



Australian Government



Basin-wide environmental watering strategy



Murray-Darling Basin Authority

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Cover image: Aerial view of a large ibis colony in the Gwydir Wetlands in 2012.

Photo: Joshua Smith, courtesy of the NSW Office of Environment & Heritage

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'.

This report may contain photographs or quotes by Aboriginal people who have passed away. The use of terms 'Aboriginal' and 'Indigenous' reflects usage in different communities within the Murray–Darling Basin.

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A note from the Chair

The Basin-wide environmental watering strategy is one of the most important parts of the implementation of the Basin Plan.

Its aim is to bring about enduring environmental change through strategic use of the water set aside for environmental health.

Importantly, the strategy identifies how we can best achieve the desired environmental outcomes in the Basin through better coordination and cooperation between agencies and across borders; and use our water as wisely as possible to maintain a river system that is resilient and healthy.

More than a century of development in the Basin has had a real effect on its rivers and ecological health and it will be through sensible and strategic use of our water that we have an opportunity to ensure the Basin is best placed to continue supporting its communities and industries for generations to come.

I thank those people who took the time to give their [feedback](#) and recognise their ongoing interest in both the environmental imperatives and how the river system is managed. Over time, as more of the management of environmental water is 'localised', giving communities a say and the opportunity to participate, this strategy will be seen as one of the foundation tools for better river management.

Achieving the environmental outcomes set out in the strategy will be a cooperative endeavour that relies on governments and communities continuing to work together.

Craig Knowles

Chair, Murray-Darling Basin Authority

Summary

As a nation, we are working towards a more sustainable future for the Murray–Darling Basin. Sustainable and efficient management of a water resource that spans such a large geographic area, across five state and territory borders and in a highly-variable climate, is a significant task. It concerns the careful balancing of the needs of people—to support productive industries and communities—with the need to restore and maintain the health of thousands of kilometres of rivers, more than 30,000 wetlands (many of national and international importance) and dependent native vegetation. This vegetation is important for shelter, food and meeting the breeding requirements of many species, particularly waterbirds and fish.

Under the new plan of management for the Basin's water (the [Basin Plan 2012](#)), desired environmental [objectives](#) were identified. To achieve them, an additional long-term average of 2750 gigalitres of water per year is being set aside to restore and maintain the health of the Basin's most important water-dependent ecosystems—to deliver a healthy, working river system into the future. There has also been significant government investment and community effort in water savings and purchase projects. It is therefore critical that the water we set aside for environmental health is used efficiently and well.

The Basin-wide environmental watering strategy (the strategy) is the next step. It builds on the Basin Plan and is intended to help environmental water holders, Basin state governments and waterway managers plan and manage environmental watering at a Basin scale and over the long term to meet the environmental objectives. The strategy is only one element in the planning process—other important elements include long-term watering plans and water resource plans (consistent with this strategy) that Basin states are preparing at a finer scale for each region.

The strategy sets out the Murray–Darling Basin Authority's best assessment of how four important components of the Basin's water-dependent ecosystems are expected to respond over the next decade, given current operating rules and procedures. This includes making the best use of all water—including held, planned, environmental and consumptive water *en-route*—to achieve these objectives (noting that other variables like climate, fire, complementary actions or certain rules may affect the outcomes in some places). The four components: river flows and connectivity; native vegetation; waterbirds; and native fish have all declined appreciably because of the way we capture, divert and manage water. They are also good indicators of the health of river systems, and respond to environmental watering.

Working together to deliver environmental water at the right times and places to stimulate a desired environmental response is expected to achieve the outcomes summarised in Table 1. To develop suitable management strategies which will work to achieve the expected outcomes, the MDBA drew upon tested practices which have emerged from decades of knowledge and experience of managing environmental watering in the Basin by many people, albeit at smaller scales. At a Basin scale, efficient and effective water management depends upon thinking about the water resource as a whole—as actions taken in one place have an effect on downstream catchments. It is also important when managing rare, unique or representative species.

The key strategies to achieve the objectives of environmental watering are outlined in this document. They include:

- harnessing local community land and water knowledge
- management of all water to benefit the environment where possible—such as cooperating to divert consumptive water deliveries through a wetland *en-route*
- management in harmony with biological cues (including responses to flow) to restore elements of a more natural flow regime—as an example, high river flows or a flow release into a wetland at times when it would naturally have occurred prior to river regulation, so as to trigger fish or bird breeding
- coordination to achieve the best outcomes and target multiple sites with deliveries of water (in and between rivers), where possible
- management of any risks associated with the delivery of environmental water
- applying adaptive management (learning from doing) when planning and prioritising the next use of environmental water.

Each year, the MDBA collaborates with the Commonwealth Environmental Water Holder, Basin state and local governments, river operators, advisory groups, Aboriginal representatives, catchment managers, irrigation groups, landholders and others; and publishes an environmental watering ‘outlook’ and priorities (an annual expression of this strategy). These provide guidance to water managers about the most important needs from a whole-of-Basin perspective, and consider prevailing and forecasted conditions and water holdings. State governments and other water managers are then responsible for planning, collaborating and delivering environmental water, and they prioritise their activities based on regional or local conditions and needs.

The Basin Plan is in the early stages of its rollout. This is the first Basin-wide environmental watering strategy—there remains significant work to be done in the next five years that will influence the next iteration (including water resource plans, sustainable diversion limit adjustment, the Constraints Management Strategy, monitoring and evaluation and much more).

Table 1 Summary of quantified environmental expected outcomes that can be achieved beyond 2019

River flows and connectivity	Vegetation	Waterbirds	Fish
Improve connections along rivers and between rivers and their floodplains	Maintain the extent and improve the condition	Maintain current species diversity, improve breeding success and numbers	Maintain current species diversity, extend distributions, improve breeding success and numbers
<p>Maintained base flows:</p> <ul style="list-style-type: none"> at least 60% of natural levels <p>Improved overall flow:</p> <ul style="list-style-type: none"> 10% more into the Barwon–Darling¹ 30% more into the River Murray² 30–40% more to the Murray mouth (and it open to the sea 90% of the time) <p>Maintained connectivity in areas where it is relatively unaffected:</p> <ul style="list-style-type: none"> between rivers and floodplains in the Paroo, Moonie, Nebine, Warrego and Ovens <p>Improved connectivity with bank-full and/or low floodplain flows:</p> <ul style="list-style-type: none"> by 30–60% in the Murray, Murrumbidgee, Goulburn and Condamine–Balonne by 10–20% in remaining catchments³ <p>Maintain the Lower Lakes above sea level</p>	<p>Maintenance of the current extent of:</p> <ul style="list-style-type: none"> about 360,000 hectares 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 <p>Maintain the current condition of lowland floodplain forests and woodlands of:</p> <ul style="list-style-type: none"> river red gum black box coolibah <p>Improved condition of:</p> <ul style="list-style-type: none"> southern river red gum 	<p>Maintained current species diversity of:</p> <ul style="list-style-type: none"> all current Basin waterbirds current migratory shorebirds at the Coorong <p>Increased abundance:</p> <ul style="list-style-type: none"> 20–25% increase in waterbirds by 2024 <p>Improved breeding:</p> <ul style="list-style-type: none"> up to 50% more breeding events for colonial nesting waterbird species a 30–40% increase in nests and broods for other waterbirds 	<p>Improved distribution:</p> <ul style="list-style-type: none"> of key short and long-lived fish species across the Basin <p>Improved breeding success for:</p> <ul style="list-style-type: none"> 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 5/10 years <p>Improved populations of:</p> <ul style="list-style-type: none"> 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) <p>Improved movement:</p> <ul style="list-style-type: none"> more native fish using fish passages

¹ Comprising tributary contributions from: Condamine–Balonne, Border Rivers, Gwydir, Namoi and Macquarie–Castlereagh catchments

² Comprising tributary contributions from: Murrumbidgee, Goulburn–Broken, Campaspe, Loddon and Lower Darling catchments

³ Border Rivers, Gwydir, Namoi, Macquarie–Castlereagh, Barwon–Darling, Lachlan, Campaspe, Loddon and Wimmera catchments

1. Introduction

The Basin Plan is about placing the Murray–Darling Basin on a sustainable footing. The overarching aim is to ensure that there is a balance between the competing demands on the water resources of the Basin (economic, social and environmental). This balance should ensure that enough water is available to support productive industries, farmers and communities into the future, while leaving sufficient water in the Basin's river system to ensure a healthy environment.

Spanning parts of four states and all of the Australian Capital Territory, the Murray–Darling Basin contains Australia's largest river system, comprising the Murray and Darling rivers and their tributaries. Ranked fifteenth in the world in terms of length (3,780 km) and twentieth for area, the Basin extends across 14% of Australia's landmass. However, in the driest inhabited continent on Earth, much of the Basin receives little direct rainfall and, because of its low topography, the long, slow-flowing rivers have high evaporation rates (around 94% of rainfall). Additionally, periodic drought is a natural part of our climate, and droughts can last a decade or more. The Murray–Darling system therefore carries one of the world's smallest volumes of water for its size.

Nevertheless, the Basin's aquatic ecosystems, which include more than 30,000 wetlands, have sustained Aboriginal people for more than 45,000 years—providing food and shelter, meeting their social needs and supporting a continuing spiritual connection to their lands. These ecosystems, which are adapted to the flow variability in the Basin, currently underpin the health and wellbeing of more than two million Basin residents, and another one million people to whom Basin water is piped. Basin water resources are also managed for river navigation, power generation, industry, fisheries and agricultural production and play an important role in tourism and cultural practices. In short, they are critical for social and economic prosperity.

In Australia's climate, supporting the economic base without overly compromising water-dependent ecosystems is challenging. Sufficient flow is vital as, in an average year, two million tonnes of salt (leaching out of our old soils and rocks) flows down the Murray–Darling. In the southern system, most rain falls across the upper reaches of the rivers in New South Wales and Victoria, and extraction by these states (particularly during drought) can result in limited flow to the floodplains of the lower reaches and out of the Murray mouth in South Australia. Without flushing flows, salinity quickly builds up and algal blooms increase, leading to ecosystem damage. The removal of tree cover combined with irrigation has also led to rising water tables, mobilising more salt. These factors (and others) threaten agricultural production and reduce drinking water quality; and Basin communities and governments have been actively working to address these issues for decades.

As more and more water has been diverted for human consumption, flow through the system to the sea has reduced by 75% on average. Water storage in dams and weirs changes the natural pattern (volume, timing and duration) of flow events through parts of the river system. It also prevents most of the natural small-to-medium sized floods that once occurred. In the lower reaches of the system, many wetlands experience 'man-made droughts' in over 60% of years (compared to natural droughts in 5% of years, pre-development). At the end of the system, the Coorong and Lakes Alexandrina and Albert (the Lower Lakes), together a Ramsar site of importance for migratory shorebirds, have been particularly affected. With reduced area of healthy wetland and floodplain woodland, and without flow triggers which stimulate waterbird breeding and fish spawning, many populations have been declining. This is also occurring over many parts of

the Basin where the river has lost its connection with adjacent wetlands, creeks and flood-dependent forests.

Within a variable climate that includes decade-long drought (as recently experienced), the level of water use had become unsustainable. The aim of the Murray–Darling Basin Plan (and other water reform) was to address this—but not to return freshwater ecosystems to a ‘natural’ state—rather, to deliver a healthy, working river system. This means one that supports the social and economic needs of people, while continuing to maintain the health of important ecosystems requiring periodic water flow. The ability to achieve this is now possible because we’ve set a sustainable level of consumptive use (or [Sustainable Diversion Limit](#)). This returns an average of 2750 gigalitres (GL) of water per year for targeted environmental use, augmenting existing state environmental water holdings and water sharing and water management arrangements.

This strategy builds on the work that underpinned the [Basin Plan](#) and the sustainable diversion limit (SDL). It further articulates the environmental outcomes that should be possible through the broader water reforms. These include: water recovered for the environment and managed by the Commonwealth Environmental Water Holder (with the final portfolio to be determined by where future water recovery occurs and following the [SDL adjustment process](#)); the outcomes of the implementation of the [Constraints Management Strategy](#); and the development and/or review of environmental watering and [water resource plans](#) across the Basin.

Achieving the trans-boundary, wide-scale environmental outcomes sought by the Basin Plan will take time and depend upon governments and communities working together on all of these initiatives. The Australian Government has invested heavily in irrigation modernisation, environmental works and measures (so water can be moved to places where it is needed), and water purchasing. Investments in better infrastructure and irrigation efficiency projects are helping industries and farmers adjust to less water availability. Getting these reforms right will mean a future for the Basin that includes strong communities with greater certainty and robust economies which are more resilient to change, underpinned by a healthy river system.

Box 1: Characteristics of a healthy, working river system

A ‘healthy, working river’ is one in which the natural ecosystem has been altered by the use of water for human benefit, but retains its ecological integrity while continuing to support strong communities and a productive economy in the long-term.

For the many rivers in the Basin, water is captured, extracted or diverted to support communities, agriculture and other industries. Communities also value healthy and functioning river and floodplain ecosystems, which provide many important services. These include clean water for drinking and agricultural use, nutrient cycling between the river and floodplain, fish stock for anglers, and an environment that supports tourism, recreation and cultural values. To achieve these multiple benefits, there needs to be a balance between the water available to the environment and the water that is used by communities and industries – hence the concept of a ‘healthy, working river’.

Typically, working rivers have dams, weirs and other infrastructure; and towns, agriculture and developments on adjacent floodplains. These will continue to exist, although how they are managed may evolve. A healthy, working river also supports biological communities, habitats and ecological processes and is resilient to natural variability.



Figure 1 David Papps (CEWH) with James Maguire (NSW Office of Environment and Heritage) and local landholders Dianne Williams and Iain Lindsay-Field viewing environmental watering at Paika Lake, NSW

(Photo courtesy of the Department of the Environment.)

Purpose of the strategy

The strategy is intended to assist environmental water holders, Basin state governments and waterway managers to plan and manage environmental watering at a Basin scale and over the long term to meet the environmental objectives in the Basin Plan. This includes making the best use of all available water (including planned and held environmental water and consumptive water *en-route*) to achieve these objectives.

The strategy describes:

- the important environmental outcomes expected to be achieved in the long term
- strategies for the management and use of water to maximise outcomes
- how various partners will work together to plan and manage environmental water
- the approach to determining the Basin annual environmental watering priorities so as to achieve the long-term outcomes.

Where possible, outcomes in this strategy are measurable to assist in evaluating success and to inform adaptive management. The strategy will evolve and be reviewed over time in response to monitoring and evaluation, new knowledge and changing circumstances. These will include the outcomes from other Basin Plan activities including the Northern Basin review, the SDL adjustment process, water recovery and implementation of the Constraints Management Strategy.

In the Basin's highly-variable climate (see [Figure 2](#)) the water available for the environment changes from year to year and from place to place. Therefore, the outcomes and watering strategies in this document are designed to enable water managers to respond to changing conditions.



The strategy is one element in planning and managing the Basin's water resources to achieve the expected environmental outcomes from the implementation of the Basin Plan. Other important elements include long-term watering plans and water resource plans that Basin states will prepare (prior to June 2019) for each region. The long-term watering plans will provide detail on environmental outcomes at a regional scale. When revised, water resource plans will need to provide for environmental watering to occur consistently with this strategy and the long-term watering plans; so as to achieve the environmental outcomes sought.

Box 2: Indigenous values and uses

The Basin Plan requires that 'Indigenous values and uses' be taken into consideration (along with other matters) in the preparation of the Basin-wide environmental watering strategy and Basin annual environmental watering priorities. The Basin Plan also requires that Basin states prepare long-term watering plans in consultation with local communities and persons materially affected by the management of environmental water. Basin states also have obligations under the Basin Plan in relation to Indigenous values and uses when preparing water resource plans. These obligations include 'having regard to the views of Indigenous people with respect to cultural flows'.

As set out in the Basin Plan, environmental watering will be undertaken in order to achieve environmental outcomes. At the same time, environmental watering can contribute to some outcomes sought by Aboriginal peoples—so it can aim for and take into account cultural values. However, Aboriginal peoples' concept of cultural water or cultural flows⁴ is broader than can be accommodated through environmental watering alone.

A multi-year project, the [National Cultural Flows Research Project](#), is currently underway with the aims of providing research on Aboriginal values relating to water and other natural resources and informing water planning and management policy. This project is likely to be an input into future review and update of the strategy (see page [80 – Future Work](#)).

The importance of a Basin perspective

Water connects across the landscape—it runs off catchments; along rivers; into billabongs, lakes and wetlands; across floodplains and ultimately to the ocean. Because of this connectivity, actions involving water taken in one place affect other parts of the Basin. Similarly, ecosystem functions and food webs are connected across administrative boundaries (such as state borders) and should be managed holistically.

The Basin contains water-dependent ecosystems of national significance and several sites are listed in international agreements for migratory waterbirds (i.e. Ramsar and Bonn conventions and bilateral agreements with China [CAMBA], Japan [JAMBA] and the Republic of Korea [ROKAMBA]). It is important that these are managed in the national interest.

⁴ The Murray Lower Darling Rivers Indigenous Nations have defined cultural flows as 'water entitlements that are legally and beneficially owned by the Indigenous Nations of a sufficient and adequate quantity and quality to improve the spiritual, cultural, environmental, social and economic conditions of those Indigenous Nations'. (From the [Echuca Declaration](#))



A Basin-wide approach to environmental watering is particularly required:

- where the water resources of multiple regions are needed to achieve desired outcomes; such as in the lower River Murray or along the Darling River
- where important ecosystems or organisms with a need for coordinated management are broadly distributed across state boundaries—such as fish, migratory waterbirds and large floodplain forests
- for rare, unique or representative species at the Basin scale; or habitats such as the estuary and the internationally-significant migratory bird sites.

Addressing constraints

In some parts of the Basin, water resource development and associated regulation make it difficult to restore more natural or ecologically-useful flows to the environment. Constraints include physical structures such as weirs, locks, dams, low-lying bridges and water pumps; and operational issues that arise from the way the Basin is managed. Many of these are vital to serve the economic outcomes of the Basin—so dams, weirs and towns on floodplains will continue to be important aspects of a working Basin. However, the operation of dams and how water will be managed along rivers may be able to be changed: by building new bridges; moving pumps; obtaining permission or rights to deliver flows at different levels; or changing policies. The extent to which these constraints can be removed or modified will affect the manner in which water can be made available and/or delivered to improve the Basin's environment.

The MDBA developed the [Constraints Management Strategy 2013 to 2024](#) to help guide the work of identifying and removing, or modifying, physical and operational constraints. This is a long-term project. The Basin-wide environmental watering strategy generally identifies outcomes that can be achieved within current physical constraints. However, some of the strategies which are fundamental to managing environmental water in the most effective way (like protecting environmental water in the river) are not easily achieved within current administrative arrangements. Therefore, governments are looking to address these issues. Addressing constraints in the coming decade would be expected to generally improve the environmental outcomes achievable beyond those outlined in this strategy.

Basin governments will consider these matters (both physical constraints and management, and operational practices) between now and mid-2016; including as part of the operation of the [sustainable diversion limit adjustment mechanism](#).

Some of the opportunities to achieve better environmental outcomes by removing or modifying constraints have been identified in some sections of this strategy. Any changes arising from the Constraints Management Strategy will be reflected in future revisions of the strategy.

Consultation and feedback

The draft of this strategy was open to public feedback between 21 August and 26 September 2014; and briefings were given to many interested groups. The report on the draft Basin-wide environmental watering strategy consultation is available on the MDBA website. Further information about the consultation period is at Appendix 8.

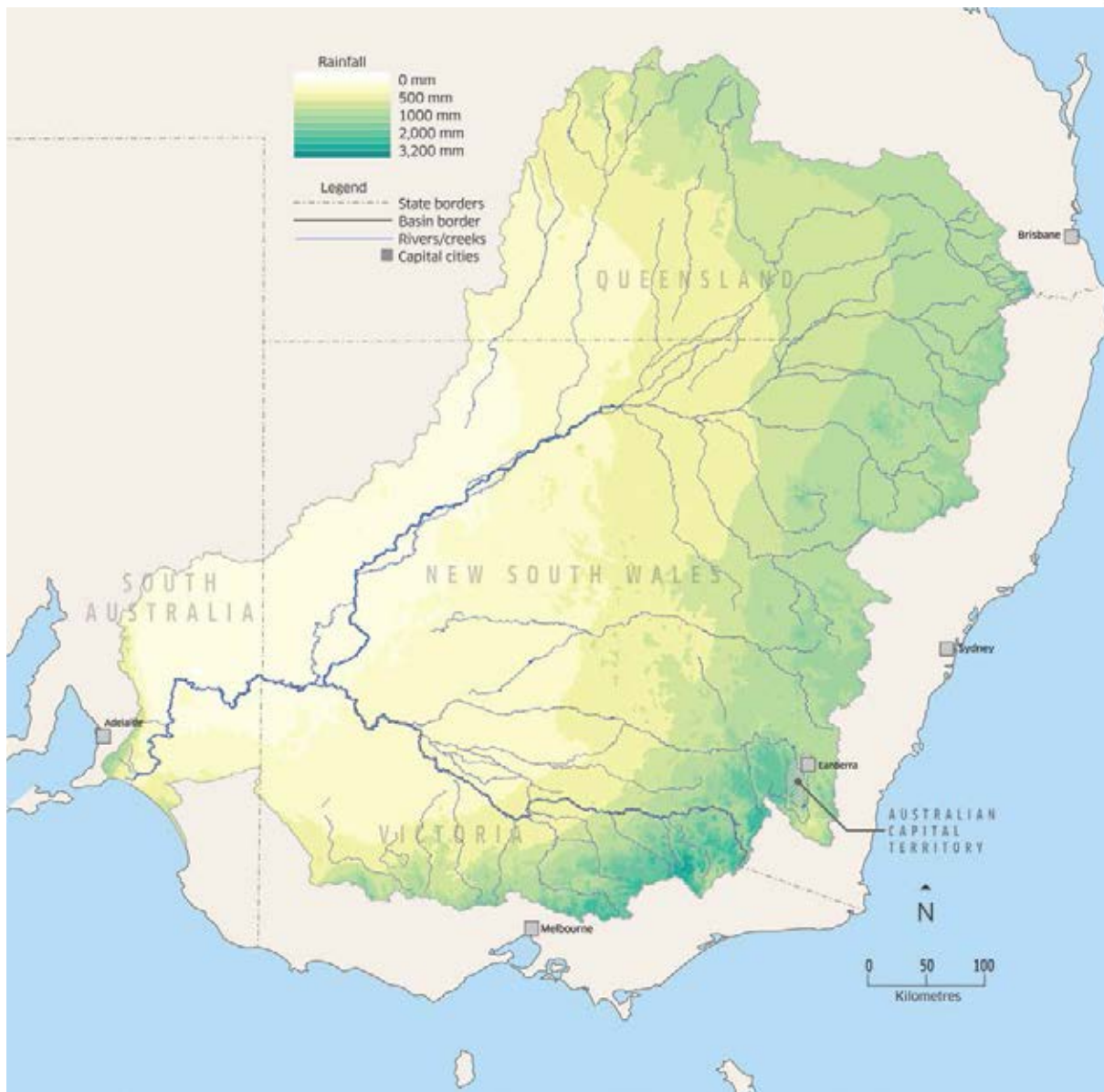


Figure 2 Murray-Darling Basin map showing average annual rainfall

Box 3: Basin statistics

Area – 1,059,000 km² – 14% of mainland Australia

*Total annual average inflow – 32,500 gigalitres (billion litres);
but highly variable*

*Rainfall – predominantly winter–spring, except for most northern catchments, which
receive summer rainfall*

23 river valleys; 77,000 km of rivers; 30,000+ wetlands

*Basin resident population – around two million; out-of-basin transfers sustain significant other
populations*



2. Expected environmental outcomes

Context

The implementation of the Basin Plan is seeking to alleviate some of the adverse effects of river regulation and consumption in a way that also provides water users with security and supports communities. With water available in the environmental portfolio, and through relevant planning instruments (e.g. water resource plans), the goal is to partially reinstate or protect some ecologically-important flows.

