-rush sedge	*Bolboschoenus fluviatilis*
Moira grass	*Pseudoraphis spinescens*
Murray cod	*Maccullochella peelii peelii*
Murray hardyhead	*Craterocephalus fluviatilis*
olive perchlet	*Ambassis agassizii*
pied cormorant	*Phalacrocorax varius*
pouched lamprey	*Geotria australis*

purple-spotted gudgeon (southern)	*Mogurnda adspersa*
river blackfish	*Gadopsis marmoratus*
river red gum	*Eucalyptus camaldulensis*
royal spoonbill	*Platalea regia*
Ruppia	*Ruppia tuberosa*
short-headed lamprey	*Mordacia mordax*
silver perch	*Bidyanus bidyanus*
southern bell frog	*Litoria raniformis*
spangled perch	*Leiopotherapon unicolor*
straw-necked Ibis	*Threskiornis spinicollis*
trout cod	*Maccullochella macquariensis*
water couch	*Paspalum distichum*
white-bellied sea-eagle	*Haliaeetus leucogaster*
white ibis	*Threskiornis molucca/moluccus*