Restoring flows so that rivers are better connected to their floodplains is important not only for the plant communities that depend upon inundation for growth and seedling survival; but also in delivering nutrients and providing habitat and feeding opportunities for animals. Such flows also often act as breeding triggers for organisms. Connecting the Basin's system of creeks, streams and rivers to the estuary, and ultimately the sea, also provides many benefits. For example, it improves water quality, exports salt and allows organisms to migrate between different habitats and catchments.

These processes underpin complex food webs and lead to an increase in the number and diversity of habitats. Invertebrates (such as insects and crayfish), vertebrates (such as fish, waterbirds, frogs and turtles), and vegetation respond to this through reproduction, growth and survival. This, ultimately, improves biodiversity (see [Figure 4](#) and the [River flows and connectivity](#) section for more information). Water managers use the most contemporary information about the links between flow and environmental outcomes, as well as local knowledge, to target environmental outcomes through the types of interactions identified in Figure 4.

The particular outcomes from environmental watering will change from year to year, depending on a range of factors including the condition of the environment, previous climatic conditions and the prevailing climate. Managed environmental watering events alone will not achieve the expected outcomes; other flows within the river, including natural events and consumptive flows, will play an important role.



Figure 3 Balonne River near St. George. Photo: Bill Johnson, MDBA

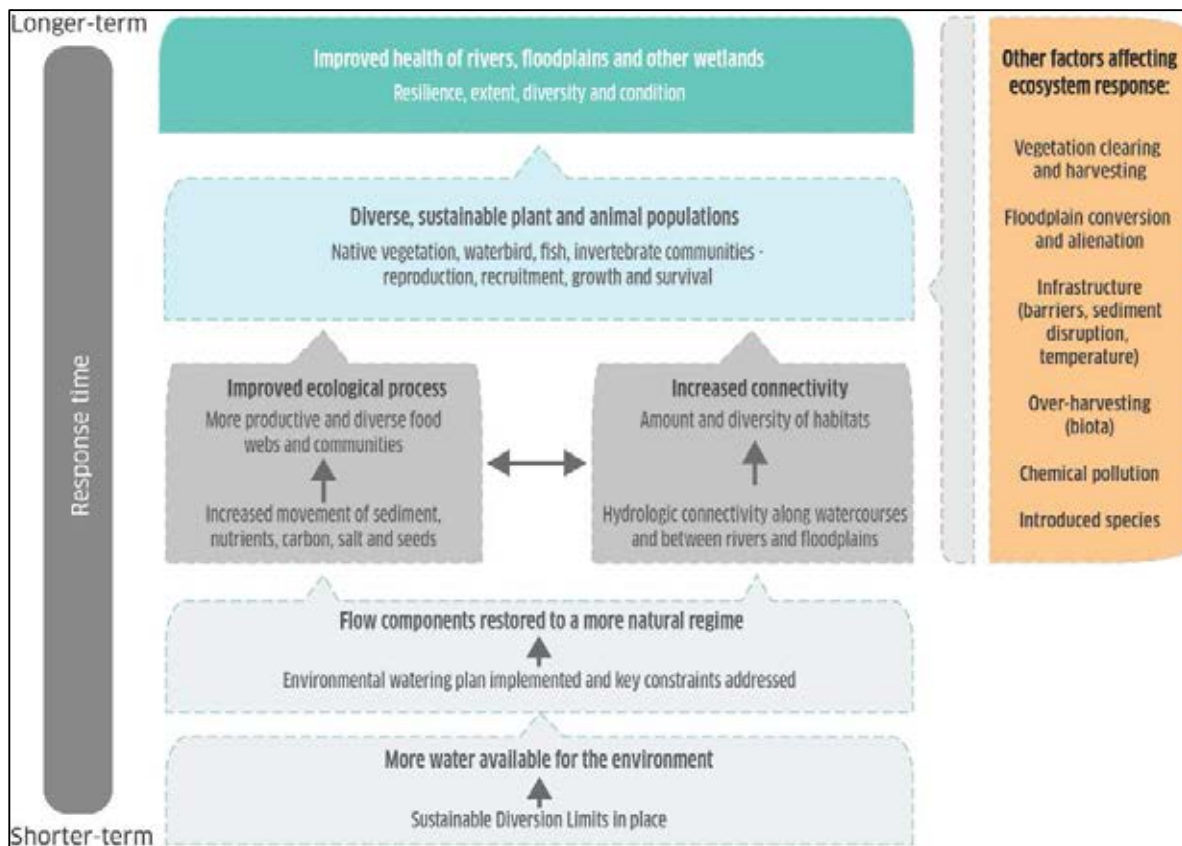


Figure 4 Relationship between flow and outcomes

The approach to environmental watering will differ between regulated and unregulated rivers:

- in some parts of the Basin, water resources are relatively less developed and water-dependent ecosystems are largely natural – such as in the Paroo River catchment. In these areas there is little need and less capacity (e.g. infrastructure) to actively manage environmental flows
- in other unregulated, but more developed systems (for example, the Condamine–Balonne catchment) targeted water recovery will serve to restore or protect flow components that will improve the water-dependent ecosystems
- in other Basin catchments, rivers are highly developed, and flows are significantly modified by regulation structures and water extraction; with consequently higher impacts on river health. The Goulburn, Murray and Murrumbidgee rivers exemplify this. These systems have complex management arrangements and multiple stakeholders with competing interests. In these rivers, environmental flows can be actively managed (within constraints) by releasing water from storages at suitable times.

The northern part of the Murray–Darling Basin generally has more of the unregulated rivers and therefore less active management of environmental water. These areas will thus have a heavier reliance on managing access to rivers to protect environmental outcomes. However, the generalisation of a more unregulated north has exceptions and in reality each catchment will need to be managed to reflect its level of regulation, water use patterns and the breakup of held and planned environmental water.

Environmental objectives of the Basin Plan

Within the context of a healthy, working river system; the Basin Plan sets out three environmental objectives for water-dependent ecosystems (see [Figure 5](#)). The Basin Plan also sets out high-level targets by which to measure progress towards the objectives (Appendix 1).

The Basin-wide environmental watering strategy further elaborates on these objectives and targets by describing the expected outcomes for four ecological components of the river system: river flows and connectivity, native vegetation, waterbirds and native fish.

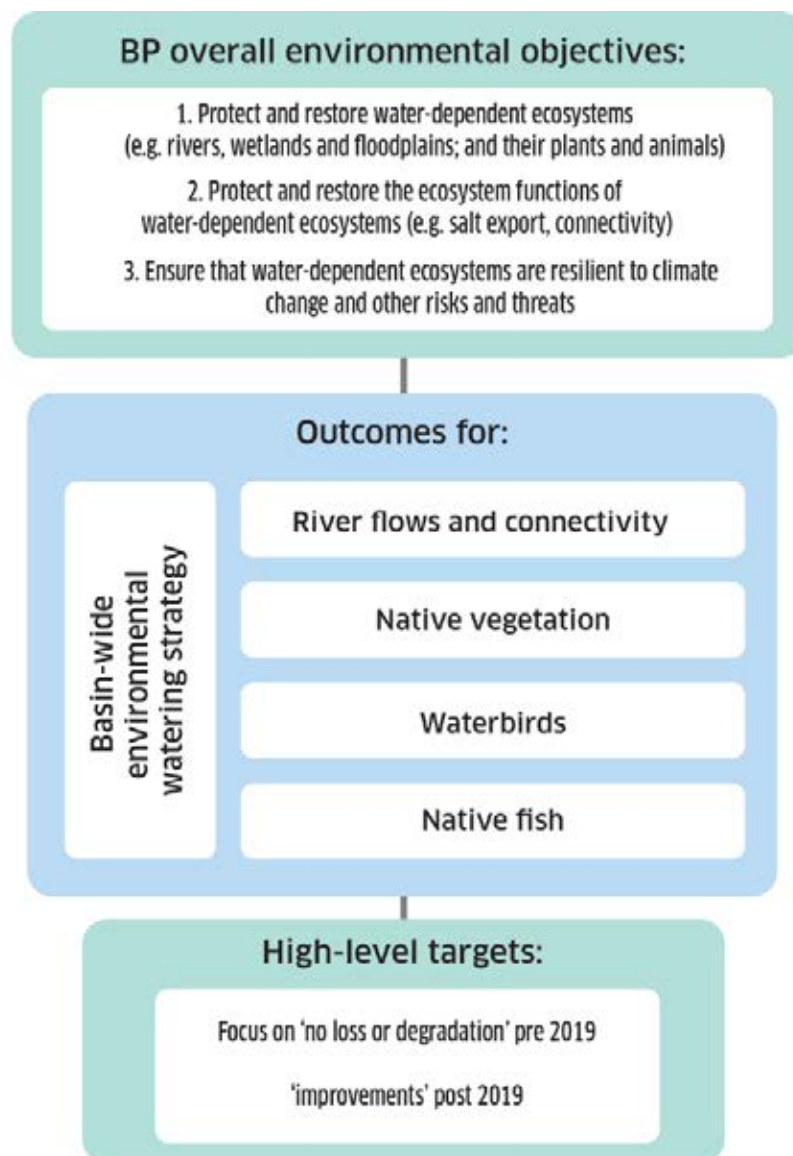


Figure 5 The focus of the strategy and outcomes

The strategy focusses on river flows and connectivity, native vegetation, waterbirds and native fish for the following reasons:

They are good indicators of the health of a river system and are measurable. Waterbirds, for instance, span the full range of freshwater environments; with different functional groups using different parts of the ecosystem (e.g. fish-eating and wading birds). The status of their populations therefore reflects the flow regimes of a range of environments and habitats within the river system. Waterbird populations are also measurable using existing scientific tools, so that it will be possible to monitor progress in achieving the expected environmental outcomes across the Basin. Monitoring and evaluation is addressed in more detail in the section [Measuring success](#).

They are important components of healthy functioning water-dependent ecosystems. For instance, [Longitudinal connectivity](#) enables organisms to move between habitats along the length of the river; while [Lateral connectivity](#) plays an important role in maintaining water quality, in addition to being important for the productivity of floodplain ecosystems.

They are responsive to environmental flows. For example, environmental flows are thought to be one of the most important actions that managers can take to restore native fish populations in the short- to medium term.

They are highly valued by people. For example, an estimated 430,000 Basin residents participate in recreational fishing, which depends upon a healthy native fish population. This activity generates around 11,000 jobs in the Basin and contributes \$1.3 billion to the Basin's economy each year. Native fish have totemic and cultural value for Indigenous communities.

They have declined appreciably as a result of water resource development. For example, waterbird numbers have declined by 72% since 1983, and a key functional group of waterbirds—migratory shorebirds—has been severely affected in places like the Coorong and Lakes Albert and Alexandrina. While waterbirds naturally respond to boom and bust periods driven by river flows and local rainfall, this overall long-term decline is particularly attributed to water extraction and capture that has prevented floodplain and wetland inundation (this is explained further in the [Waterbirds](#) section of this document).

They require a Basin-wide approach to be managed effectively. Native fish, migratory waterbirds and large floodplain forests are distributed across catchment and jurisdictional boundaries; and rare or unique communities require coordinated management.

The outcomes described in this strategy constitute the MDBA's best assessment of how the Basin's water-dependent ecosystems are expected to respond to environmental watering over the next decades. However, the various Basin ecosystems will take differing amounts of time to respond to environmental watering, particularly in an unpredictable climate, plus other natural resource management activities will impact on the ability to achieve these outcomes. This is discussed further in the section [Influence of other factors on expected environmental outcomes](#).

The approach outlined in this strategy and used by environmental water managers will also result in other outcomes (in addition to those reflected in these four components). As our knowledge and ability to predict changes improves, outcomes for additional matters related to the Basin Plan's objectives and targets may be added in future reviews of this strategy (see

section 7 [Future work](#)). Outcomes for water quality are already laid out within the Basin Plan (see Box 4 below), so only a few significant Basin water quality issues are covered in this strategy.

Box 4: Water quality

A Basin Plan objective is to maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the Basin.

Water quality and salinity targets are outlined in the Basin Plan. They include targets for managing water flow, water-dependent ecosystems, irrigation water, recreational water and long-term salinity planning and management (not reproduced here). The Basin Plan also requires each Basin state to develop a water quality management plan for each of their water resource plan areas—so water quality management will receive dedicated effort in coming years.

A salt export objective stated in the Basin Plan is to allow adequate flushing of salt from the River Murray system into the Southern Ocean. The additional water recovered under the Plan will contribute to this outcome; however, it will also be reliant upon other factors including the prevailing climate and active salinity management (including salt interception schemes).

Environmental water managers must and do consider their impact on water quality for other downstream uses. They must have regard to water quality targets for dissolved oxygen, cyanobacteria (e.g. blue–green algae) and salinity levels when making decisions about the use of environmental water (refer to the section ‘Manage risks associated with the delivery of environmental water’ on page [58](#)).

However, more generally the objective for the use of environmental water is to protect and restore water-dependent ecosystems and their associated ecosystem functions. Therefore in relation to water quality, environmental water managers will primarily have regard to targets identified for water-dependent ecosystems.

Timelines

The decline in the condition of the Basin’s water-dependent ecosystems has occurred over many decades. Redressing this decline is a long-term process; and improvements in the Basin’s environment will take some time to secure and measure.

Comprehensive improvement of the Basin’s water-dependent ecosystems will take place at different timescales and in some cases may take decades to occur. Some ecosystem responses—such as flow connections across floodplains and movement of waterbirds and native fish—will occur rapidly in response to environmental watering. Other responses—such as improved population structure of long-lived native fish—will not be evident for at least five to ten years. Observing widespread restoration of ecosystem responses and populations of key species that support a healthy river system in the Basin will likely take 20 or more years.

River flows and connectivity

Improvements in river system health can be achieved by improving the pattern of river flows.

Many of the Basin's rivers are regulated to provide water for towns and cities, and for recreational and economic activity, including irrigated agriculture. Water is captured for storage in dams (both on and off river), weirs, and locks; and made available for consumptive use as required. Water capture changes the volume and duration of river flows including over-bank, in-channel freshes and base flows, and also affects the seasonality of flow. The connectivity of rivers, both with the adjoining landscape and downstream (see figure below), have been affected by changes to flows.



Figure 6 Hydrological connectivity and flows

As discussed earlier (and as illustrated in [Figure 4](#)) environmental watering aims to restore parts of more natural flow patterns across the Basin. Environmental outcomes for vegetation, birds and fish are a consequence of both improved flows and greater connectivity along rivers and between rivers and their adjacent riparian areas and floodplains.

Longitudinal connectivity

Longitudinal connectivity throughout river systems (either flowing into downstream reaches or, in the case of connected systems, through to the sea) varies across the Basin. It fulfils important environmental functions—among them moving nutrients and sediments, allowing for organisms to disperse (including spawning), improving water quality and flushing salt out to sea.

River regulation and diversions have reduced the volume of water passing into the lower sections of many rivers, diminishing the health and resilience of lowland floodplains. Impacts often increase cumulatively downstream; therefore the greatest impacts on environmental health are seen in the connectivity of the Darling River with the River Murray and the connectivity of the River Murray with the Lower Lakes and Murray mouth.

Connectivity between the River Murray, Lakes Alexandrina and Albert, the Coorong (the estuary) and the Southern Ocean allows the movement of aquatic animals (particularly fish, some of which need to move between fresh water and salt water to survive).

Figure 7 illustrates longitudinal connectivity between rivers in the Basin (based on modelled flow using data from 1895–2009). It shows the proportion of inflowing water flowing out the end of each catchment naturally (blue bars); prior to the Basin Plan (red bars); and with water recovery under the Basin Plan (green bars)⁵.

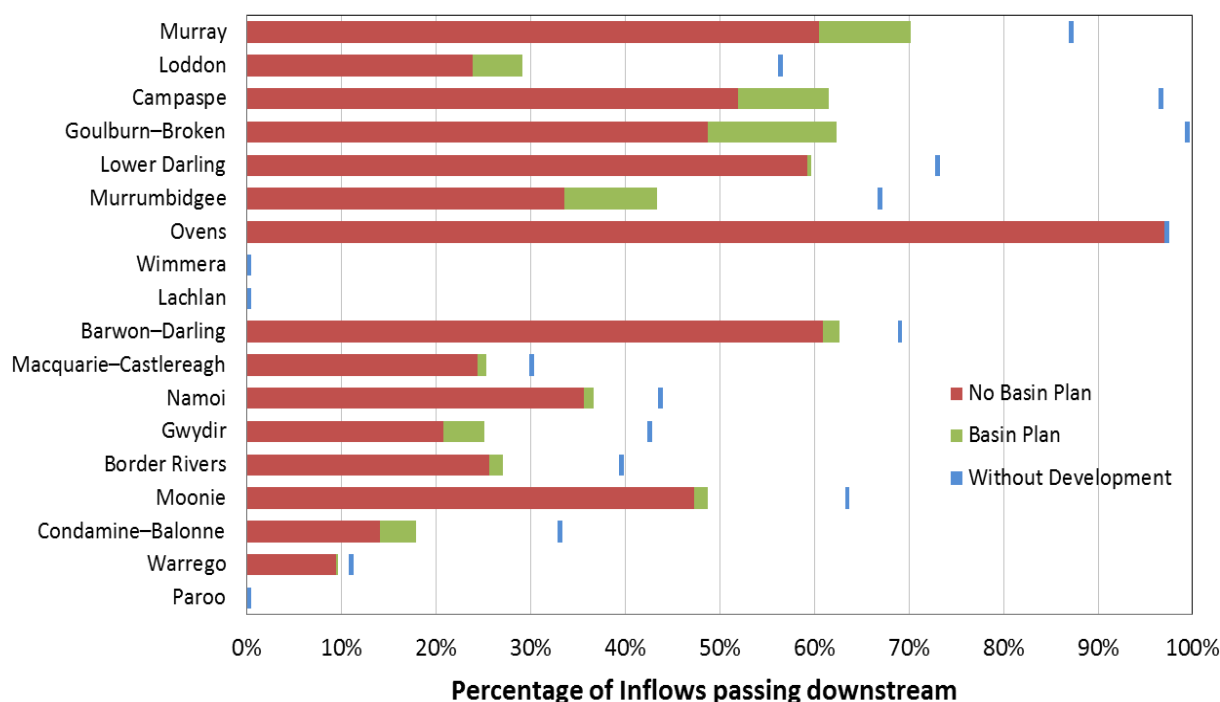


Figure 7 Proportion of inflowing water flowing out the end of river catchments across the Basin

Figure 7 shows, as a general trend, that the impact of development on connections between rivers has been greater in the southern Basin compared to the northern catchments (i.e. a larger gap between the red and blue bars). This reflects the historically higher level of development and extraction present in the southern valleys. Similarly, the proportional improvement in longitudinal connectivity achieved by environmental watering under the Basin Plan will also be greatest in the more southern developed valleys.

In-stream infrastructure like locks and weirs and other barriers may still limit the movement of some species in future. However, constructed fishways, higher flows that directly link upstream and downstream environments or modifications to the operations of structures should increasingly allow better passage of organisms.

⁵ While not physically connected, the Bogan, Macquarie and Castlereagh rivers are grouped in the Basin Plan into one water resource plan area. The Bogan and Castlereagh rivers are largely undeveloped, whereas the Macquarie is highly developed. Accordingly, their combination in Figure 7 may be misleading. The percentage of inflows passing downstream in the Macquarie by itself are: No Basin Plan–5%, Basin Plan–6% and Without Development–7%.

Lateral connectivity

The level of connection between rivers and their riparian corridors and floodplain (lateral connectivity) underpins floodplain and riverine ecological processes.

This level of connection varies in frequency, extent and timing across the Basin. While some valleys have experienced little change; in most developed valleys the frequency of flows which connect rivers with their floodplain has substantially reduced. In these rivers, the flows delivered from dams are almost always in-channel—so natural over-bank events have been reduced to the point that many floodplain ecosystems and the functions they support are at risk. This is illustrated in [Figure 8](#) (for part of the Murray floodplain). The two maps in this figure show that prior to development, the natural inundation frequency ranged from every year (i.e. 10 in 10 years) for some areas, every second year (i.e. five in 10 years) for a wider area, and through to once every ten years. Now, however, most of this floodplain is currently inundated only once or twice in a ten year period.

The pattern demonstrated in Figure 8 is repeated in many catchments throughout the Basin, including in unregulated valleys where water sharing plans permit most medium-sized events to be pumped.

The Basin Plan aims to at least partially reinstate this connection between rivers and their lower-lying floodplains. Valleys with highly altered river flows and large areas of lowland floodplains are the most important places in which to improve lateral connectivity. Priority examples include the Condamine–Balonne, Gwydir, Macquarie, Barwon–Darling, Lachlan, Murrumbidgee, Murray, Lower Darling and Goulburn–Broken.

Another group of the Basin's major river valleys have relatively intact high flow regimes, limited floodplains or their floodplains are at higher elevations (e.g. Border Rivers, Namoi, Campaspe, Loddon and Wimmera). In these systems, the improvements expected from the Basin Plan will largely be confined to in-channel flows or small over-bank events.

In the valleys where lateral connectivity is relatively unchanged by development (such as in the Paroo, Warrego, Moonie, Nebine and Ovens), connectivity needs to be maintained. The revision of water resource plans in these catchments will need to consider how to protect important parts of the flow regime.

The degree to which lateral connectivity can be improved throughout the Basin will be impacted by the extent of the floodplain which may be able to be managed (see Managed floodplain section [below](#)).

[Figure 9](#) shows catchments where the Basin Plan should result in connectivity improvements, for the different parts of the flow regime (base flows, freshes and bank-full/over-bank events). See [Figure 12](#) and the section on flow regimes for further explanation.

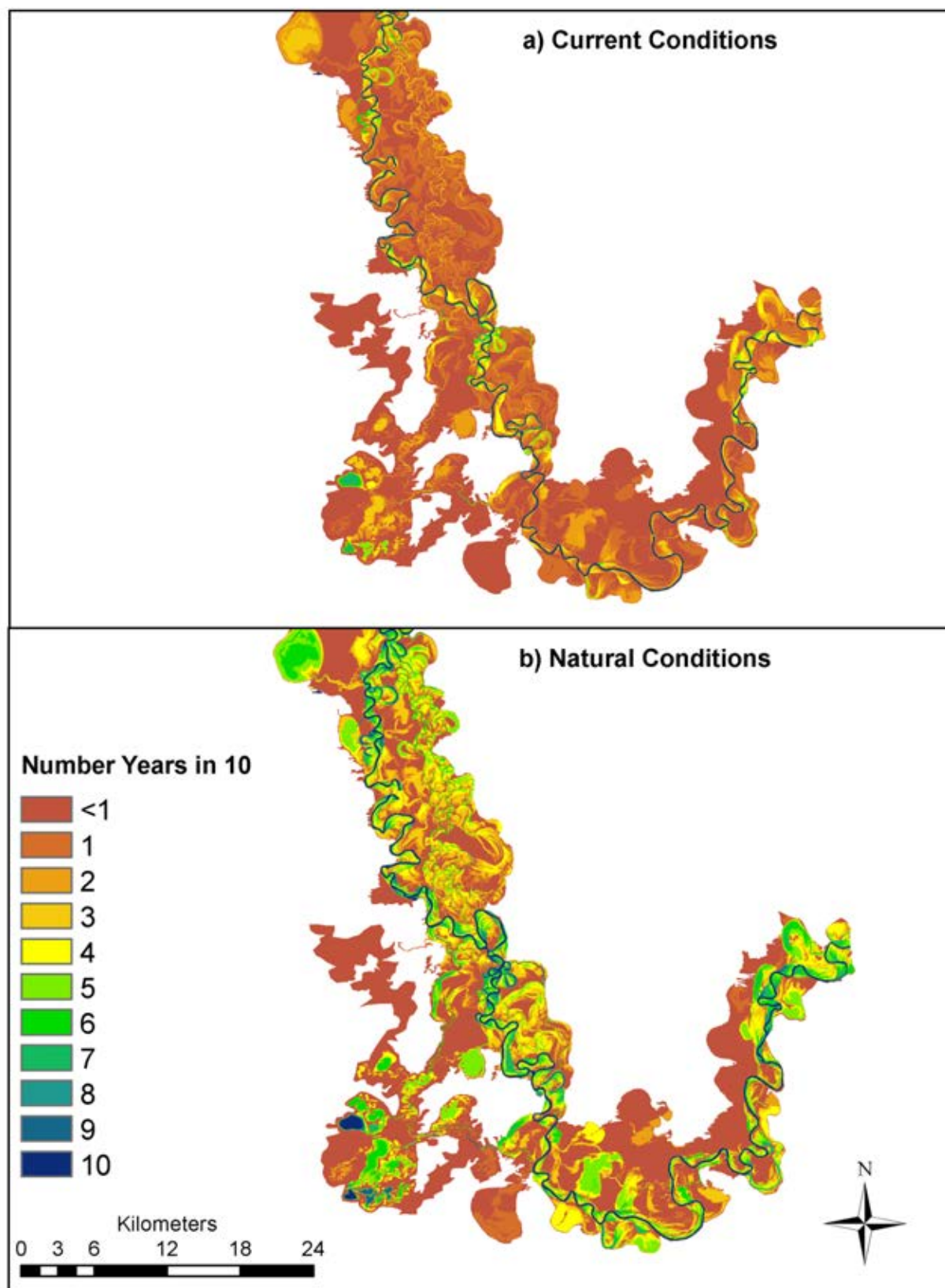
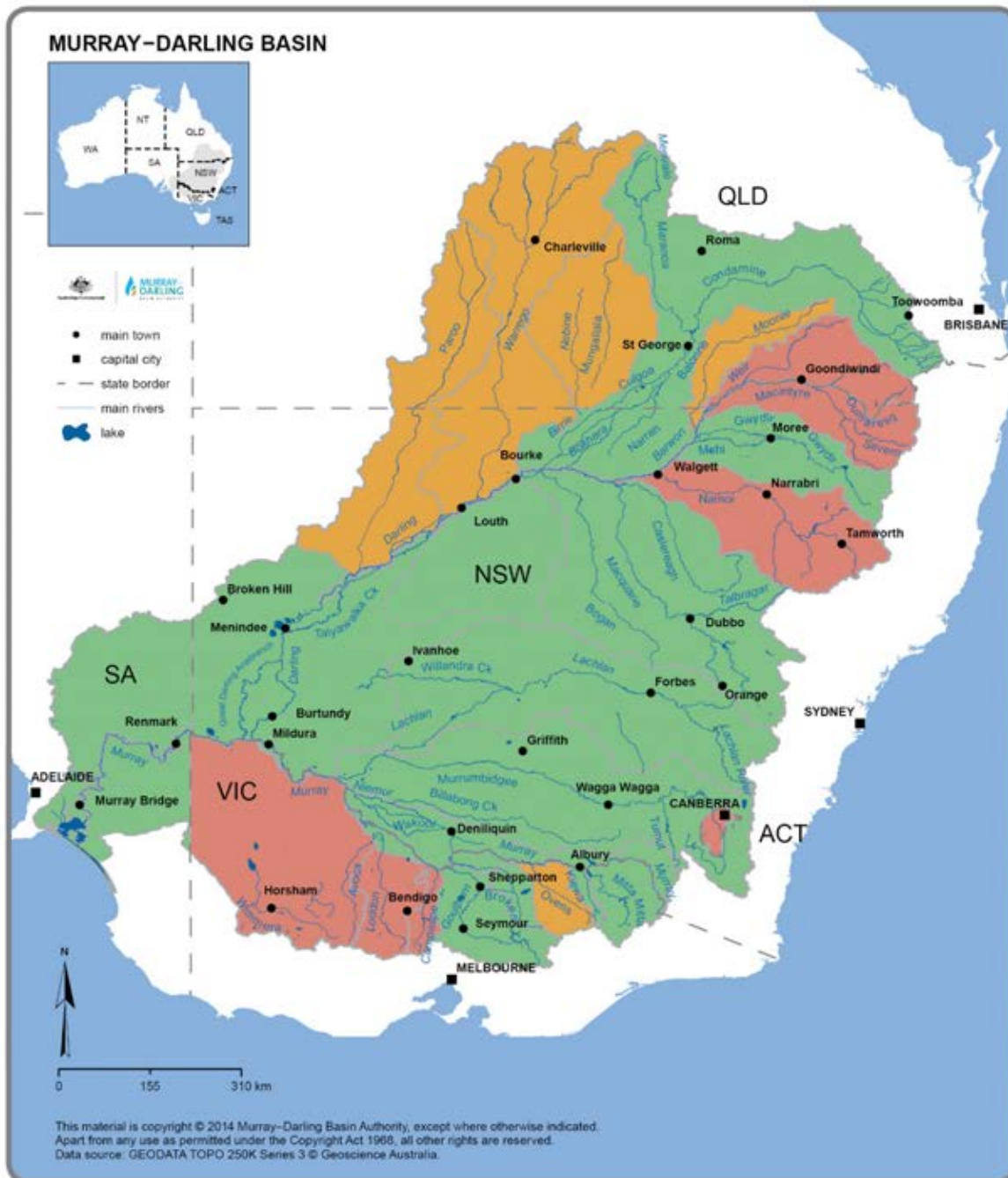


Figure 8 Frequency of inundation between Euston and Lock 10 on the River Murray under natural conditions



Legend:

- Minimal water resource development, therefore no improvements sought – rather, maintenance of all current flow components
- Improvements in connectivity are possible under the Basin Plan for base flows, low in-channel freshes and bank full/low floodplain over-bank flows
- Improvements sought in base flows and low in-channel flows only – as bank full and low floodplain over-bank flows are either relatively intact or there is limited floodplain

Figure 9 Level of flow component improvement expected under the Basin Plan (by catchment)

*It should be noted that the degree to which bank-full versus over bank flows can be achieved will depend on current constraints in each region and the work underway to address them.

Managed floodplain

In the context of a healthy, working river system (see Box 1) it is useful to think about the extent to which we can *actively* manage flows on the floodplain; versus areas which may be managed more passively and those which are out of scope for active management.

Connection to most medium and higher-level floodplains is out of the scope of what can be achieved through managed environmental watering, as there are towns and high-value agriculture or infrastructure in these areas. However, in low-lying areas that still flood periodically, people currently avoid building permanent infrastructure—these are areas which may be able to be improved.

The degree to which reconnection is possible will vary river to river, depending on the potential to address any impacts on private and public land and the current rules and practices for managing water. The scope to make potential improvements is being considered under the Constraints Management Strategy.

[Figure 11](#) shows the different areas (managed and unmanaged) of the floodplain and—to the extent possible with current inundation mapping—how they are likely to be influenced by the Basin Plan.

The **managed** floodplain includes:

- ‘likely inundation within current operational constraints’: an estimate of the extent of floodplain which could be **actively** managed with water recovered for the environment within the traditional operational constraints in the Basin. These areas occur within regions which generally have large headwater storages such as the Macquarie, Murrumbidgee and Murray regions. In the southern connected Basin, modelling of flood inundation has been linked to Basin Plan modelled flows to determine the extent of the managed floodplain. There are important caveats on this—see the notes under Figure 11 for detail
- ‘floodplain in undeveloped valleys’ shows the extent of floodplain expected to be maintained under the Basin Plan through **passive** management; including through rules in water resource plans and also, to a large degree, through natural events. Environmental water in these less developed regions (e.g Paroo, Warrego, Ovens regions) is not actively managed (i.e. released from storages) like those catchments in the category described above
- ‘likely additional area inundated with constraints relaxed’ depicts the additional area which **may** be able to be inundated (in the Gwydir and southern Basin) if key constraints to delivering higher flows are overcome, as highlighted in the lower River Murray (as highlighted in red in Figure 11).

The **unmanaged** floodplain includes:

- the ‘extent of floodplain beyond the scope of environmental watering under the Basin Plan’, which is generally reliant on natural large flow events for inundation.

In this assessment, the area of the managed floodplain in the River Murray is bolstered by inclusion of the area that can be inundated by the [Living Murray ‘environmental works’](#) sites. This refers to joint work by the Basin governments and the MDBA over the past ten years to plan and build infrastructure (including channels, levees, flow regulators and pumping stations) to help get water efficiently to high conservation value sites on the River Murray floodplain.

This engineering approach allows water to be delivered to sites which **otherwise could not be actively managed**. Such sites generally only received extensive inundation during high river over-bank flows; whereas regulated (in-channel) flows can now achieve similar outcomes through engineering works. These types of solutions are important opportunities that should be explored in the context of a healthy, working river system and where maintaining such high-value sites is important (i.e. The Living Murray floodplain sites are [Ramsar](#) listed).

Other opportunities for engineering solutions will be explored under the Basin Plan's [sustainable diversion limit adjustment](#) process. However, these solutions can only target a modest proportion of the overall floodplain. Also, some environmental sites have only limited potential for water exchange from the floodplain in this way, in comparison to natural watering events. Therefore, improving overall lateral connection with the managed floodplain will still be important in maintaining many important sites—including facilitating the vital exchange of water and nutrients between the floodplains and rivers.



Figure 10 Paroo River – an example of a river in an arid landscape. Photo: Kate Hodges

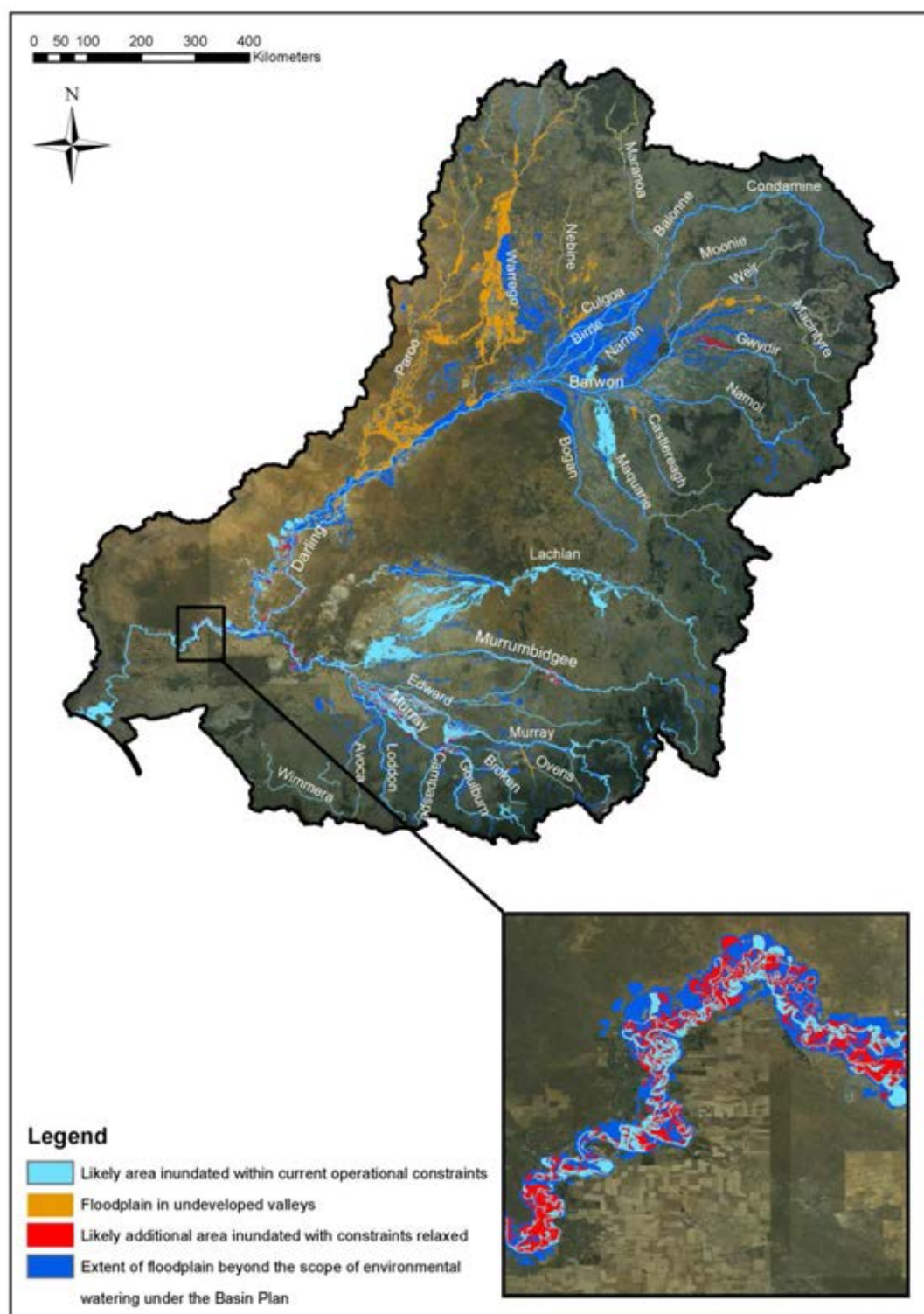


Figure 11 The extent of floodplain in the Murray–Darling Basin

Note: In the southern connected Basin, modelling of flood inundation extent has been linked to Basin Plan modelled flows to determine possible managed extents. In some areas there hasn't been a history of delivering higher managed flows. With these higher flows some local impacts may occur, which may mean only smaller areas can be managed currently, depending on local annual decisions. In the northern Basin, flood inundation information is not as detailed. This means that for areas in the Barwon–Darling, Condamine–Balonne, Gwydir and Bogan regions, the actively-managed floodplain has not currently been estimated. Work is currently underway through the Northern Basin review to look at inundation associated with Basin Plan flows.

Flow regimes

[Figure 9](#) shows the components of the flow regime that can be improved as a result of the Basin Plan. It divides the flow regime into categories (see [Figure 12](#)), each of which is important to ecosystem health. The identified improvements to the flow regimes across the Basin will support both longitudinal and lateral connectivity. In addition to the flow categories below, periodic drying (see Box 5) and hydrodynamic diversity (see Box 6) are important characteristics of the river systems of the Basin that should be considered by water managers.

Base flows (or low, in-channel flows⁶) are an important component of the flow regime—they maintain aquatic habitat for fish, plants and invertebrates. Base flows comprise long-term seasonal flows which provide drought refuge during dry periods and contribute to nutrient dilution during wet periods or after a flood event. These flows are generally maintained by seepage from groundwater; but also by low surface flows.

In-channel fresh events are small-to-medium flow events which inundate benches or small anabranches, but stay in the river channel. They are generally relatively short in duration (i.e. a few days to a month). These events replenish soil water for riparian vegetation, maintain in-stream habitats and cycle nutrients between parts of the river channel. They also inundate snags and woody debris—important sites for fish spawning events (see [Figure 13](#)). These types of flows occur in most years, or possibly multiple times within a year.

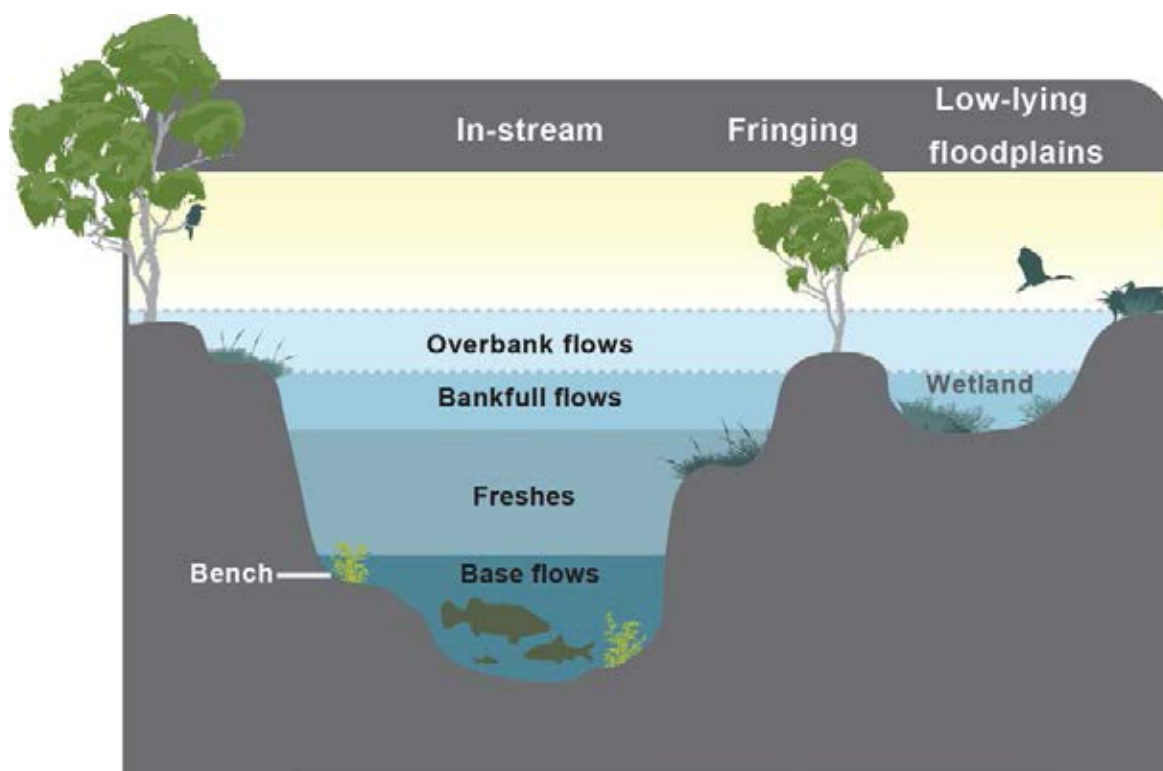


Figure 12 An illustrative river cross-section showing components of a flow regime

⁶ The lowest 20% of flows



Bank-full and low-floodplain (over-bank) flows are the larger flow events that fill the river channel and may inundate channel benches, the riparian zone, anabranches/flood-runners and low parts of the floodplain, and replenish local groundwater. They are important for the water-dependent ecosystem surrounding the floodplain, comprising vegetation communities such as river red gum, black box and lignum. These events also provide opportunities for birds to breed and allow fish to move from the river to the wider floodplain next to the river, and back to the river. Large-scale nutrient and sediment cycling between the river and the floodplain is an important benefit from these types of events.

Large-scale events which inundate the higher floodplain occur only during very wet years and cannot be actively managed with water recovered under the Basin Plan.

Box 5: Periodic drying and disconnection

Ecosystems are well adapted to the natural flow variability in the Basin. Periodic drying (following inundation), and disconnection of wetlands and billabongs from the main stem of rivers, are both important elements in the flow regime for many parts of the Basin.

Accordingly water management, particularly in drier periods, should include drying phases (where these would have been a natural characteristic of that river or stream; and if we know that the health of certain plants, animals or the stream itself can be improved). In some cases, drying phases have been lost because of regulation of rivers. Where possible, reinstating them will be important.

In other cases, river regulation has extended drying phases such that they are harmful. Water management should also seek to address these impacts.

Seasonality

Water is often released from storages at times when flows would not occur under natural conditions. For example in the south of the Basin, naturally higher flows predominantly occurred following winter–spring rainfall; now flows are primarily released to meet irrigation demand in the hotter months. The effect of river regulation on seasonal flow patterns differs throughout the Basin and depends, in part, on the distance downstream from storages and the location of significant irrigation off-takes.

Flow volumes, timing and durations are all important in the life-cycles of native fish and waterbirds. Environmental releases will be able to reinstate a portion of the flows consistently with natural seasonality, e.g. by reinstating some winter and early spring flows in the southern Basin. However, most major dam releases will still coincide with irrigation demands as this underpins our economic use of rivers.

Box 6: Hydrodynamic diversity

Rivers naturally have high variation in the speed at which water flows. This is a result of the interaction between flows and the physical structure of the river channel; known as hydrodynamic diversity. This variation creates pools, runs and riffles, as well as variation across the channel—with slow-flowing edges and fast-flowing mid-sections. Hydrodynamic diversity is critical for many species of aquatic biota. Where it has been altered by human intervention; some species (e.g. trout cod, Murray crayfish) are regionally extinct.

Hydrodynamic diversity has been significantly affected across the Basin, particularly by the construction of weirs, which have created pool habitats and eliminated fast-flowing habitats. The lower 800 km of the River Murray has been most affected by development—it has continuous weir pools at low to moderate flows.

Hydrodynamic diversity can be restored by delivering varying flows; by changing how weirs are operated; and through actions such as reintroducing snags (trees, branches and root masses, which break up the flow, restoring stream complexity and providing rest sites and shelter).



Figure 13 A trout cod which was fished from the snags in the background of this photo. Photo: Scott Raymond

Expected outcomes for river flows and connectivity

All the outcomes for flow and connectivity set out below are expected to occur by 2024.

Longitudinal connectivity

With the overall changes to flow volumes linking the Basin's rivers, the environmental watering outcomes expected are:

- to keep base flows at least 60% of the natural level⁷ (note: this will be especially important during dry years)
- a 10% overall increase in flows in the Barwon–Darling: from increased tributary contributions from the Condamine–Balonne, Border Rivers, Gwydir, Namoi and Macquarie–Castlereagh catchments collectively
- a 30% overall increase in flows in the River Murray: from increased tributary contributions from the Murrumbidgee, Goulburn, Campaspe, Loddon and Lower Darling catchments collectively
- a 30 to 40% increase in flows to the Murray mouth.

Lateral connectivity

The improvements in lateral connectivity that are expected are:

- a 30 to 60% increase in the frequency of freshes, bank-full and lowland floodplain flows in the Murray, Murrumbidgee, Goulburn–Broken and Condamine–Balonne catchments
- a 10 to 20% increase of freshes and bank-full events in the Border Rivers, Gwydir, Namoi, Macquarie–Castlereagh, Barwon–Darling, Lachlan, Campaspe, Loddon and Wimmera catchments
- current levels of connectivity maintained in the Paroo, Moonie, Nebine, Ovens and Warrego catchments.

The degree to which these outcomes can specifically target the lower floodplain will depend on current constraints in each region and the work underway to address them.

End-of-basin flows

Improvements in flows and connectivity in the Basin, and local management, will improve the connection of the river to its estuary (the Coorong) and to the sea.

The minimum outcomes expected are:

- the barrage flows are greater than 2000 GL/year on a three-year rolling average basis for 95% of the time, with a two year minimum of 600 GL at any time
- the water levels in the Lower Lakes are maintained above:
 - sea level (0m AHD) and
 - 0.4 metres AHD, for 95% of the time, as far as practicable, to allow for barrage releases

⁷ Some less-developed rivers have base flows greater than 60% of natural. Where this is the case, the aim is to protect that current level of flow. In other catchments, base flows are currently well below the target 60% of natural flows, especially during dry times. Cease-to-flow events should not exceed natural, where possible.

- salinity in the Coorong and Lower Lakes remains below critical thresholds for key flora and fauna including:
 - salinity in Lake Alexandrina is lower than 1,000 EC 95% of the time and less than 1,500 EC all the time
 - salinity in the Coorong's south lagoon is less than 100 grams per litre 95% of the time
- the Murray mouth is open 90% of the time to an average annual depth of one metre.

In addition, improvements in flow and connectivity are expected to contribute towards the achievement of the Basin Plan Salt Export objective⁸. This is 'to ensure adequate flushing of salt from the River Murray system into the Southern Ocean' (see [Box 4](#) Water quality).

Basis of expected flow and connectivity outcomes

MDBA used flow models developed for the Basin Plan to predict how flow and connectivity would respond to environmental water. Longitudinal connectivity, end-of-basin flows and lateral connectivity were modelled under different flow scenarios, including:

- a no-development scenario, which represents the Basin as a natural system
- a baseline scenario, which represents the Basin with the consumptive use and the rules and sharing arrangements as at June 2009, and
- the Environmentally Sustainable Level of Take, set at 2750 GL.

To calculate the expected outcome, MDBA compared the model's prediction for baseline with the model's predictions for the 2750 GL scenario. For example, in the Murrumbidgee the model predicted a 40% increase in flows at or above 9,000 ML/d (equating to small over-bank flows) under the 2750 GL scenario; compared to the baseline scenario.

It should be noted that the models take into account climate variability by using data from 1895 to 2009, and assume the major river operating constraints in the southern connected system are in effect for the entire model period.

For a list of sources used to develop expected environmental outcomes, see Appendix 2.



Figure 14 Delivering water to Gunbower Forest, August 2014. Photo: Ben Dyer, MDBA

⁸ Section 9.09 of the Basin Plan, 2012.

Native vegetation

The riverine, wetland and floodplain environments of the Murray–Darling Basin support hundreds of native plant species—including many threatened ones. Extensive and diverse vegetation on and around rivers, wetlands and floodplains provides food and habitat for waterbirds, woodland birds, frogs, turtles, fish, macroinvertebrates and other mammals. It also contributes organic matter to rivers and plays an important role in maintaining water quality, and soil and bank stability.

Additionally, people value the Basin's native vegetation. It has cultural significance for Aboriginal people, aesthetic appeal, and provides opportunities for recreation. It is also important for tourism, grazing and (in some places) forestry.

This strategy focuses on the riverine, wetland and floodplain vegetation communities which depend on permanent and periodic inundation from the river as well as rainfall; particularly the dominant overstorey species that require inundation for part or all of their life cycle (river red gum, black box and coolibah), lignum (a significant floodplain shrub) and important aquatic vegetation. For the purpose of the strategy, these vegetation communities have been classified into the 'structural groups' of: forests and woodlands, shrublands and non-woody vegetation.

River red gums (*Eucalyptus camaldulensis*), which can be many hundreds of years old, line many of the Basin's rivers; and have a life-cycle heavily dependent upon water, including periodic inundation. Depicted in Australian art and literature, this species is valued as part of our cultural identity; and in arid central Australia is considered sacred—representing life and water and often providing vital refuge for many animals in an otherwise hostile environment. In more temperate parts of the Basin (particularly low-lying floodplains in the southern part) it forms extensive forests and woodlands. The Barmah Forest contains the largest river red gum forest anywhere in the world and is home to many threatened animals, such as the superb parrot, squirrel glider and Murray cod.

On higher parts of many floodplains, further away from the rivers but still dependent upon periodic flooding, black box (*Eucalyptus largiflorens*) and coolibah (*Eucalyptus coolabah*) are often the more dominant overstorey species. They also grow along watercourses in the more arid areas.

Under these dominant overstorey species are diverse plant communities. Lignum (*Muehlenbeckia florulenta*) occurs on the floodplains and riparian zones of almost all the major rivers in the Basin, except in the south-east. This 'tangled' (multi-stemmed) plant grows primarily after flooding, and provides significant habitat (rookeries) for colonially-nesting waterbirds such as the straw-necked ibis (see [Figure 28](#)).

Non-woody vegetation forms narrow fringes or grows within river channels and wetlands. It includes grasslands, sedgeland/rushlands, herblands and fully-submerged species (for example Moira grass, common reed, cumbungi, water couch and marsh club-rush). In some places non-woody vegetation can be found across more extensive areas—often in terminal wetlands and frequently-inundated floodplains. *Ruppia tuberosa* is a seagrass also known as tuberous seatassel, which provides food and habitat for macroinvertebrates and fish, including the small-mouth hardyhead. It is also an important food source for migratory waterbirds, particularly in the Coorong.

Figure 15 provides a generalised example of where different vegetation communities are located on the floodplain and their required watering frequency. It should be noted that the actual watering regime required for such vegetation communities depends on their location in the Basin and the local composition of plant species.

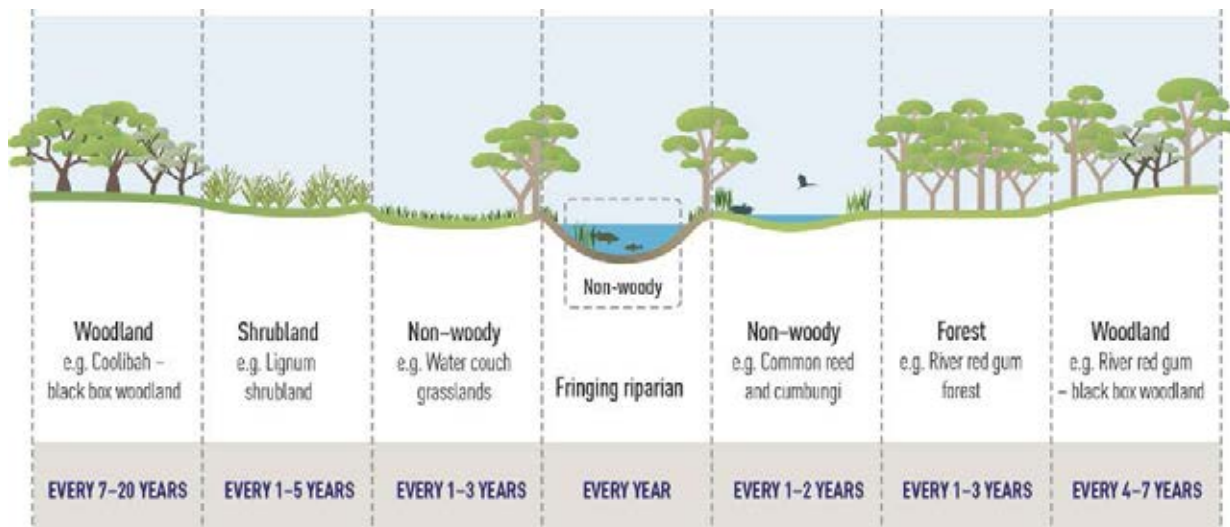


Figure 15 A stylised example of structural groups of vegetation, their position on the floodplain and their required watering frequency

Figure 17 illustrates the extent of black box, coolibah and river red gum on the managed floodplain that will be impacted by the Basin Plan.

Condition of water-dependent vegetation in the Basin

The condition and area covered by water-dependent vegetation across the Basin has been declining. This is primarily a result of water resource development and land management practices; combined with periodic drought. The recent decade-long millennium drought also had a significant impact.

Over the period 2008–2010, the *Sustainable Rivers Audit* rated riverine vegetation condition in the northern Basin catchments as ‘moderate’ on average. However, many of the unregulated catchments were rated as being in ‘good’ condition. Riverine vegetation condition in the southern more regulated catchments was, on average, ‘poor’; and only one of the 13 southern catchments was rated in ‘good’ condition (the Central Murray). Overall, the condition of vegetation in the southern catchments has been declining rapidly over the past two decades.

The high-flow events in 2011 and 2012 (following significant rain) improved the condition of some vegetation. However, in many places these improvements were modest, and follow-up watering is required to consolidate this improvement in condition.

The MDBA commissioned a condition assessment (as at 2013) of water-dependent trees (river red gum, black box and coolibah) for the development of this strategy. The purpose of this assessment was to provide higher resolution data; particularly in the managed floodplain. Additionally, we sought to identify how changes in flow might be expected to influence such condition. (A summary of this data is at Appendix 3).

At November 2014 data accuracy and resolution only provide for condition scoring with confidence in the Lachlan, Murrumbidgee, Lower Darling, Murray, Goulburn–Broken and

Wimmera–Avoca. The condition of river red gums can only be scored within five categories⁹ and black box within two categories¹⁰ with confidence. Examples of these are presented in Figures 18 to 21.

While the condition of vegetation has declined in general across the Basin, some vegetation types have been particularly affected. For example, during the millennium drought *Ruppia tuberosa* in the Coorong's south lagoon experienced a critical decline due to low flows and unfavourable salinity and water levels. *Ruppia tuberosa* and *Ruppia megacarpa* once formed an extensive vegetation community that provided habitat for macroinvertebrates and fish; and an important food source for migratory shorebirds.

Despite its reduced population, *Ruppia tuberosa* still plays a critical functional role in the food web, and is an important indicator of the health and resilience of the Coorong system. *Ruppia megacarpa*, a key health indicator species for the north lagoon, is now absent from the Coorong because of unfavourable flows, water levels and salinities. These issues also characterise the south lagoon and highlight the ongoing threats for remnant *R. tuberosa* populations.



Figure 16 Researchers measuring lignum growth, Narran Lakes. Photo: Arthur Mostead

⁹ Scores between 0–2 are categorised as ‘severely degraded’; >2–4 are ‘degraded’; >4–6 are ‘poor’; >6–8 are ‘moderate’; >8–10 are ‘good’ condition.

¹⁰ Scores between 0–6 are categorised as ‘severely degraded to poor’. >6–10 are ‘moderate to good’ condition.

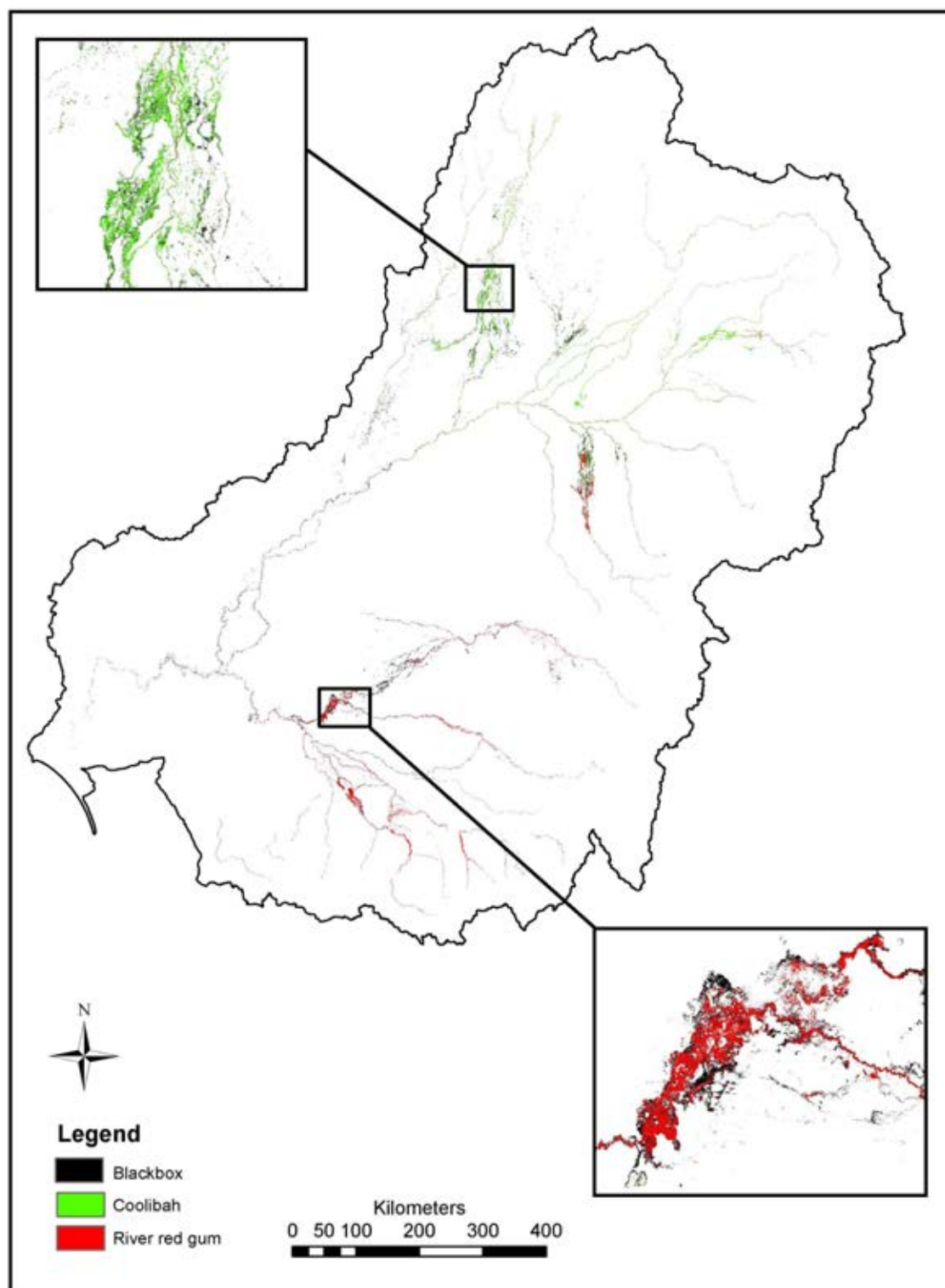


Figure 17 The extent of black box, coolibah and river red gum on the managed floodplain in the Basin that is expected to be maintained

(More detail is provided in Appendix 3: Expected vegetation outcomes by region on page 88)

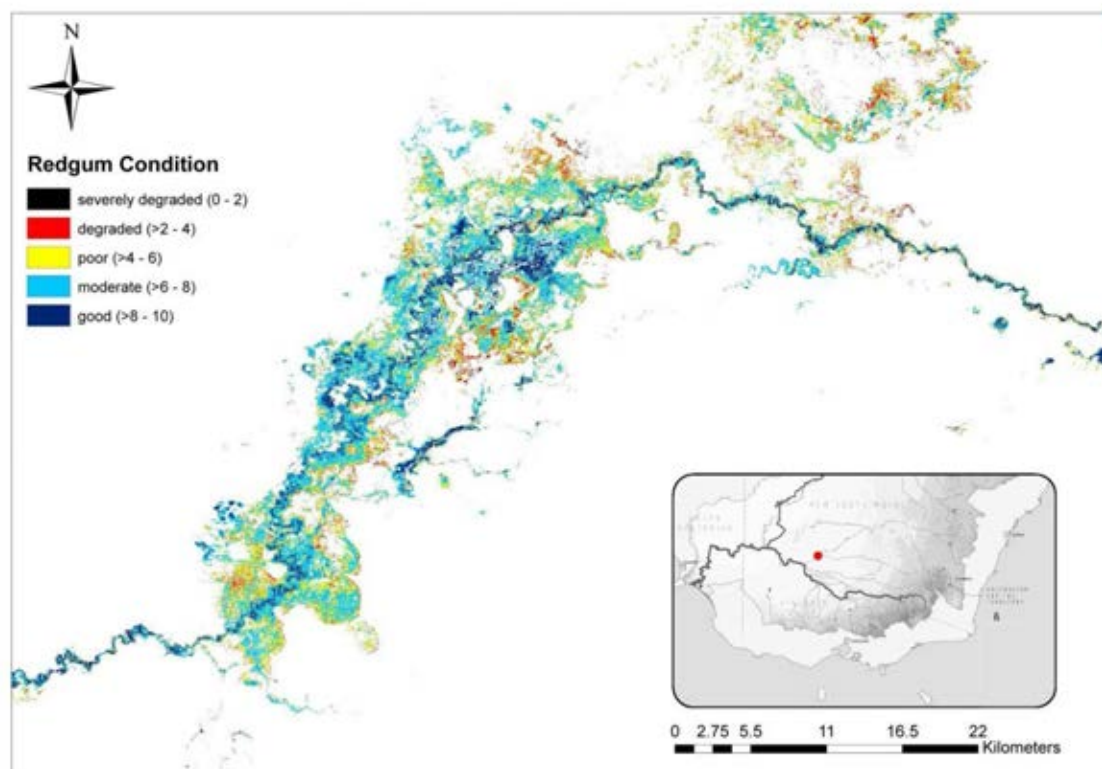


Figure 18 The condition of red gum on the managed floodplain in the Murrumbidgee that is expected to be improved

(More detail is provided in Appendix 3: Expected vegetation outcomes by region on page [88](#))

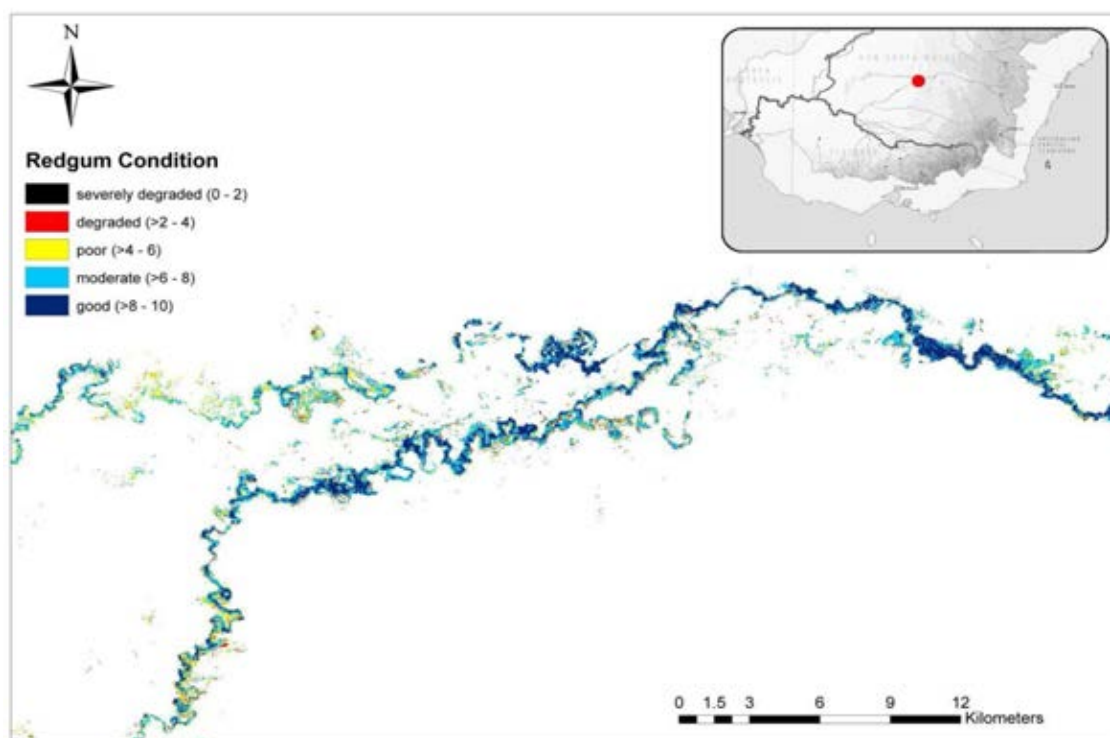


Figure 19 The condition of red gum on the managed floodplain in the Lachlan that is expected to be improved

(More detail is provided in Appendix 3: Expected vegetation outcomes by region on page [88](#))

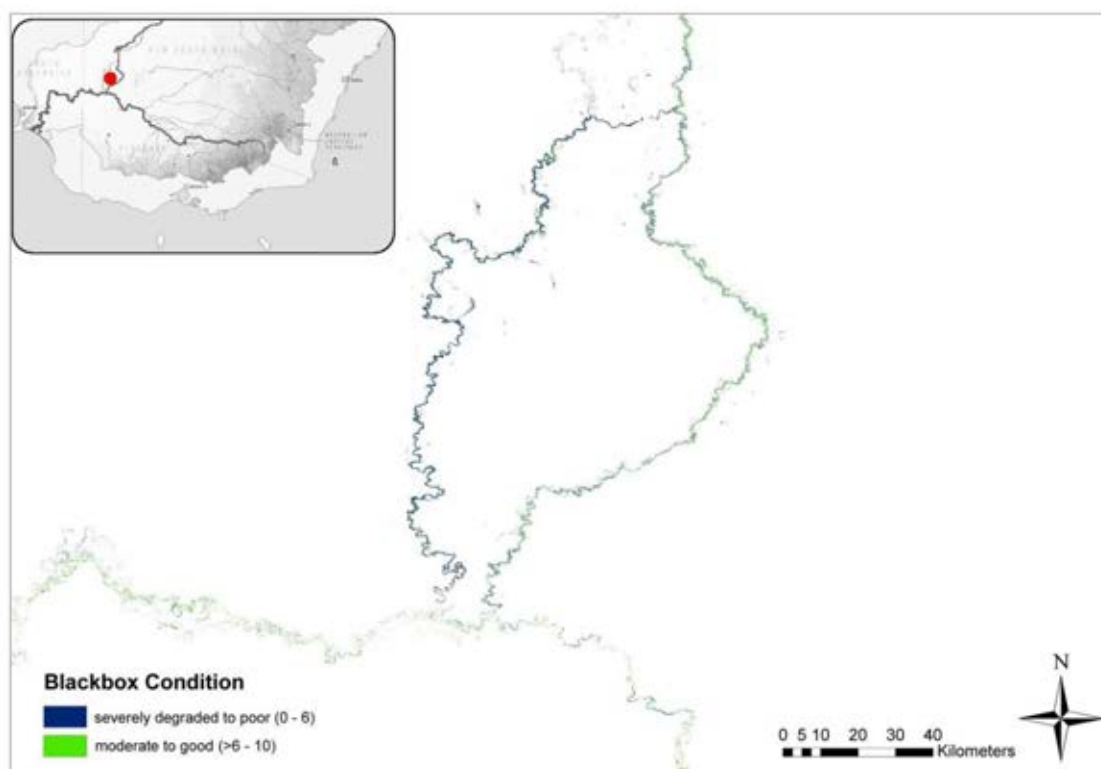


Figure 20 The condition of black box on the managed floodplain in the lower Darling that is expected to be maintained

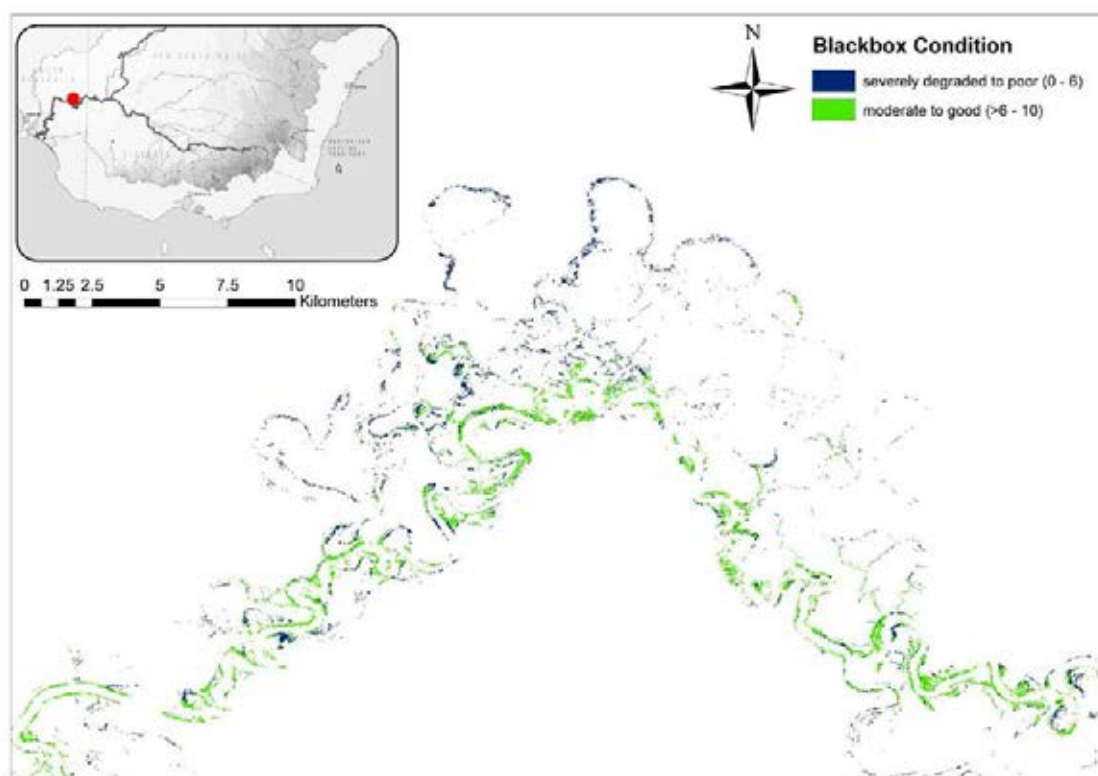


Figure 21 The condition of black box on the managed floodplain in the lower Murray that is expected to be maintained

(More detail is provided in Appendix 3: Expected vegetation outcomes by region on page 88)

Expected outcomes for water-dependent vegetation

The vegetation outcomes expected under this strategy are, at a minimum, to maintain the extent¹¹ and to improve the condition of water-dependent vegetation on the parts of the Basin's floodplain that can be actively managed. Other parts of the floodplain will continue to support diverse vegetation communities; however, their extent and condition will be heavily influenced by factors outside the realm of the Basin Plan (e.g. natural flooding, climatic conditions, land use decisions and fire).

Achieving these outcomes depends on reinstating lateral and longitudinal connectivity. The previous section on [River flows and connectivity](#) details the level of connectivity that is expected to be achieved. The specific expected outcomes for Basin vegetation groups, based on the expected improvements in flows, are as follows.

Forests and woodlands

The expected outcomes for forests and woodlands in the Basin are:

- to maintain the current extent of forest and woodland vegetation (see [Figure 17](#) and Appendix 3 for a regional breakdown) including approximately¹²:
 - 360,000 ha of river red gum
 - 409,000 ha of black box
 - 310,000 ha of coolibah
- no decline in the condition of river red gum, black box and coolibah across the Basin¹³
- by 2024, improved condition of river red gum in the Lachlan, Murrumbidgee, Lower Darling, Murray, Goulburn–Broken and Wimmera–Avoca (see Appendix 3 for a regional breakdown)
- by 2024, improved recruitment of trees within river red gum, black box and coolibah communities—in the long term achieving a greater range of tree ages. (River red gum, black box and coolibah communities are presently comprised primarily of older trees; which places them at risk.)

Shrublands

The outcomes expected for shrubland vegetation are:

- to maintain the current extent of extensive lignum shrubland areas within the Basin
- by 2024, improvement in the condition of lignum shrublands.

These outcomes apply to lignum communities across the following regions (at a minimum): [Lower Lachlan](#), [Lower Murrumbidgee](#), [Lower Darling](#), [Lower Condamine–Balonne](#) (including Narran Lakes), [Lower Gwydir](#), [Macquarie Marshes](#), [Lower Border Rivers](#) and the [River Murray](#) from the junction of Wakool River to downstream of Lock 3 (including Chowilla and Hattah Lakes).

¹¹ Extent to be maintained in this strategy is specified at a basin and catchment scale. Some change to extent, including increases and/or decreases of certain types of vegetation, is expected to occur at local scales. However, the degree of such change is likely to be minor and, therefore, more appropriate for regional plans to address.

¹² The areas specified for river red gum, black box and coolibah are within a range of plus or minus 10%.

¹³ Limitations in the data available in many areas of the Basin, particularly in the north, mean that it is not yet possible to specify the current condition of river red gum, black box and coolibah. As additional data become available it will be possible to accurately calculate the condition at 2014 and to describe the expected outcomes for these species across the Basin.

There is not enough data to measure areas of lignum at a Basin scale. However, information is available at a regional scale and Basin states are encouraged to quantify this vegetation type within their catchments.

Non-woody vegetation

The outcomes for non-woody vegetation are:

- to maintain the current extent of non-woody vegetation
- by 2024, increased periods of growth for communities that:
 - closely fringe or occur within the main river corridors (see Appendix 3)
 - form extensive stands within wetlands and low-lying floodplains including Moira grasslands in Barmah–Millewa Forest; common reed and cumbungi in the Great Cumbung Swamp and Macquarie Marshes; water couch on the floodplains of the Macquarie Marshes and Gwydir Rivers; and marsh club-rush sedgeland in the Gwydir
- a sustained and adequate population of *Ruppia tuberosa* in the south lagoon of the Coorong, including:
 - by 2019, *R. tuberosa* to occur in at least 80% of sites across at least a 50 km extent
 - by 2029, the seed bank to be sufficient for the population to be resilient to major disturbances¹⁴.

Basis for expected vegetation outcomes

The current extent of vegetation is based on 2013 Landsat data and represents the vegetation that is or may be able to be inundated on the managed floodplain with 2750 GL of environmental water; assuming current constraints are maintained. MDBA used modelling to predict the area of the floodplain which can be influenced with environmental water. The current condition is based on 2013 'RapidEye™' satellite imagery data. When calculating improvement in condition in the future, MDBA will ensure that any comparative assessment uses datasets with equal coverage.

Outcomes for *Ruppia tuberosa* were developed using expert scientific advice and published papers. For a list of sources used to develop expected environmental outcomes, please see Appendix 2.



Figure 22 Phylands Swamp inundation in August 2014. Photo: Ben Dyer, MDBA

¹⁴ Advice suggests that this would require at least 10,000 seeds/m² within the bed of the core population of *R. tuberosa*.



Figure 23 Environmental watering promotes flowering of Moira grass at Little Rushy Swamp, Barmah National Park, NSW. Photo: Keith Ward



Figure 24 Watering at Chowilla floodplain late 2014. Photo: Callie A. Nickolai, courtesy of DEWNR

Waterbirds

Waterbirds are highly mobile, moving between catchments and basins in search of suitable habitats as conditions change. More than 120 species have been recorded in the Murray–Darling Basin. They depend on rivers and wetlands to provide breeding, roosting and nesting habitat, as well as food and protection from predators. Many of the wetlands upon which they depend are listed under the [Ramsar Convention on Wetlands of International Importance](#); and as such, we have an obligation to conserve them.

Waterbirds can be grouped together into ‘functional groups’. For instance: large waders (e.g. egrets); colonial nesting waterbirds (e.g. herons and ibis); migratory shorebirds (e.g. sandpipers); ducks (e.g. the grey teal) and fish-eating birds (e.g. pelicans). Such groups have different habitat requirements. For example, ducks need habitat ranging from deep water to vegetated shorelines; colonial nesting waterbirds need flooded trees, lignum and dense reed beds for nest sites and nesting material; and migratory shorebirds require large expanses of mudflat with shallow water to enable feeding. For migratory shorebirds, this habitat is mostly found on coastal mudflats, estuaries, shorelines and certain inland wetlands.

Waterbirds are also important for the Basin’s Aboriginal communities. Some species hold spiritual significance—the Brolga has a role in dance and the Dreaming—and play a role in women’s and men’s cultural business. Waterbirds may be an indicator for water in a dry landscape. They are also a food source (meat and eggs). Aboriginal people previously used waterbird down for clothing and warmth; now feathers are used for artwork and ceremonies.

Condition of waterbirds in the Basin

More than 30 years of annual waterbird surveys have shown a 72% decline in total population (average abundance) of waterbirds between the first decade of the survey (1983 to 1992) and the third decade of the survey (2003 to 2012) (see [Figure 25](#)). Abundance declined within each functional group, with shorebirds declining by 76% and large-waders by 57%. The number of nests and broods and the number of species breeding declined significantly, the latter by 72%. Overall, the number of different species was the only measure of the waterbird population that did not decline over the survey.

Other investigations have found this same pattern of decline. The Coorong and Lakes Albert and Alexandrina comprise the most important site in the Basin for shorebirds and the seventh most important site in Australia. Nine shorebird species of international significance and ten species of national significance have been recorded in the Coorong. Studies have shown that the abundance of three common shorebirds—the sharp-tailed sandpiper, red-necked stint and curlew sandpiper—declined significantly between 1984 and 2007.

Waterbirds naturally respond to ‘boom and bust’ periods driven by river flows and local rainfall. River regulation has diminished the extent and frequency of the flows that drive ‘booms’. While the populations will always be low in drier years, the natural reproductive response in the higher flow years has been less evident over the previous decades. There has been less opportunity for populations to build over time because suitable conditions (such as medium flows) rarely occur; as such flows are mostly captured in dams and weirs. Therefore, the starting population at the beginning of each boom period is trending lower over time.

Certain wetlands in the Basin are very important for waterbird abundance, breeding and species richness. In any year, most waterbirds (80% of total abundance) can be found on 20 wetlands (see Appendix 4). The sites used vary from year to year according to where water is prevalent, but over time approximately thirty-three sites appear to be consistently important (refer (Figure 26 and Appendix 4). The MDBA considers these sites to be of Basin significance for waterbirds.

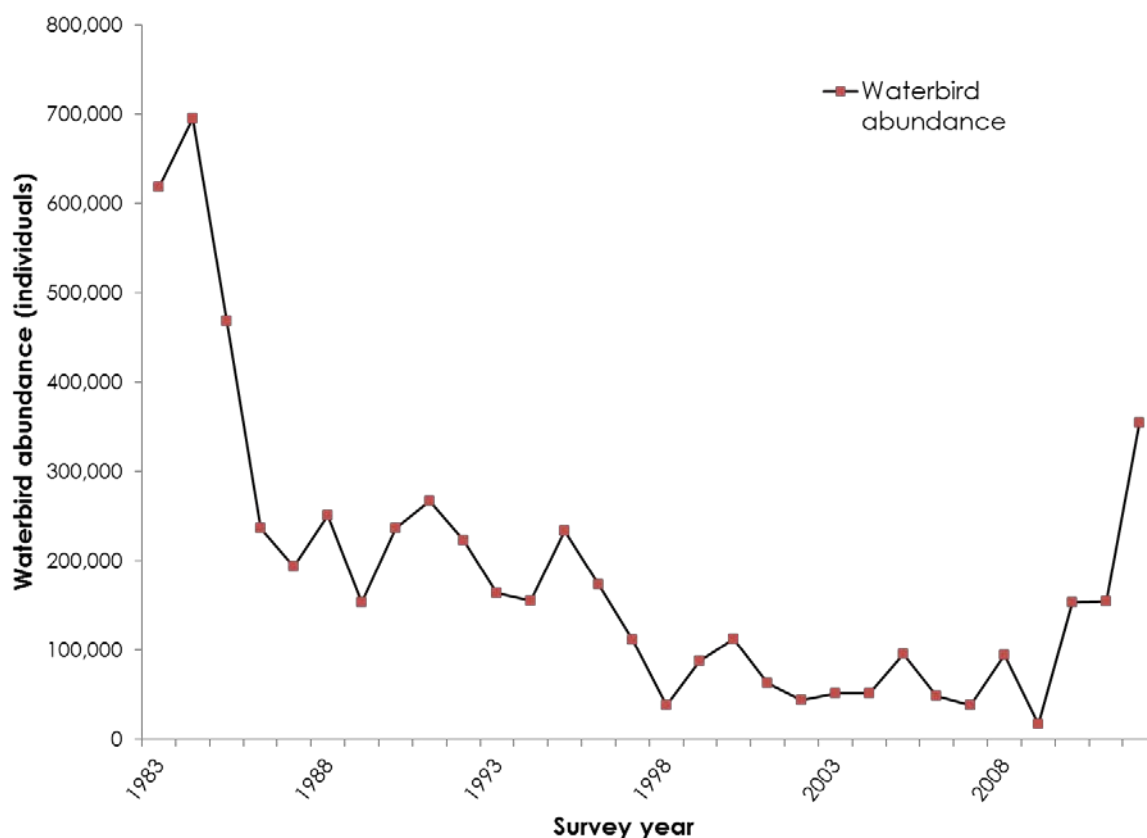


Figure 25 Abundance of all waterbirds in the Murray–Darling Basin

Notes: Surveyed during annual aerial waterbird surveys of eastern Australia, 1983–2012 (Kingsford *et al.* 2013).
Survey bands cover about 13.5% of the land area of the Murray–Darling Basin.

Many of these sites are the large well-known wetlands – the Lower Murrumbidgee floodplain, Macquarie Marshes and Paroo overflow lakes (as well as the Coorong, Lake Alexandrina and Lake Albert). Other sites of importance include natural lakes that are used for water management, such as Menindee Lakes and smaller wetlands like Fivebough Swamp. Some of these sites can be managed actively with environmental water, whereas others in unregulated catchments will need to be considered in the development of water resource plans. Some storages or water transfer basins that are not or cannot be managed for environmental outcomes are nonetheless important refuge for some species during drought—for example Coolmunda Dam, Split Rock Reservoir and Burrendong Dam. There are other sites that are of local or regional significance for waterbirds, and these should be identified and considered by regional planning frameworks.

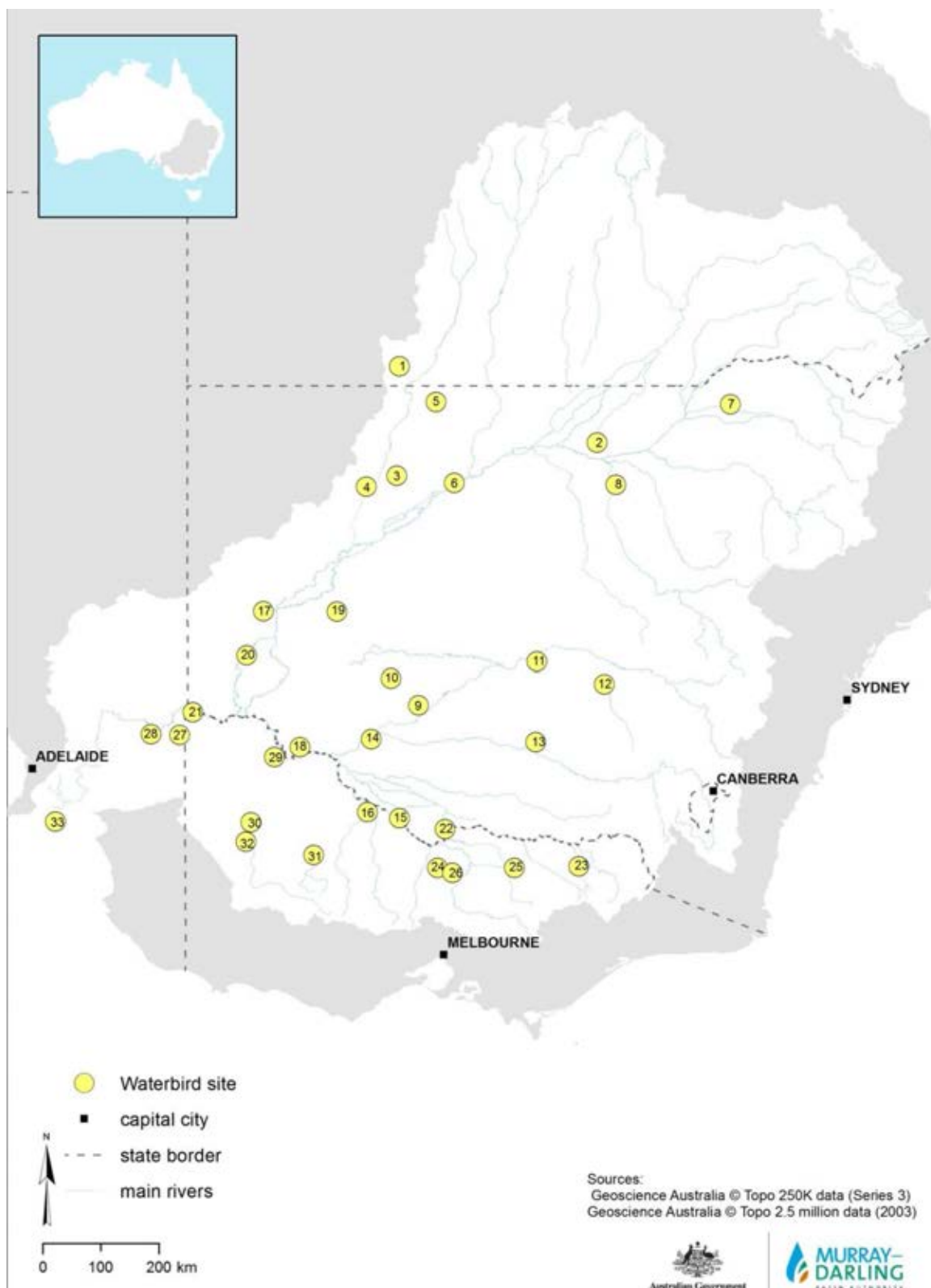


Figure 26 Significant sites for waterbirds in the Murray–Darling Basin

(More detail is provided in Appendix 4: Important Basin environmental assets for waterbirds on page 92)

Expected outcomes for waterbirds

The expected outcomes for waterbirds are increased abundance and the maintenance of current species diversity. From 2024 onwards, the expected outcomes are:

- that the number and type of waterbird species present in the Basin will not fall below current observations
- a significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario¹⁵, with increases in all waterbird functional groups
- 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 of the other functional groups to increase by 30–40% compared to the baseline scenario, especially in locations where the Basin Plan improves over-bank flows¹⁶.

Achieving these outcomes would result in waterbird populations similar to those in the early-1990s, which is necessary to ensure resilience of populations across the Basin.

Achieving the outcomes for waterbird abundance and diversity relies upon successful breeding, a diversity of habitats in good condition to support life-cycles, and protection of drought refuges so that waterbirds can survive dry times. The availability of breeding habitat and food resources is closely linked with floodplain inundation, which will increase with environmental watering under the Basin Plan.

Waterbird species prefer different habitats for feeding and resting, roosting and breeding; and must move between them to survive, reproduce and breed. A mosaic of wetland habitats is important in determining waterbird distribution and abundance, and is a prerequisite for a sustainable waterbird population.

Climatic variations affect water availability, and the size and condition of waterbird populations. Supporting refuges will provide feeding and roosting resources (Appendix 4).

The waterbird outcomes described above are Basin-wide. However, because of the importance for migratory shorebirds, for the Coorong, Lakes Albert and Alexandrina, the expected outcomes are:

- by 2019, at a minimum, to maintain populations of the following four key species: curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper, at levels recorded between 2000 and 2014.

¹⁵ Represents the Basin with the consumptive use and the rules and sharing arrangements as at June 2009

¹⁶ Refer to Figure 9

Basis of expected waterbird outcomes

There is a strong relationship between waterbirds and flow. This relationship enabled MDBA to predict how waterbirds would respond to environmental water using modelling scenarios developed for the Basin Plan.

Based on historic correlations between surveyed waterbird populations and flow in the Basin, waterbird populations were modelled under different flow scenarios, including:

- a 'no-development' scenario which represents the Basin as a natural system
- a baseline scenario, which represents the Basin with the consumptive use and the rules and sharing arrangements as at June 2009, and
- the Environmentally Sustainable Level of Take set at 2400 GL, 2800 GL and 3200 GL.

To calculate the expected environmental outcome, MDBA compared the model's prediction for baseline with the model's predictions for the various level of take scenarios (2400, 2800 and 3200 recovery). For example, under the baseline scenario, waterbird abundance **in the surveyed areas** was predicted to be, on average, 168,000 individuals; compared to the ESLT scenarios of between 202,000 and 214,000 individuals. This equates to a 20–25% increase.



Figure 27 Breeding magpie geese in flight at Gingham Watercourse. Photo: Daryl Albertson, courtesy of NSW Office of Environment & Heritage

The expected increase in waterbird breeding events was also based on the modelled scenarios. In particular, the flow conditions conducive to waterbird breeding (e.g. a certain flow that inundates waterbird habitat for over three months) can be identified in the modelled flows; and the change between the baseline scenario and what happens under the Basin Plan can be quantified as an increase in opportunity.

Outcomes for migratory shorebirds in the Coorong were derived from expert scientific advice and published papers, as there was less capacity to accurately model shorebird response using a flow model.

For a list of sources used to develop expected environmental outcomes, see Appendix 2.



Figure 28 Nesting straw-necked ibis at Lower Gingham wetland. Photo: Joshua Smith

Native fish

More than 60 native fish species occur in the Murray–Darling Basin. This includes freshwater, estuarine, marine and migratory fish. Many of the Basin's 44 freshwater species are unique to Australia, with the home range of at least 16 species restricted to the Basin.

Native fish play an important role in freshwater ecosystems and are a vital part of food webs. Some species are high-level predators and others consume algae, plants and invertebrates like insects and shrimp. In turn, fish are a vital source of food—for other fish, waterbirds and shorebirds, turtles and other aquatic fauna. They also play an important role in nutrient cycling.

Native fish are highly valued by people. Fish have totemic and cultural values for Aboriginal communities. Recreational fishing is an important pastime throughout the Basin and generates \$1.3 billion annually. One commercial fishery operates in South Australia, producing around \$4 million from finfish in 2008–09. All of these values depend upon healthy native fish populations.

Condition of native fish in the Basin

Many native fish species were once widely distributed in the Murray–Darling Basin. However, changes to natural flow regimes have degraded fish habitat and reduced habitat connectivity across the Basin. This has led to a significant decline in the abundance and distribution of almost all native fish species in the Basin.

Silver perch was once a common species in the middle reaches of the River Murray, but during the 1990s numbers fell by 95%. Trout cod and Macquarie perch could once be found along nearly 1000 kilometres on the Lower Murray, but now only occur in isolated populations and upper tributaries. Commercial fishing in the River Murray once targeted Murray cod before major declines from the 1950s reduced profitability. Catches of some target species in the Lakes and Coorong Fishery in South Australia have also declined. Smaller species—like olive perchlet and southern purple-spotted gudgeon—have also declined or been lost from whole catchments. At the same time, changes to rivers have favoured alien species like carp.

The 2008 [Sustainable Rivers Audit](#) (SRA) report card (SRA 1, 2004–2007) recorded the poor condition of fish communities across much of the Basin. Only three valleys had fish communities in moderate condition (Paroo, Condamine and Border Rivers), while 12 were in poor to very poor condition; and the remaining eight valleys were in extremely poor condition. [SRA 2](#) (2008–2010) showed improved fish condition only in the Paroo.

Flows, habitat and connectivity are all essential for healthy native fish populations. Fish need all these elements for food and shelter, spawning and nesting, and for nursery/rearing areas and refuges (see [Figure 29](#)).

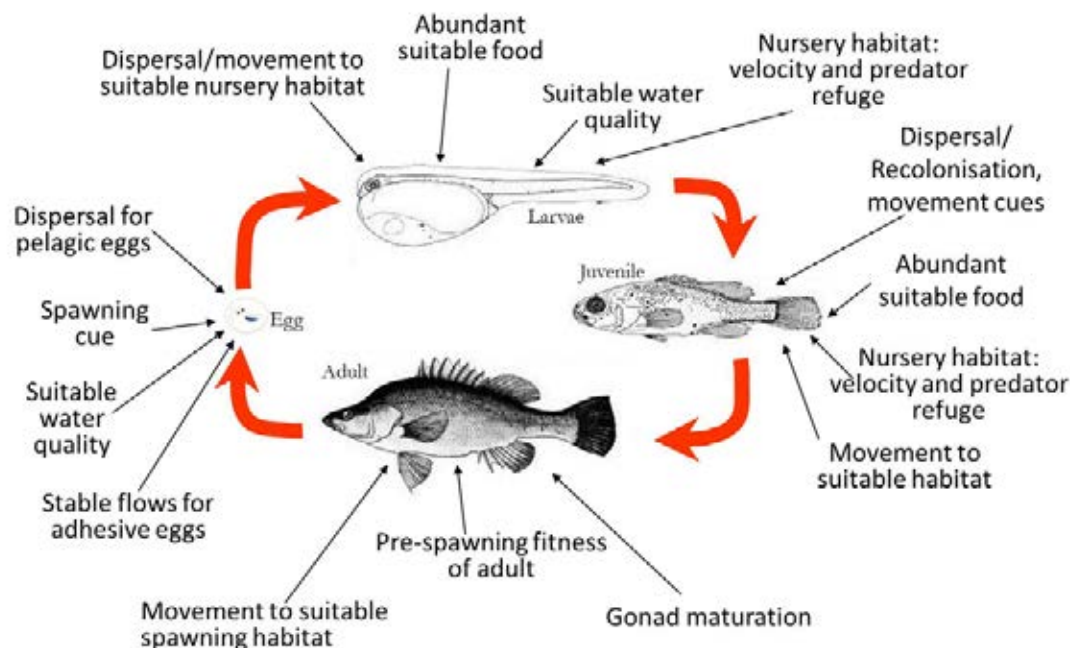


Figure 29 The influence of flows on the different stages within the life-cycle of fish. (Figure courtesy of the Arthur Rylah Institute.)

The interaction of flows with the physical structure of rivers creates sections of fast-flowing, slow-flowing and still water habitats at local to landscape scales (hydrodynamic diversity, as explained in Box 6). This hydrodynamic diversity is important for native fish. Loss of hydrodynamic diversity is a major cause of decline for native fish species like Murray cod, silver perch, trout cod and Macquarie perch that all rely on flowing habitats. Flows also maintain the health of habitats and in-stream and emergent vegetation upon which many fish depend. Flows also strongly influence the quality, size, and persistence of refuge habitats through dry periods.

Water quality is as important to native fish as water quantity. Flow strongly influences water quality. Appropriate water temperature is a critical part of water quality because unnaturally cold water inhibits fish feeding, breeding and growth. Oxygen levels, pH, salinity, chemical cues and food content are also important.

Flows that inundate benches (see [Figure 12](#)) and floodplains increase carbon input, which in turn drives productivity and stimulates food production. This is critical for larval and juvenile fish, as they have low energy reserves and need ready access to food in order to survive.

In addition, flows give fish physical access to a range of aquatic habitats and provide cues that stimulate movement—a key ecological process for native fish. As examples, larvae drift downstream in the water column; many juvenile and adult fish move both up and downstream to find homes; and they also move in and out of off-channel habitats such as wetlands.

Fish movement is impeded by poor water quality (such as cold water), inappropriate water velocity and by constructed physical barriers. Some physical barriers can be overcome with sufficient flows, e.g. by 'drowning-out' low-level weirs. Others require structures like fishways or ladders to aid fish passage (see [Figure 30](#)), whose operation requires particular flows.

Many positive outcomes for native fish can be achieved with improved water management. Species that will benefit most are those that depend on flows for specific life cycle needs.

For example:

- flows that maintain minimum water depths during the nesting season of Murray cod and trout cod increase the survival of offspring
- recruitment of silver perch and golden perch is improved by within-channel flow pulses in spring/summer
- spawning aggregations of mulloway form in response to freshwater discharge through the Murray mouth. Successful recruitment of this species often coincides with seasons of good flows from the River Murray.

Fish communities in the Basin

For the purposes of this strategy, native fish of the Murray–Darling Basin are broadly categorised into three communities: southern Basin, northern Basin and estuarine (see Appendix 5 for details).

The three divisions are based on natural fish assemblages that have been shaped by different geographic, climatic and ecological characteristics of the Basin. They are not isolated systems and connectivity between them is essential for functional fish communities. Murray cod and golden perch occur in both the southern and northern Basin. These species are particularly sought after by recreational fishers, particularly in rural and Indigenous communities across the Basin.



Figure 30 Fishway at Brewarrina weir. Photo: Peter Taylor



Figure 31 Fishing in the backwaters of the River Murray in Wallpolla State Forest. Photo: Corey Brown, 2009

Expected outcomes for native fish

In the long term, the overall expected outcome is a diverse native fish community with sustainable populations occupying a greater proportion of their historic distribution than is currently the case.

A number of factors have contributed to the decline of native fish across the Murray–Darling Basin. Recovery will require many of these to be addressed. Flow restoration and improved water management are key actions that will contribute to native fish recovery. Restoring flows can directly improve connectivity, benefitting native fish by connecting populations. Flows can also improve fishway operation, further improving connectivity for fish. Improved connectivity can provide access to greater areas of habitats or reinstate habitat types that have been reduced. Improved water management can stimulate fish to breed and provide habitat and food for young fish. These can result in improved movement, recruitment and distributions. Flow can enable and improve complementary activities to provide greater outcomes for native fish (e.g. stocking threatened species in habitats reinstated and maintained by improved flows).

The following broad outcomes are expected by 2024:

- no loss of native species currently present within the Basin
- improved population structure of key species (see Appendix 6) through regular recruitment
- increased movement of key species
- expanded distribution of key species and populations in the northern and southern Basin.

The following outcomes are expected (refer [Table 7](#), Appendix 6 for further details):

- for short-lived species¹⁷:
 - restored distribution and abundance to levels recorded pre-2007 (prior to major losses caused by extreme drought). This will require annual or biennial recruitment events depending on the species
- for moderate to long-lived species:
 - improved population structure (i.e. a range of size/age classes for all species and stable sex ratios where relevant) in key sites. This will require annual recruitment events in at least eight out of 10 years at 80% of key sites, with at least four of these being 'strong'¹⁸ recruitment events
 - a 10–15% increase of mature fish (of legal take size) for recreational target species (Murray cod and golden perch) in key populations
 - annual detection of species and life stages representative of the whole fish community through key fish passages; with an increase in passage of Murray cod, trout cod, golden perch, silver perch, Hyrtl's tandan, congolli, short-headed lamprey and pouched lamprey through key fish passages to be detected in 2019–2024; compared to passage rates detected in 2014–2019.

¹⁷ For flathead galaxias, this outcome will only relate to annual recruitment events, given incomplete knowledge of pre-2007 distributions and abundances

¹⁸ What constitutes a 'strong' recruitment event will depend on the species and its status at a given location.

- for estuarine species – additional outcomes are:
 - detection¹⁹ of all estuarine-dependent fish families²⁰ throughout 2014–2024
 - maintenance of annual population abundance (Catch Per Unit Effort – CPUE) of key estuarine prey species (sandy sprat and small-mouthed hardyhead) throughout the Coorong
 - detection of a broad spatial distribution of black bream and greenback flounder; with adult black bream and all life stages of greenback flounder present across >50% of the Coorong in eight out of 10 years
 - detection in nine out of 10 years of bi-directional seasonal movements of diadromous species through the barrages and fishways between the Lower Lakes and Coorong
 - increased rates of native fish passage in 2019–2024 compared to 2014–2019
 - improved population structure of mullet, including spawning aggregations at the Murray mouth in six out of 10 years and recruitment in at least five out of 10 years.

By extending the range of existing populations and establishing additional populations, expanded distributions of key fish species are expected by 2024 (refer to Appendix 6 for details), including:

- a doubling of the current (mostly restricted) distributions of key species in the northern Basin
- significant increases in the distributions of key species in the southern Basin.

Basis for expected fish outcomes

The fish outcomes were developed using expert opinion in conjunction with literature reviews, conceptual modelling, reviews of existing fish data sets and information on fish assets. A series of expert workshops were held to consider fish outcomes and water management strategies to improve native fish. Individual workshops covered the northern, southern and estuarine fish communities and additional workshops considered Basin-wide perspectives. Expert opinion also shaped the selection of final outcomes (movement, recruitment and distribution) – determining that these factors were likely to exhibit a measurable response to improved water management within the timeframes of the strategy.

The selection of key fish species was informed by a conceptual modelling process, along with expert opinion, to identify the likelihood of their response to improved water management. The conceptual modelling process considered life history characteristics and habitat requirements of fish that would interact with water management. Priority was given to species with a threatened status in the Basin and socio-economic value.

For a list of sources used to develop expected environmental outcomes, see Appendix 2.

¹⁹ Detection is defined differently for each estuarine native fish species and should be guided by the most up-to-date Ramsar ecological character description for the Coorong, Lower Lakes and Murray mouth.

²⁰ Refers to taxonomic families.



Figure 32 The native Murray cod. Photo: Gunther Schmida



Figure 33 Cage which traps carp while allowing native fish passage. Photo: Ivor Stuart

Influence of other factors on expected environmental outcomes

The expected outcomes described in part 2 of this document constitute the MDBA's best assessment of how the Basin's water-dependent ecosystems are expected to respond to environmental watering over the next decades.

However, the various Basin ecosystems will take differing amounts of time to respond to environmental watering, particularly in an unpredictable climate. In addition, many factors influence ecosystem condition. For example, vegetation clearing and regeneration, infrastructure (e.g. dams and weirs), introduced species (e.g. carp), bushfires and unforeseen influences (such as changes in rules for river operations) will confound, diminish, and in extreme cases may prevent an ecosystem response.

Broader natural resource management must therefore be undertaken in tandem with environmental watering. For this purpose, it is important that:

- environmental water managers link with other natural resource management groups and plan for integrated outcomes where activities are related (e.g. by adjusting annual watering priorities in response to other natural resource management actions to ensure that the use of water maximises outcomes)
- all environmental water managers, scientists and river operators communicate effectively with, and find opportunities to work with, local communities—so that environmental watering contributes to broader natural resource management outcomes and vice versa
- the impact of non-water related threats to the environment are considered in management plans and watering actions (e.g. recent fire history or the impact from adjacent land uses)
- constraints currently restricting environmental outcomes in some areas are addressed as far as possible (that is, greater environmental outcomes will become available through implementation of the Constraints Management Strategy)
- effective networks and activities are in place that facilitate all of the above.

Box 7: Risk of alien fish

Alien fish (particularly carp) are a risk and should be considered when deciding on watering strategies.

Unfortunately, it is not possible for water to benefit native fish and definitely exclude any benefit to carp. Therefore decisions should give priority to achieving objectives for native biota; even where this may also benefit alien species. Complementary measures to reduce alien species may need to be considered in some areas (e.g. carp barriers or culling programs).

Many of the issues that relate to carp are also relevant to other alien fish species such as gambusia.

3. Water management strategies for maximising environmental outcomes

The strategies set out below should be considered in all elements of planning and management of water across the Basin to maximise the environmental outcomes achieved. This includes long-term watering plans, water resource planning, annual water planning and prioritisation, river operations and the delivery of consumptive and environmental water (refer also [Roles and responsibilities](#) section). Consideration of these strategies will need to be within the context of not creating unacceptable third party impacts or creating additional risks to the reliability of water entitlements.

Water management strategies emerging from experience

Environmental watering has been undertaken in the Basin for decades—some of the earliest actions occurred in the 1980s (for example, at the Macquarie Marshes). Over this time much has been learned about how to manage environmental water effectively. The strategies or management approaches that have emerged from this experience should continue to be applied across the Basin in relation to environmental watering, namely:

- harness local community land and water knowledge to guide water use and outcomes
- as far as possible, contribute to environmental benefit when managing all water
- manage water in harmony with biological cues (including responses to flow) to restore elements of a more natural flow regime with appropriate variability and seasonality
- coordinate management of water for the best outcomes and to target multiple sites and functions in and between rivers
- manage risks associated with the delivery of environmental water
- apply adaptive management in the planning, prioritisation and use of environmental water.

These strategies are discussed further below.

Harness community land and water knowledge

Landholders, land managers, community groups and Aboriginal peoples often have detailed knowledge about rivers and wetlands in their valley. This knowledge can include observations about the condition of local wetlands, their water needs or movement of water through the landscape; where native fish are in the river; or possible risks with different types of flows and opportunities to achieve complementary social, cultural and economic outcomes. The outcomes from water use are more likely to be maximised if this local knowledge and experience can be tapped (see Case study 1 below).

Community input is valuable in all of the elements of environmental watering including long-term and annual planning and delivery. Across the Basin this occurs through a range of mechanisms including: community reference groups; environmental and other water advisory committees; local and regional engagement officers; regional and local Indigenous engagement forums and facilitators; broad community engagement forums and direct engagement of industry groups, local government, NGOs (including water trusts) and individual landholders. For example, the Commonwealth Environmental Water Holder has recently established a network of local engagement officers throughout the Basin.

Case study 1: Community involvement delivers results

In spring 2012, consultation with landholders and representative community groups by the NSW Office of Environment and Heritage, Murray Catchment Management Authority and Commonwealth Environmental Water Holder led to the delivery of over four gigalitres of environmental water to Tuppal Creek, near Deniliquin.

The Tuppal Creek landholders greatly assisted NSW environmental water managers to develop the watering objectives, delivery timing and flow release rates for the event. They were also directly involved in the monitoring program.

Environmental flows helped improve vegetation condition and water quality, as well as supporting the breeding of frogs such as the spotted marsh, barking marsh and Peron's tree frog. Monitoring results have shown that river red gum and black box trees surrounding the creek system have increased canopy cover and fresh growth, while water plants including rushes and sedges are also growing in abundance. The flows have also assisted the wetland vegetation to withstand the hot weather over summer.

The Tuppal Creek community is enthusiastic about future watering opportunities in the region.

Click [here](#) to view a [YouTube video](#) about this watering event.



Figure 34 Tuppal Creek landholder Jim MacDonald and his daughter Grace. Photo: Vince Bucello

Case study 2: Environmental watering delivers benefits for country and culture at Fletchers Creek

The Barkindji Nation have lived in the area of Fletchers Creek, lakes around Wentworth and Dareton and all along the Darling River for thousands of years.

For generations, the river people lived a semi-nomadic life sustained by local water and food; allowing them to remain connected to country.

Construction of a road four decades ago disrupted the flow of water between Fletchers Creek and Fletchers Lake. Less water meant fewer opportunities to continue cultural practices such as harvesting emu and swan eggs, fish, yabbies, mussels, snails and turtles from the water and animals attracted to water—kangaroos, emus, echidnas and goannas.

Land had become degraded and infested with weeds and pests, including foxes and rabbits. Unauthorised recreational bike use had added to the damage; cars had been dumped; and ancestral burial grounds had been disturbed.

The Barkindji Maraura Elders Council formed a company in 2010 to provide employment for their people working to restore country. This company, the Barkindji Maraura Elders Environment Team (BMEET), secured Working on Country funding to control weeds and pests and to survey a stretch of the dry Fletchers Creek, providing baseline data. Murray-Darling Freshwater Research Centre staff helped to train Aboriginal people to monitor vegetation health.

When BMEET asked how water could be returned to Fletchers Creek (an ephemeral waterway that had not flowed into the lake for more than a decade) the Murray Darling Wetlands Working Group stepped in. The two groups entered a partnership project to deliver environmental water to Fletchers Creek and monitor the results.

In December 2013, pumps were used to inundate five kilometres of Fletchers Creek, delivering around 20 megalitres a day for 18 days. The water was sourced from NSW Office of Environment and Heritage entitlements. The watering event aimed to improve the condition of native floodplain and wetland vegetation communities.

The watering has transformed the land and waterway—bringing new life—to the delight of the Aboriginal custodians.

Birds have come seemingly from nowhere to breed; emu and swan eggs are available to harvest again. Birdwatchers have followed, identifying 33 bird species. Frogs are abundant and there is new growth on vegetation and new plants emerging—from lignum to cooba.

Elders are enjoying the opportunity to gather bush tucker again while young people are learning what it means to have water on country.

A walking trail has been constructed linking three monitoring sites, with signage about cultural and ecological values. A smart-phone application is being developed to provide a virtual tour along the trail.

The environmental watering event has helped the Barkindji Maraura meet their responsibility to care for country. They feel a sense of pride in the improved condition of the environment and return of wildlife.

'The changes we have seen are a direct result of returning water to the creek, part of our work and commitment to proudly and respectfully preserve and care for country', said Dameion Kennedy, Project Supervisor, BMEET.

Monitoring of the sites continues and they hope to source more environmental water for spring 2015.



Figure 35 Dennis King, a member of the Barkindji Nation employed to restore country, observes the watering of Fletchers Creek, NSW. Photo Barbara Bell, 2013

As far as possible, contribute to environmental benefit when managing all water

All water in the Basin, including natural events and consumptive water, has the potential to contribute to improving the ecological condition of rivers, wetlands and floodplains. While in the river, consumptive water can often contribute to ecosystem outcomes, without adding any further risks to the reliability of the associated entitlements. A recent example for Gunbower Creek is provided below.

In some cases river operating practices will need to be reviewed, and possibly altered, to provide river operators a mandate to manage rivers to achieve environmental outcomes.

Case study 3: Using consumptive water to achieve environmental purposes – Gunbower Creek, Victoria

Gunbower Creek's flow is largely driven by irrigation demands. There is significant and rapid fluctuation in water levels as water is turned 'on' and 'off' to meet water orders. During the winter months (when there is no irrigation demand) Gunbower Creek recedes to a series of residual pools that provide little to no habitat for fish; and predation on young fish is therefore extremely high. The rapid fluctuation and cessation of flow over winter is thought to be a major cause of the lack of recruitment of large-bodied fish in the creek. For example, Murray cod have a courtship, nest selection and nest protection phase which can be disrupted by sudden changes in water levels.

In 2013–14 the North Central Catchment Management Authority gained approval to use water already en-route down the River Murray to meet consumptive orders, but diverting it first into Gunbower Creek for environmental purposes.

The environmental water delivery was designed to smooth out the fluctuations in water levels within the creek and meet life-cycle needs of such fish. The flow rate was 'shaped' to deliver a spring rise followed by holding a high flow (from September through to February) to allow Murray cod to nest, spawn and for larvae to emerge, drift downstream and move into nursery zones of vegetation along the margins of the creek. A winter base flow was also provided (200–300 ML/d) so young fish were not forced into remnant pools where they would be at risk of dying.

After achieving this purpose within Gunbower Creek, most of the water was returned to the main River Murray. Water from the Commonwealth and Victorian environmental water allocations compensated for losses (e.g. through seepage or evaporation) during this management activity—to ensure that water availability for consumptive orders was not affected.

Monitoring identified three separate spawning events of Murray cod within Gunbower Creek, indicating the flow pattern was successful in creating suitable spawning conditions. Further monitoring will be carried out to see if these larvae successfully grow into young fish in the population.

Data supplied by Anna Chatfield, NCCMA, 4 July 2014.

Manage water in harmony with biological cues (including responses to flow) to restore elements of a more natural flow regime with variability and seasonality

Events such as fish spawning or migration and waterbird nesting are typically triggered by biological cues. These cues may be changes in water levels, river flows, water temperature or carbon and nutrient input resulting from local rainfall or a flood upstream. Sometimes a partial cue occurs—like when a rain event is largely captured in a dam upstream, but a small dam spill or some tributary inflows still trigger a biological response. A biological cue may also result from the absence of rain and flow—triggering ecological processes necessary for the survival of biota during a drying phase, such as fish movement to waterholes that provide refuge.

The best way to ensure that environmental watering is effective and creates these conditions is to work in harmony with biological cues. Nevertheless, adding or managing water in the absence of flow cues may be necessary to arrest decline. In these cases, water holders will consider the local circumstances and available evidence to make sure outcomes are achievable.

A further consideration in the highly-modified parts of the Basin—where rivers are ‘working rivers’—is the need to manage so as to achieve environmental outcomes that are appropriate in that context. The aim isn’t to return to a natural system (which is impractical). Rather, managers are looking to use infrastructure (e.g. channels, locks, regulators, blocking banks or levees) to deliver water flow that simulates natural conditions important for, say, stimulating the flowering or seedling germination of river red gum.

[Case study 4 below](#) provides an example of environmental water releases that extended the recession of a natural (or unregulated) flow event to achieve ecological outcomes in Barmah–Millewa Forest and down the length of the River Murray.

[Case study 5 below](#) outlines some of the challenges in achieving environmental outcomes in unregulated systems.

Further strategies to manage environmental water in harmony with biological cues in both regulated and unregulated catchments are outlined in the [Water management strategies to achieve outcomes for river flows and connectivity](#) section.



Figure 36 Wetlands near Gunbower, Victoria, after receiving an environmental water allocation via a regulator, 2008. Photo: Arthur Mostead



Figure 37 Lake Mulwala and Yarrawonga weir from the air. Photo: Michael Bell 2004

Case study 4: Coordinated use of environmental water to extend a natural flow event

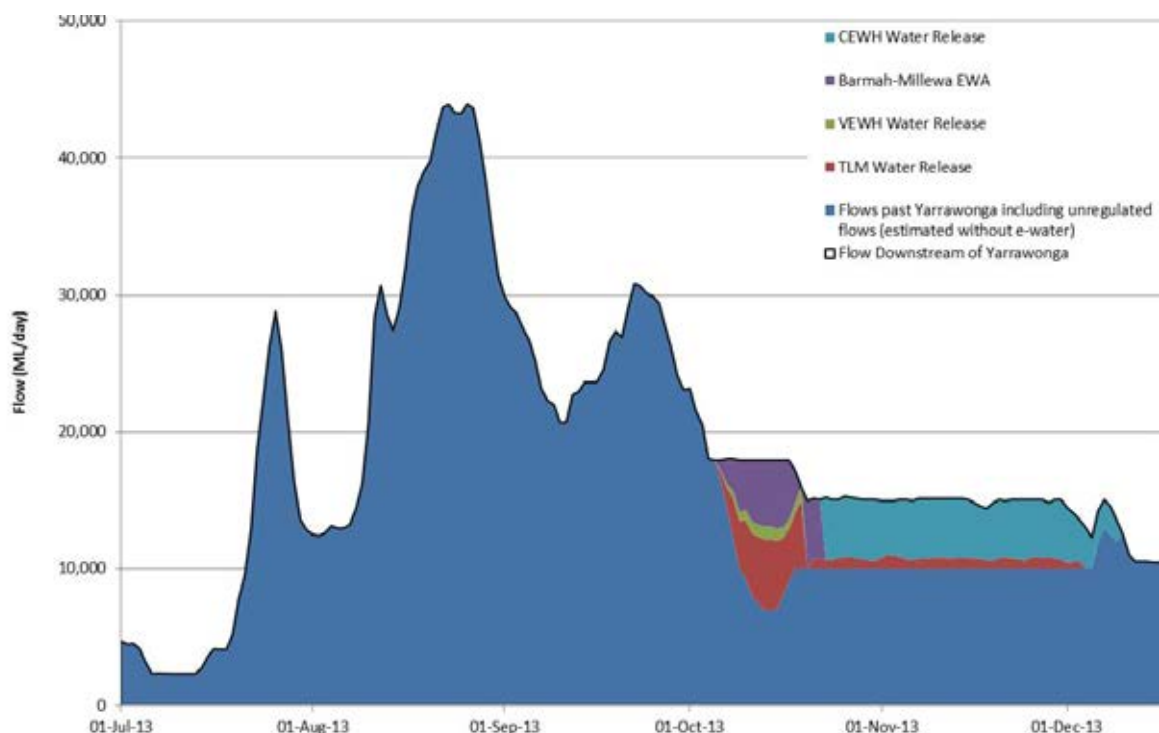


Figure 38 Flows in the River Murray downstream of Yarrawonga augmented by environmental releases to inundate Moira grass in the Barmah–Millewa forest

Note: Environmental water released included holdings from the Commonwealth Environmental Water Holder (CEWH), Barmah–Millewa Environmental Water Account (EWA), Victorian Environmental Water Holder (VEWH) and the Living Murray (TLM).

From late July 2013 high unregulated (natural) flows occurred in the upper River Murray system. These inundated large areas of Barmah–Millewa Forest. Environmental water holders took the opportunity to extend the duration of this inundation.

As natural high flows receded, environmental water was used to maintain flows in the River Murray channel downstream of Yarrawonga at 18,000 megalitres (ML) per day (as part of a two week trial in consultation with local landholders). This was then reduced to 15,000 ML/d from mid-October until the beginning of December. Maintaining these flow rates provided stable inundation levels across the Moira grass plains, which then resulted in successful and extensive vegetative growth, flowering and seed production. This was the strongest Moira grass response in seven years.

The return flows from this watering of Barmah–Millewa Forest were subsequently coordinated with flows from the Goulburn, Murrumbidgee and Darling Rivers and contributed to a combined environmental water delivery of 450,000 ML over the South Australian border. These flows supported:

- *fish outcomes, including breeding of golden and silver perch in the lower River Murray and Lake Alexandrina*
- *conditions for the flowering and fruiting of *Ruppia tuberosa* in the Coorong*
- *an increase in the number of waterbirds across Lake Albert, Lake Alexandrina, the Coorong and the Murray mouth, compared to the previous few years*
- *the Murray mouth remaining open without the need to dredge.*

Coordinate the planning and management of water for the best outcomes and to target multiple sites and functions in and between rivers

Maximum benefit and efficiency can be achieved by coordinating environmental flows to pass through multiple sites and provide a range of ecosystem functions. This is best achieved when different environmental water managers, holders and river operators work together across site and catchment boundaries.

A range of forums and agreements will be needed to coordinate environmental watering across the Basin. The ideal forum and its frequency of meeting will depend on the level of connectedness of the area, the degree of regulation, the state of the storages and other factors.

For example, in highly-connected and regulated systems such as the southern Basin, it will be necessary for a range of environmental water holders, river operators and other stakeholders to work together in the annual planning and delivery process. State and Commonwealth governments have, in principle, agreed to establish an appropriate coordination forum in the southern Basin.

In less connected but regulated systems, relevant state agencies with water holder and river operator functions, Catchment Management Authorities or equivalent groups, landholders and Indigenous representatives will be needed. (The Environmental Water Advisory Group—or EWAG—in the Macquarie valley is a good example of such arrangements.)

In unregulated systems, it may be possible to incorporate most elements of the annual delivery process within rules in state water resource plans (cross-agency and supplemented with occasional stakeholder consultation). The Paroo system is such an example—where the environmental outcomes set out in the water resource plan are to be achieved through operating rules on licences.

In the north of the Basin, the need to coordinate flows from unregulated catchments with releases from connected, regulated catchments might increase in future; in order to achieve the desired environmental outcomes in the Darling River.

Case study 4 (on preceding page) is a good example of coordinated planning and use of environmental water in the River Murray system for benefit at multiple sites. Four different environmental water managers pooled their holdings and, in partnership with river operators and landholders, coordinated the timing of their releases. Releases included the return flows from Barmah–Millewa Forest and the Goulburn, Broken, Campaspe, Murrumbidgee and Darling Rivers. This coordinated environmental watering event delivered 1090 GL to South Australia between November 2012 and June 2013; and included contributions from The Living Murray (289 GL), the Commonwealth Environmental Water Holder (787 GL) and South Australia (14 GL).

This approach achieved a number of environmental outcomes in the Barmah–Millewa Forest, the tributaries, and subsequently down the length of the River Murray. Activities such as this are underpinned by clear and shared objectives, risk management and communication strategies.

Case study 5: Achieving environmental outcomes in unregulated systems

In-stream waterholes and weir pools are critical drought refuges in northern Basin rivers—particularly in the Barwon–Darling River system. They support the viability of aquatic biota that lack specific adaptations to drought (e.g. all species of fish, turtles, some invertebrates etc.). Viable populations of these species depend upon networks of waterholes that persist during periods when flow ceases and connect during flow events.

To maintain these aquatic habitats as viable refugia, the NSW Barwon–Darling Water Sharing Plan has provisions that limit pumping access by irrigators; with a range of rules that protect certain portions of the flow regime, particularly during low- or no-flow periods. In addition, critical flow thresholds have been identified and established at a number of ‘hydrological indicator sites’ throughout the Northern Basin. These also provide guidance on environmental watering requirements in these systems.

To further enhance the environmental benefits of these access rules or where there is insufficient flow in the system to adequately support aquatic life, there is the potential to purchase—either as a temporary trade or by permanent acquisition of unregulated flow entitlements—water from upstream entitlement holders that are willing to forego their access on a short-term or permanent basis. For example, an unregulated entitlement holder upstream could potentially sell their access to a particular nominated flow event, providing for in-stream environmental benefits. Alternatively, in the situation where waterhole habitats are threatened with drying down and are therefore not able to provide adequate refuge habitat, and where no unregulated flows are available, there is the potential to purchase water that has been stored privately in on-farm dams and re-release it back into the river.

Feasibility of these options will be further explored with the implementation of the [Northern Basin Work Program](#).



Figure 39 Waterhole at Black Rocks on the Darling River. Photo: Neal Foster, 2014

Manage risks associated with the delivery of environmental water

There are a number of potential risks from undertaking environmental watering actions including:

- temporary water quality issues associated with large watering events (e.g. blackwater and salinity, see also Box 4 Water quality on [page 11](#))
- spread of invasive species (e.g. weeds and alien fish)
- inundation of private property or infrastructure either directly or indirectly.

The identification and management of any risks associated with the delivery of environmental water is considered throughout the relevant planning and delivery phases, to ensure that:

- people, property and cultural heritage are protected from unintended impacts
- the environmental outcomes of water use are maximised
- the use of environmental water is efficient
- there is good stewardship of environmental water holdings.

Manage adaptively

Adaptive management is a way of thinking about management, as well as a process of linking available knowledge with policies and actions. It is a systematic process for continually improving practices through learning from the outcomes of previous management (particularly from monitoring):



Figure 40 Adaptive management cycle

Adaptive management begins with clear, agreed objectives. The likely results should be considered before actions are taken. Management can then be revised or improved in light of observed outcomes.

Adaptive management includes:

- clear objectives and measurable objectives and outcomes, accepted by different groups
- local knowledge, active involvement and long-term commitment from stakeholders
- clear roles and responsibilities
- communication between communities, organisations and scientists

- learning about a system through active management and to changing an approach where needed
- commitment by communities and government to long-term monitoring and evaluation
- a monitoring and evaluation process that is itself adaptive
- regard for the social, economic and technical aspects of management.

Case study 6: Adaptive management of golden perch spawning

One of the priority objectives of environmental water delivery in the lower Goulburn River is to enable spawning of golden perch. Based on circumstances that led to a spawning event in 2010, a small environmental flow (a fresh) was delivered in November of 2011 and 2012—however, spawning did not ensue.

After reviewing this event, two freshes were delivered in November and December 2013—aimed to be as high as possible, in order to give the strongest cue. Golden perch eggs and larvae were collected, signifying a successful outcome from the water deliveries.

Some important information was collected from this: spawning occurred on the first fresh, with almost no spawning during the second fresh. Spawning was detected two days after the start of the rise of the fresh, as well as at the peak (7,000 megalitres/day at McCoys Bridge). The event was not preceded by floodplain inundation, as was previously thought to be important. Further data also suggested that large-scale spawning occurs in years with a greater variation in flow (regardless of height) rather than from one specific flood event (although large flows are also important for recruitment—creating environments favourable for migration when conditions in the Goulburn River are not suitable).



Figure 41 Golden perch held by fisherman. Photo: David Kleinert, 2009

Water management strategies to achieve outcomes for river flows and connectivity

The broad strategies to achieve the anticipated changes in flow and connectivity are outlined in this section; while those specific to achieving ecological outcomes for vegetation, waterbirds and fish are in the following sections.

As discussed previously, there has been experience in supplementing the flow regime of rivers with additional environmental water from dams; or identifying and protecting parts of the natural flow that are environmentally significant, and should therefore be considered by river managers. The most common approach is to mimic ecologically-significant parts of the natural flow regime that are important for the ecological outcomes being sought.

To achieve the expected outcomes for flow and connectivity, environmental water holders and managers will need to provide for environmental watering through planning (including long-term watering plans and water resource plans) and delivery, by adopting strategies relevant to the conditions, such as:

- releasing water between natural flow events to prolong higher flows
- adding or managing water to the end of a flow event by extending the recession (or tail) so that a more natural pattern is achieved. This could be through releasing flows in-stream; or using infrastructure (e.g. locks, regulators and earth banks) to control the duration and extent of inundation on the floodplain
- augmenting and coordinating tributary flows in regulated parts of the Basin (particularly those which naturally contribute large flows downstream) to help in meeting downstream environmental outcomes
- building upon a smaller event to achieve a higher peak flow (this may be possible in some circumstances, where any third party impacts can be managed)
- maintaining the integrity of flows throughout the length of the river and protecting flows from re-regulation, extraction or substitution with other water
- protecting patterns of flow events (like base or peak flows) in less-regulated rivers. This can be achieved by maintaining the integrity of these flows down the river; either through rules, special arrangements, or through temporary purchases of water access licences
- reducing the frequency and length of artificial dry periods
- operating rivers to improve and/or reinstate hydrodynamic diversity.

Addressing impediments to environmental water delivery is also an important strategy (this includes river operating practices and physical constraints). The expected outcomes identified in this strategy can be achieved within current constraints. However, addressing physical constraints and reviewing operating practices to provide more flexible river operations (including associated legal arrangements) will improve the environmental outcomes that can be achieved with the water available. These issues are being explored through the Constraints Management Strategy.

Water management strategies to achieve outcomes for native vegetation

To achieve the expected outcomes for native vegetation, environmental water holders and managers will need to provide for environmental watering through planning (including long-term watering plans and water resource plans) and delivery (including river operations) that:

- provides appropriate flow regimes (including frequency, timing and duration, as illustrated in [Figure 12](#)) that support the character of water-dependent vegetation on the managed floodplain including:
 - delivering in-channel freshes to maintain and improve condition, and inundation events to support recruitment of river red gum, black box and coolibah communities which fringe the main rivers within the Basin (Appendix 3)
 - delivering in-channel freshes to support vegetation fringing rivers and low-lying wetlands, and small over-bank events to inundate areas of large expanses of low-lying non-woody wetland communities which fringe the main rivers within the Basin (Appendix 3)
 - creating and augmenting lateral connectivity by increasing bank-full and, where possible, over-bank events, extending flow durations and protecting flow peaks (including by limiting extraction) to support vegetation communities (including lignum shrublands and river red gum, black box and coolibah forests and woodlands listed in Appendix 3)
- identifies and delivers long-term watering requirements for locations listed in Appendix 3 and other regionally significant sites of water-dependent vegetation, including:
 - watering requirements that support recruitment events and improve condition, including requirements for drying periods
 - identification of strategies to protect or restore flow regimes (in less-regulated systems) required to support water-dependent vegetation, e.g. water access rules
 - cooperative arrangements required to achieve vegetation outcomes, particularly for the lower River Murray, Border and Darling rivers.

The most relevant and contemporary understanding should be used to determine the appropriate frequency, timing and duration of flows for different vegetation types for each region. Typical frequencies and targets have been identified (an example is shown in [Figure 15](#)), and in work to establish the *Environmentally Sustainable Level of Take* process in the Basin Plan.

Water management strategies to achieve outcomes for waterbirds

To achieve the expected outcomes for waterbirds, environmental water holders and managers will need to provide for environmental watering through planning (including long-term watering plans and water resource plans) and delivery (including river operations), that:

- protects and restores significant waterbird sites (both regionally and Basin-wide—see Appendix 4) including:
 - creating and maintaining lateral connectivity, by increasing bank-full and, where possible, over-bank 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
 - coordinating flows to achieve outcomes for waterbirds; be it breeding opportunities for colonial nesting waterbirds, or foraging opportunities for migratory shorebirds in areas such as the Coorong and Lower Lakes.
- supports a network of waterbird sites across the Basin (important for waterbird breeding, nesting, foraging, resting and as drought refuge) by:
 - identifying and delivering long-term watering requirements for priority environmental assets in their region that will support breeding, maintain a diversity of habitats and protect drought refuges, including (but not limited to) sites considered to be of Basin significance by the MDBA as listed in Appendix 4.



Figure 42 Waterbirds in flight. Photo: Jennifer Spencer, courtesy of NSW Office of Environment & Heritage

Water management strategies to achieve outcomes for native fish

To achieve the expected outcomes for native fish, environmental water holders and managers will need to provide for environmental watering through planning (including long-term watering plans and water resource plans) and delivery (including river operations) that:

- supports native fish species to complete their life-cycles
- supports the needs of the whole fish community, by identifying and delivering relevant environmental water requirements
- improves native fish habitat
- protects and improves existing populations of threatened species.

More detail on each of these strategies is outlined below.

In applying the water management strategies for native fish, environmental water holders and managers must consider:

- the broad-scale assets that are of Basin significance for native fish (listed in Appendix 7)
- any regional and local-scale assets otherwise identified for native fish, especially where they relate to threatened species.

Supporting life-cycle completion

Planning and management should include:

- consideration of spawning and recruitment outcomes for all native fish species, especially where flow affects critical parts of their life-cycles (such as movement and dispersal)
- aligning protection of environmental flows and environmental water delivery with natural productivity, seasonality and timing of fish growth, movement and reproduction. (For example, late winter to early autumn is a critical time in the northern Basin, while a range of flows during winter are important in the southern Basin.)
- coordinating the planning and management of water to enable fish to complete key life-cycle requirements that occur across site and catchment boundaries; paying particular attention to the connectivity requirements of native fish—such as access to and exit from off-channel habitats at the appropriate time.

Supporting the needs of the whole fish community

Planning and management should identify and deliver relevant environmental water requirements, including:

- providing for fish outcomes on a decadal time scale. This may include identifying options for delivery of decadal flow regimes (including cease-to-flow, base flows, low flows, freshes and over-bank events) that outline inter-annual, annual, biennial and multi-year flow requirements for fish
- prioritising and protecting natural inflows, especially those that coincide with naturally high periods of in-stream productivity. Natural inflows trigger greater responses from native fish compared to water sourced from large dams and storages. For example, in the northern

Basin—protecting the first post-winter flow event—as it is one of the most biologically-significant events for the fish community

- focussing on opportunities to maximise longitudinal and lateral fish movement. This may include: performance indicators of fishway operation; periodic drown-out of low-level natural and man-made barriers (e.g. weirs); connectivity to off-stream habitats; and secondary connection events that allow fish recruited in off-channel habitats to return to the river
- following natural hydrographs as much as possible when water levels need to change (both rising and falling). For example: implementing actions that allow water levels to fall gradually; extending the recession of natural and managed flows; and mitigating large daily fluctuations in water levels through river and channel management (including extraction). These actions will prevent fish stranding in off-channel habitats, abandonment of nests and loss of nursery habitats
- maintaining drought refuge habitats to build population resilience and to prevent catastrophic loss of fish populations during extended dry periods.

Improving native fish habitat

Planning and management should include:

- protecting and improving unregulated systems for native fish and recognising the importance of these areas for the overall biodiversity of the Murray–Darling Basin, particularly in the northern Basin
- identifying and protecting priority dry period refuges (e.g. waterholes with high persistence levels) for fish in regulated and unregulated systems. Actions such as scouring flows prior to dry periods, maintenance of longitudinal connectivity between refuges, and protecting small inflows during dry conditions can be important
- reinstating in-channel flow variation, including at in-channel habitats with regulated stable water levels. Appropriately planned short-term flow variation can stimulate movement of juvenile fish, and gradual increases in normally stable water levels can trigger spawning responses in some species (e.g. silver perch can respond positively to a flow variation over only two days, with height changes up to 0.2m)
- providing for delivery arrangements that reinstate hydrodynamic diversity and improved in-stream habitats (e.g. faster-flowing habitats are particularly important for Murray cod, trout cod, Macquarie perch, golden perch and silver perch)
- maintaining a salinity gradient in the estuary, whilst ensuring that the spatial extent of the gradient varies.

Protecting and improving existing populations of threatened species

Planning and management should include:

- encouraging range expansions in populations of threatened species through appropriate flow regimes generally; and through delivery of appropriate flow regimes to additional sites that could support the introduction of threatened species
- coordinating the planning and management of flows to support the recovery of threatened species that complete life-cycles over large distances

- managing water quality risks to vulnerable populations and species. For example, cold water temperatures can limit reproduction and growth of native fish and should be mitigated where possible.

Managing to conditions

The Basin's variable climate requires that environmental watering is responsive to both antecedent (historic) conditions and expected (future) availability of environmental water.

The practice of managing environmental water in response to resource availability scenarios has been adopted over the past decade by most environmental water holders in the Basin. Various combinations of conditions and water availability result in categories of resource availability scenarios – e.g. 'very dry', 'dry', 'moderate', 'wet', and 'very wet'. Different outcomes will be sought depending on the resource availability scenario prevailing. (Further information on determining the resource availability scenario is available on our [website](#) in the document 'Statutory guideline on environmental watering'). This approach will be especially valuable when identifying Basin annual priorities and managing environmental water during drier periods.

Table 2 (on the next page) outlines environmental management objectives and outcomes appropriate for each resource availability scenario. The different management objectives have been tested by the Basin states, the MDBA and the Commonwealth Environmental Water Holder over the last decade. This is because held and planned environmental water supplements what is already in the river; and this varies year to year. For example, in moderate years environmental water might be used to connect the river to billabongs via high flows, whereas in a dry year this might not be possible.

Annual strategies to achieve expected outcomes for native vegetation, native fish and waterbirds are given in Table 2 for each resource availability scenario. When identifying Basin annual priorities, the MDBA will consider Table 2 along with the outcomes in Section 2 and the strategies in Section 3 of this document. Section 5 provides further explanation of the process.

Table 2 Resource availability scenarios, management outcomes and strategies to achieve them

	Scenario: Very Dry	Scenario: Dry	Scenario: Moderate	Scenario: Wet to Very Wet
Management objectives:	Avoid irretrievable loss of or damage to, environmental assets:	Ensure environmental assets maintain their basic functions and resilience:	Maintain ecological health and resilience:	Improve the health and resilience of water-dependent ecosystems:
Management outcomes:	Avoid critical loss of species, communities, and ecosystems. Maintain critical refuges. Avoid irretrievable damage or catastrophic events.	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.	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.	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.
Annual strategies to achieve outcomes will include:	<p>Allow drying to occur but relieve severe unnaturally prolonged dry periods. Prioritise watering where possible for:</p> <ul style="list-style-type: none"> • water-dependent vegetation sites identified as critical refuges for other species • waterbird drought refuges, particularly those identified in Appendix 4 • identified dry period native fish refuges, particularly for threatened species identified in Appendix 7. <p>Manage unnaturally low flow levels to mitigate water quality issues, particularly in the lower Basin, that are likely to cause irretrievable damage.</p>	<p>Allow drying to occur consistent with natural wetting–drying cycles to support maintenance of vegetation condition where possible. Prioritise watering where possible for:</p> <ul style="list-style-type: none"> • water-dependent vegetation sites identified as critical as refuges for other species • waterbird drought refuges, particularly those identified in Appendix 4 • identified dry period native fish refuges, particularly for threatened species identified in Appendix 7, and including opportunities to maintain refuge habitat (e.g. scouring flows). <p>Prioritise discharges through barrages, where possible.</p>	<p>Undertake follow-up watering events to promote longitudinal and lateral connectivity (where possible) to:</p> <ul style="list-style-type: none"> • support successful recruitment or to assist in restoring and maintaining vegetation condition in floodplain communities near river wetlands and anabranches (including but not restricted to communities in Appendix 3) • support growth, reproduction and recruitment for waterbirds (particularly at sites listed in Appendix 4) including low-lying floodplain–river connectivity for foraging opportunities • promote in-stream flows and low-lying floodplain–river connectivity for fish breeding, foraging, growth and movement; including for estuarine species. 	<p>Build on natural events to maximise longitudinal and lateral connectivity to:</p> <ul style="list-style-type: none"> • support maintenance and improvement in vegetation condition and large-scale recruitment events, on a broader extent of the lower floodplain (including but not restricted to communities in Appendix 3) • support growth, reproduction and large-scale recruitment for waterbirds, including the episodic productivity of large wetlands that are supporting waterbird breeding and foraging • support growth, reproduction and large-scale recruitment and movement for native fish.

4. Roles and responsibilities

The management of environmental water in the Basin will be undertaken by a range of agencies under a framework which fosters coordination between local agencies, states and the Commonwealth; for both planning and real-time water delivery.

[Figure 43](#) outlines the key parts of the process for managing environmental water. Planning and prioritisation at the basin and regional scale informs the active delivery of water in real time. Further detail is provided in the following sections which outline the key roles and responsibilities for the implementation of environmental watering.

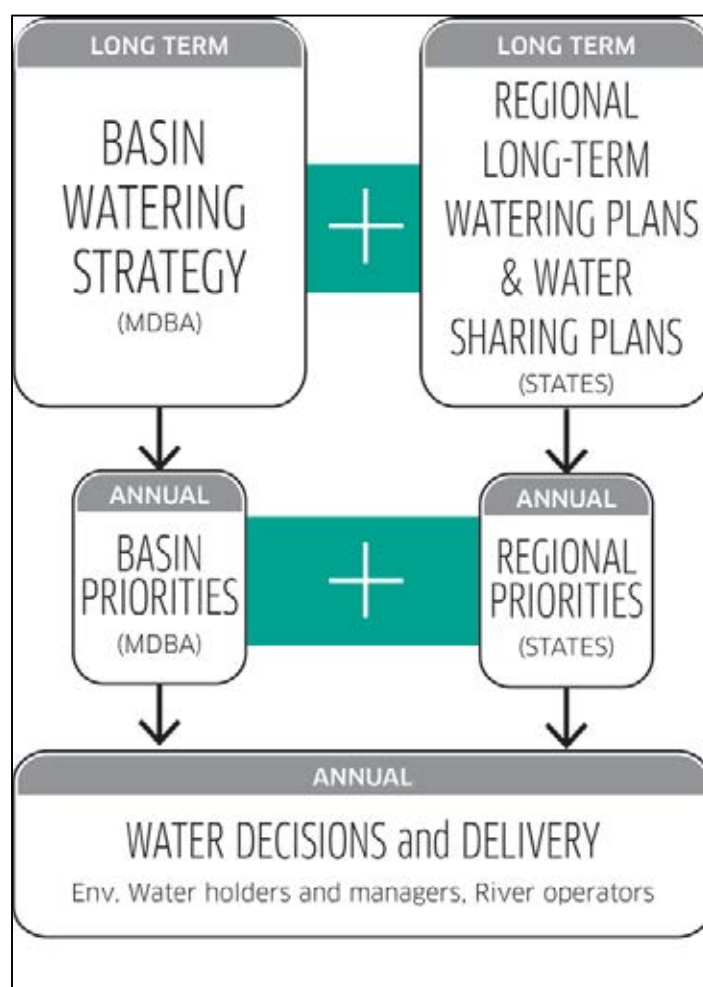


Figure 43 Key elements of the framework for environmental watering in the Murray–Darling Basin

Local knowledge and experience is important for effectively managing and delivering environmental water; with communities having an important role in providing critical information that informs each stage of the planning process. With the support of environmental water managers and Basin states, the MDBA will publish information on its website that assists communities to become involved in environmental watering in their local area. More information is provided in ‘Harnessing community knowledge’ in [Section 3: Water management strategies for maximising environmental outcomes](#).

Box 8: Role of the Commonwealth and state governments

Murray–Darling Basin Authority:

- oversees and evaluates the implementation of the Murray–Darling Basin Plan, including the [Environmental Watering Plan](#)
- identifies the longer-term Basin-scale outcomes and annual environmental watering priorities to achieve the objectives of the Environmental Watering Plan
- operator of River Murray system on behalf of Basin governments
- manages The Living Murray (TLM) (on behalf of the NSW, Vic, SA, ACT and Commonwealth governments) which delivers environmental water to improve the health of six icon sites in the Murray catchment
- collaborates with all parties (Commonwealth, state and local) to coordinate the planning, prioritisation and use of environmental water.

Commonwealth Environmental Water Holder (CEWH):

- manages the Commonwealth’s water holdings (entitlements and allocations), acquired through government investment in water-saving infrastructure and water buy-backs as part of national water reforms
- decides on use, carryover and trade of the Commonwealth’s water holdings to maximise environmental outcomes at both local catchment and basin scales. This is undertaken consistent with the Basin-wide environmental watering strategy (this document) and the Basin Plan’s Environmental Watering Plan; and in consideration of Basin annual priorities
- collaborates with all parties (Commonwealth, state and local) associated with environmental water management to coordinate the planning, prioritisation and use of environmental water.

Basin states (NSW, VIC, QLD, SA and ACT):

- identify long-term and annual environmental outcomes, priorities and watering needs for environmental assets and functions in each catchment
- manage state environmental water, including planned environmental water (water set aside in water resource plans for environmental outcomes) and/or held water entitlements and allocations
- determine the best ways to use (either through rules or active decisions on water use and delivery, carryover and/or trade) available water in the interests of achieving environmental outcomes at local catchment and Basin scales, in line with the Basin Plan’s environmental watering plan; in consideration of Basin annual priorities
- place orders for watering actions—including Commonwealth environmental water—with river operators
- collaborate with all parties associated with environmental water management at state and local levels; as well as the MBDA and the CEWH to coordinate the planning, prioritisation and use of environmental water.

Long-term planning

Long-term planning for environmental watering in the Murray–Darling Basin operates at two geographical scales: the basin scale and the regional scale; usually based around catchments (or water resource areas). There are three long-term planning instruments: the Basin-wide environmental watering strategy; and water resource plans and long-term watering plans for each water resource area. These planning tools aim to coordinate environmental watering across the Basin to achieve long-term outcomes.

The MDBA is responsible for the Basin-wide environmental watering strategy, which is reviewed at least every five years in consultation with stakeholders. The Commonwealth Environmental Water Holder (CEWH) must manage its water consistently with this strategy.

Basin states are responsible for preparing long-term watering plans and water resource plans for each water resource plan area (refer [Figure 44](#)).

The states' long-term watering plans will be developed in consultation and collaboration with holders and managers of environmental water, state and Commonwealth government agencies, river operators and local communities. To achieve integration where management crosses water resource area or state boundaries, they will be developed in consultation and collaboration with relevant government jurisdictions and agencies. The long-term watering plans will:

- have regard to this strategy—including the environmental outcomes, their associated strategies and the roles and responsibilities for environmental watering
- include regional watering requirements and priorities
- identify the watering requirements of priority environmental assets and environmental functions in the region
- identify possible cooperative arrangements.

Long-term watering plans are also likely to be referenced in, or enabled by, relevant state water resource plans. The Basin Plan requires Basin states to ensure there is consistency between their water resource plans and their long-term watering plans. Currently, much of the information which would go into the long-term watering plans exists in documents or practices that have been developed to manage environmental water in those catchments over recent years. The long-term watering plans are an opportunity to consolidate this work.

Some water resource plans (particularly in unregulated catchments) contain operating rules governing water access and/or rules for the delivery of planned environmental water that is not held in the form of water entitlements. In these cases environmental outcomes are effectively hard-wired into the plans and there is little in the way of water in public storages to be managed. It is important that such rules are reviewed and modified as water resource plans are updated to support achievement of Basin-scale and regional environmental outcomes without creating additional risks.

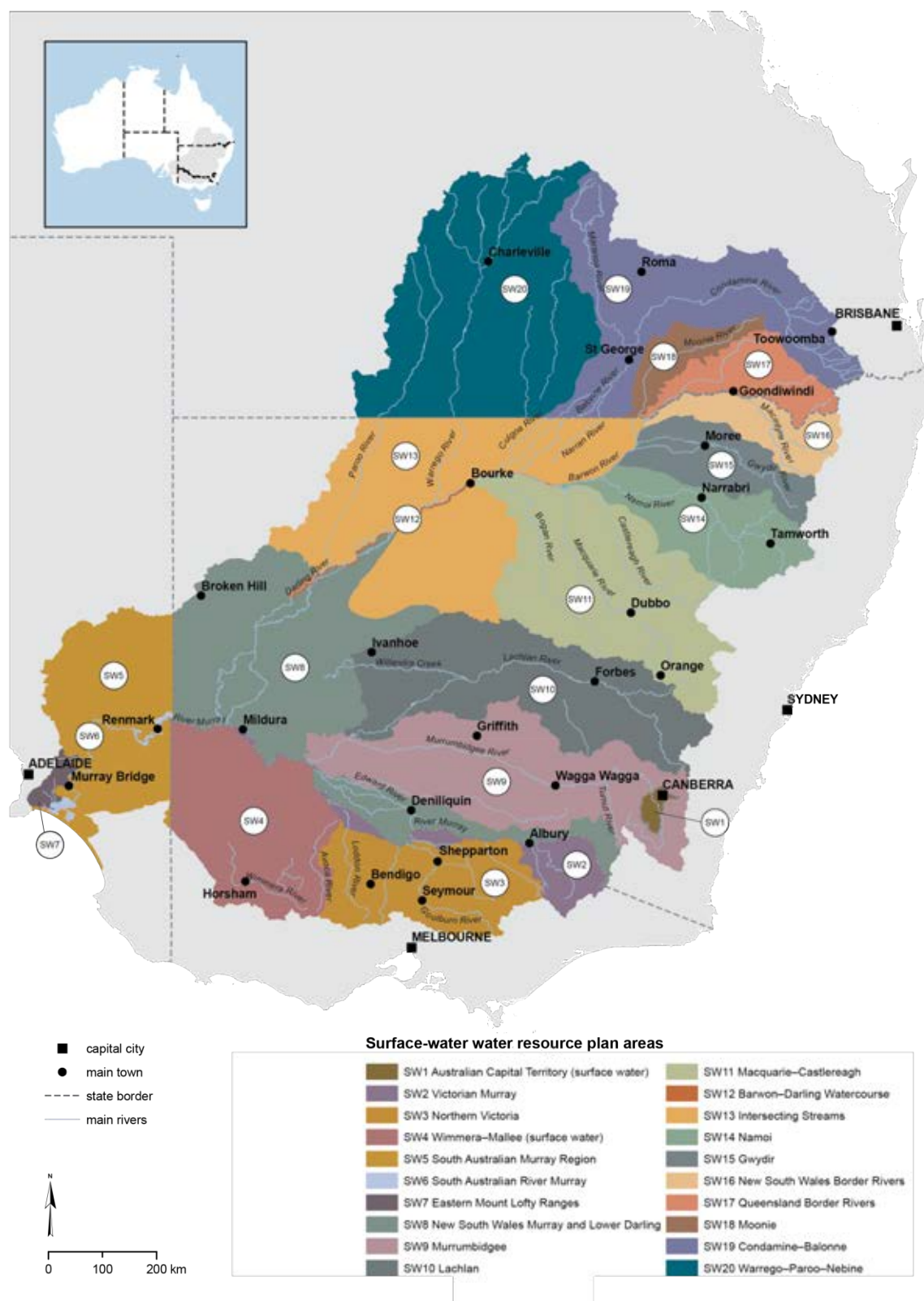


Figure 44 Surface water resource plan areas in the Basin for which long-term environmental watering plans need to be developed

Annual environmental watering

The annual planning process for environmental water provides a robust information base to support environmental water managers in making decisions throughout the water year. Annual planning processes consider environmental water demands across the Murray–Darling Basin, both within catchments and across state and catchment boundaries.

A generic description of the annual environmental watering process is provided below; noting that this may evolve or change over time or be adapted to reflect local conditions.

Planning

Environmental water managers typically undertake planning between January and the end of June to identify potential environmental watering opportunities for the coming water year(s).

Throughout the planning process the MDBA, Commonwealth Environmental Water Holder (CEWH) and state environmental water managers consult closely with one another and river operators. This consultation is critical for coordination and ensuring that proposed watering is feasible. Consultation is also undertaken with a range of stakeholders, including local environmental water advisory groups, Aboriginal representatives, local governments, irrigation groups, landholders, catchment natural resource managers and site managers.

To inform environmental water planning and support the coordination of environmental water across the Basin, states provide the MDBA with environmental watering priorities for each water resource plan area at the end of May each year. Annual environmental watering priorities consider the condition of sites; prevailing climate; history of watering; forecasts for climate; and available water resource outlooks, including likely holdings of environmental water.

The [Basin annual environmental watering priorities](#) that are identified by the MDBA are informed by the state environmental watering priorities, as well as input from other relevant sources. Published in June each year, they describe important Basin environmental outcomes for the coming year (see [How MDBA will identify Basin annual environmental watering priorities](#) for more detail on this process). These Basin annual environmental watering priorities are an input into the planning undertaken by water holders.

Environmental water holders (e.g. CEWH, Victorian Environmental Water Holder, TLM and Riverbank) also produce annual plans. These set out how they anticipate their portfolios will be used, how they will coordinate with other holders and any river operational considerations or risk management issues that may need to be considered in the coming year. Here are a few examples:

CEWH: [Commonwealth environmental water annual use options: planning approach](#)

VEWH: [Seasonal watering plan 2014-15](#)

NSW: [Managing environmental water](#)

More information is provided in ‘coordinate the planning and management of water for the best outcomes and to target multiple sites and functions in and between rivers’ in [Section 3: Water management strategies for maximising environmental outcomes](#).

Implementation

Towards the beginning of the new water year the focus shifts from planning to implementation. More detailed consideration is given to current and forecasted conditions and water availability, to determine which of the options identified during the planning process can feasibly be implemented. Local on-ground knowledge is important for detailing a specific watering action—including the flow magnitude, timing, rates of rise and fall, the area to be inundated and triggers for commencement. It also provides critical input to the detailed risk assessment that is undertaken before a decision is made on a watering action.

The decision by environmental water managers to commit water to an action is made in consultation with other relevant environmental water managers and with river operators, who are responsible for managing the delivery of the water and operational monitoring. Local community consultation and input is crucial at this stage of implementation and during water delivery, as conditions can change rapidly and may result in the need to adjust, suspend or even cancel the watering action.

A range of partners are involved in the delivery of environmental water: including environmental water holders and managers, river operators, land and waterway managers and owners and local communities (refer Box 9).

In the southern Basin, governments have agreed that they will cooperate to mobilise environmental water to achieve the best environmental outcomes. This will include some coordinated planning and implementation to deploy the various water holdings in a way that is suitable, given the flow conditions that arise in any given year.

When delivering environmental water, managers and holders (in collaboration with river operators):

- respond to prevailing conditions and opportunities as they arise
- maximise environmental benefit (e.g. responding to natural flow events, coordinating the water delivery, and building on local and Aboriginal knowledge)
- coordinate operation of related infrastructure (e.g. releases from storages, operation of locks, weirs, regulators, related channel systems pumps and use of diversion banks)
- manage and mitigate risks, including any impacts on third parties.

River operators have a critical role to play in the delivery of environmental water. Operators are required to deliver water to their customers within the river management practices agreed by various Basin governments. The river operators' responsibility is to deliver water to all entitlement holders, whether it is for environmental or consumptive use.

River operators manage environmental water with the same diligence and caution they use to deliver irrigation and town water. This includes continually appraising any risks, forecasting rainfall events and tributary inflows against peak regulated operating levels, and being careful to manage any possible impacts while delivering water. Environmental water holders work with operators in real time to manage adverse impacts, while still getting the best environmental outcomes.

Review

Upon completion of the watering action, a review process is undertaken to inform future watering actions and long-term management. This review is informed by the operational monitoring, results of ecological monitoring, and feedback provided by site managers and the local community.

Water resource plans

Chapter 10 of the Basin Plan sets out how water resource plans are to be developed. In particular, water resource plans must provide for environmental watering to occur in a way that is consistent with the environmental watering plan and this Basin-wide environmental watering strategy.

This strategy elaborates on the objectives in the environmental watering plan and quantifies the expected outcomes. It also provides information about how and where environmental watering is required to achieve the Basin-wide environmental outcomes.

Water resource plans must also take account of long-term watering plans. Where a long-term watering plan is not yet in place, states will need to assemble the type of information that long-term watering plans contain—in order to ensure that water resource plans facilitate the environmental watering required by environmental assets and ecosystem functions. In most cases this will require appropriate rules to be included in water resource plans.



Figure 45 Local landholders in the Murrumbidgee meet with MDBA's Paul Doyle to discuss constraints, 2014

Box 9: Partners involved in water delivery

There are a number of stakeholders who actively work in partnership across the Basin to coordinate environmental water delivery. Currently this includes:

- *Managers of held and planned environmental water*
 - *CEWH*
 - *NSW Office of Environment & Heritage*
 - *NSW Office of Water*
 - *QLD Natural Resources and Mines*
 - *Victorian Environmental Water Holder*
 - *Victorian Department of Environment and Primary Industries*
 - *The Living Murray (Vic, NSW, SA, ACT and Cwlth governments)*
 - *South Australian Department of Environment, Water and Natural Resources*
- *River and infrastructure operators*
 - *State Water*
 - *Sun Water*
 - *South-east Queensland Water*
 - *MDBA*
 - *Goulburn-Murray Water, Lower Murray Water, Grampians–Wimmera–Mallee Water*
 - *SA Water*
 - *Snowy Hydro*
 - *Irrigation companies*
- *Land and waterway managers*
 - *National Parks in each state (e.g. Parks Victoria, NSW National Parks and Wildlife Service)*
 - *Forestry*
 - *Private landholders*
 - *Catchment Management Authorities/ Local Land Services*
- *Local communities (community and environmental water advisory groups).*

5. How MDBA will identify Basin annual environmental watering priorities

Introduction

The *Basin annual environmental watering priorities* are the annual expression of this strategy. Each year the MDBA will publish an environmental watering 'outlook' in March and Basin annual environmental watering priorities at the end of June. These provide guidance to water holders and managers on priorities for the coming water year from a whole-of-basin perspective. The Basin priorities developed by the MDBA are not an exhaustive list of all important locations in the Basin. They identify assets, functions and processes, and environmental outcomes that the MDBA considers of Basin significance for watering in the subsequent year (July–June). Water holders will consider these priorities alongside priorities of local or regional significance.

Environmental water holders and managers make decisions throughout the year about the use of environmental water. In some years there may be more places or processes that need more water than there is available. In these circumstances choices will need to be made about the relative priority of sites or watering actions. The MDBA and states identify priorities before the beginning of each water year. The states will do the detailed planning and priorities for most catchments.

How watering priorities will be identified

The principles applied to determine Basin Priorities (Part 6, Division 1 of the Environmental Watering Plan of the Basin Plan) are:

1. consistency with the principles of ecologically sustainable development and international agreements
2. consistency with environmental watering plan objectives
3. flexibility and responsiveness
4. condition of environmental assets and ecosystem functions
5. likely effectiveness and related matters
6. risks and related matters
7. robust and transparent decisions.

Guided by these principles, the process to identify Basin annual priorities will follow the broad steps identified below.

Reflect on environmental watering since the release of any previous priorities

A mid-year review of environmental watering is carried out to determine whether outcomes from previous priorities have been met, or are likely to be. Where the outcomes are not fully met the priorities may be considered for relisting. The MDBA publishes an outlook statement in March which addresses these matters.

Identify the resource availability scenario and management outcomes

The MDBA will consider conditions in the previous season, current water availability, long-term weather forecasts, antecedent conditions and likely water availability to judge the upcoming resource availability scenario (see Table 2) in the Basin. Consistent with the outcomes and strategies identified in Part 2 and Part 3 of this document, the MDBA will identify management outcomes and priorities consistent with the conditions expected in the coming year. Priorities are expressed in such a way that there is flexibility if different seasonal conditions than expected eventuate.

Particular attention will be paid to outcomes that need coordination across state borders, as these cannot be addressed by states acting alone. The assessment of sites is combined with an assessment of functions and a consideration of outcomes desired.

Assess threats, opportunities and Basin-wide significance

Threats and opportunities are assessed using flow data and other available information. This assessment evaluates when environmental water requirements identified for various sites were last met. The Basin-wide significance of a potential Basin annual priority is considered. This includes: the significance of the environmental benefit if the priority is met; the risk of not listing the priority; certainty and likelihood of benefit; and synergies and multiple outcomes. These assessments will help determine whether a site, environmental watering action or outcome should be a Basin annual priority.

Consider complementary outcomes and risks

Environmental watering may provide benefits to Aboriginal communities by meeting Aboriginal environmental outcomes and cultural values and uses. Water-dependent cultural values include resource, teaching and ceremonial sites; and sites that contain physical evidence of occupation.

Environmental outcomes may also lead to social and economic benefits. For example, improved water quality and reduced salinity levels lower the cost to treat water and reduce damage to water infrastructure associated with salinity. Environmental flows can also raise tourist numbers along waterways in regional communities by maintaining habitat for fish, as well as improving the aesthetic values associated with a healthy environment. The potential for complementary outcomes is considered at a broad level at the stage of identifying possible priorities. However, detailed consideration would also be given to this when at the stage where a state or the CEWH is considering implementation.

The MDBA will also consider the broad risks associated with the delivery of a particular priority, to ensure that the priority is practical and feasible. However, environmental water holders make the final judgement about the level of acceptable risk in relation to environmental watering—and which mitigating strategies are adopted.

Consider state annual environmental watering priorities

The priorities are informed by local experience and knowledge. The MDBA works with environmental water holders and managers to help identify regional priorities considered important at a Basin level. The MDBA consults with environmental water holders and managers before publishing the Basin environmental watering outlook early in the calendar year. This provides a mid-year summary of progress, considers weather and water availability forecasts, and gives an early indication of possible priorities. MDBA formally considers state annual environmental watering priorities in early June.

Consult and collaborate

The Basin priorities are refined and tested against seasonal, operational, scientific and management knowledge.

Feedback from consultation with governments, water holders, river operators, peak groups, community representatives and people directly affected by environmental watering is gathered. Together with formal reporting from holders and managers of environmental water, this information is used to inform the development of priorities. Consultation with communities is undertaken in collaboration with existing state consultation processes.

As components of the environmental watering plan are implemented and planning cycles between and within jurisdictions are integrated, the MDBA will adapt and improve how it identifies Basin priorities. Improvements will be underpinned by consultation and engagement; and improvements in knowledge and processes.

Priorities in very dry years

In some years there will be a lot of competition for where environmental water could be used in the Basin. This will be particularly evident in individual dry years and during droughts. As outlined in Table 2, the management objectives for delivery of environmental water in these years ranges from 'avoiding irretrievable loss of or damage to environmental assets'; through to maintaining basic functioning, where possible. While all of the steps outlined in the sections above will still be appropriate, there will be a heightened need to compare potential benefits and risks of alternative watering options.

Experience from the recent millennium drought was that managers had to thoroughly and continually weigh up the outcomes and risks of using the small amounts of available environmental water in different places. One of the hardest decisions was whether to use small amounts of water on drought refuges in different parts of the Basin, or to provide water to keep the river running to the Coorong and the sea. There is no single answer which will be right for all similar dilemmas in the future. However, one aspect that Basin governments found useful was to consider the material difference that the available water could have at different sites verses the risk of catastrophic events.

Where there may be trade-offs involved in allocating water amongst competing priorities or conflicting views in the setting of Basin annual priorities, the MDBA will use its best endeavours to resolve these. This may include discussions with the states prior to the publication of the Basin annual watering priorities. It is important to note that the MDBA's priorities provide guidance—the ultimate decision on use rests with the environmental water holders.

6. Measuring success

The MDBA will monitor the success of this strategy as part of the broader Basin Plan monitoring and evaluation program, in partnership with Basin governments and the community. Measurements of success will feed directly into adaptive management and improvement of the strategy over time.

Ultimately, the success of the strategy will be measured by the progress towards achieving the environmental objectives of the Basin Plan. This will be determined by comparing monitoring data to environmental watering targets identified in the Basin Plan (reproduced in Appendix 1). The expected outcomes identified in this strategy provide further context or elaboration on the objectives and targets in the Basin Plan that will assist the evaluation process.

The primary test of success is that there should be *no loss or degradation* of the environmental outcomes being sought in the initial phase of the Basin Plan implementation (up until June 2019) and *improvements* thereafter (from July 2019) (refer [Figure 46](#)). Long-term watering plans to be developed by Basin states for each region over the coming years will establish finer-scale objectives and targets for environmental assets and functions.

As the Basin Plan is being implemented progressively, monitoring and evaluation programs will be developed. Monitoring and evaluation will need to be able to tease out the contribution of environmental watering from other factors like climate, other natural resource management activities, fire and the rate of water recovery. For example, if the period from 2014 to 2019 is a sequence of dry years, then the observed environmental response would be expected to be muted relative to a sequence of wet years. This would need to be considered when evaluating whether we have met the expected outcomes identified in this strategy.

Direct observations about how various outcomes change over years will need to be complemented by a 'counter factual' analysis based on predicting what is likely to have happened with and without the Basin Plan. This means that the effectiveness of environmental watering must be measured relative to what would have happened had no Basin Plan been in effect. During a sequence of dry years, a muted environmental response may still be considered successful.

For more information on the approach to monitoring and evaluation, see the [Basin Plan evaluation framework](#).

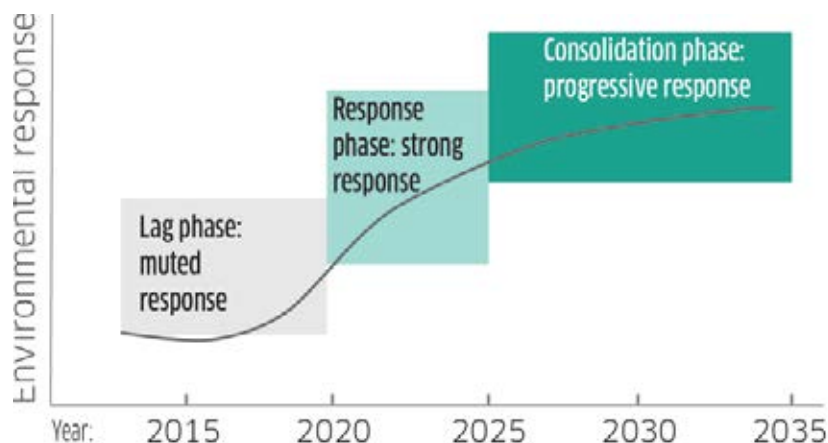


Figure 46 Illustrative environmental response to Basin Plan implementation

Different organisations have monitoring programs, or are developing them—these will be drawn upon to measure the success of this strategy. An example is the work on long-term intervention monitoring being undertaken by the Commonwealth Environmental Water Office. This project involves measuring ecological responses to Commonwealth environmental watering actions at seven sites in the Basin over five years, commencing in 2014–15. The MDBA is working with Basin states and the CEWH to identify how the current programs will inform our assessments and whether further coordination or enhancement of programs could be achieved to better inform our evaluation.

The CEWH, Basin state governments and the MDBA will report annually on the implementation of the environmental management framework. This will include reporting on: the purposes of environmental watering actions; the actual volumes delivered (and how these aligned with the Basin-wide annual environmental watering priorities for that reporting period); as well as how those organisations coordinated, or contributed to coordination, across the Basin. While compliance with Basin-wide annual environmental watering priorities is not mandatory, Basin states and the CEWH must report to the MDBA if the Basin priorities are not met.

Evaluating this information will allow us to identify the factors that enable or act as barriers to coordinating environmental watering and achieving Basin-wide priorities (noting that, in some cases, there will be sound reasons for watering that is not consistent with Basin-wide priorities). In some years, the findings may influence Basin-wide priorities set the following year. What has been learned is also expected to feed into decisions by the Basin states and the CEWH over the following years.



Figure 47 Monitoring river biological health at Biggara, Victoria. Photo: Tapas Biswas, MDBA

7. Future work

Review and update of the strategy

The MDBA must review and update the strategy no later than five years after it is first made or since the strategy was last reviewed and updated. A review could be undertaken in response to various triggers, including: new information arising from monitoring and evaluating responses to environmental watering; an SDL adjustment; new knowledge about the Basin's ecology; or improved understanding of climate change and its impacts on the Basin environment.

Any review will be conducted in accordance with requirements in the Basin Plan, including working with states, Basin communities and environmental water managers and river operators.

Ongoing development

This first strategy addresses four of the high-level outcomes (Section 2) identified for the Basin's water-dependent ecosystems; namely river flows and connectivity, waterbirds, native vegetation and native fish. These will be updated, as appropriate, consistent with the principle of adaptive management. Outcomes for other important elements may be included in future revisions of the strategy as scientific understanding and/or modelling capability improves, particularly at the Basin scale. This strategy will also be refined in response to new information and what has been learned through implementing long-term watering plans and annual priorities.

In developing the strategy, the MDBA was required to have regard to a number of matters, including optimising social, economic and environmental outcomes, and Indigenous cultural values and uses. These are areas in which knowledge and tools for assessment are still being developed in Australia.

Systematic planning tools for environmental water planning

The MDBA is developing systematic planning tools to support the implementation of the Basin Plan—including identification of Basin annual environmental watering priorities. These tools will improve the objectivity, robustness and scientific validity of the process. Tools being developed include:

- an environmental assets and ecosystem functions database as a repository of information
- a process to prioritise the assets and functions in terms of their ecological condition, biophysical type, relative importance of their biodiversity and functional values, and their need for environmental watering
- a classification and typology of water-dependent ecosystems in the Basin.

Fish work

One of the areas of potential development is hydrodynamic diversity. MDBA has identified that there would be benefit in investigating sites and options for restoring hydrodynamic diversity to improve the delivery of flows, including the management of weir pools.

MDBA will also look at developing a fish community index to quantify how improving water management benefits the whole native fish community.

Indigenous values and uses

The Basin Plan requires that Indigenous values and uses be considered as part of environmental water management—in particular, in the preparation of water resource plans. Basin states have the lead for how this will be approached.

To assist in the overall task, the MDBA is contributing to a multi-year project—the [National Cultural Flows Research Project](#)—which aims to provide research on Aboriginal values. The project proposes to draw on a range of scientific research methodologies and generations of cultural knowledge to:

- provide a greater understanding of Aboriginal values relating to water and other natural resources
- provide Aboriginal people with information and approaches to help ensure that Aboriginal water requirements and preferences are reflected in water planning and management policy
- inform the development of new governance approaches to water management that incorporate aspects of Aboriginal governance and capacity building.

The MDBA is also trialling a systematic approach (called the Aboriginal Cultural Flows Health Indicator) for incorporating cultural values into water planning in cooperation with Aboriginal people.

As the information becomes available from these processes and other work being undertaken by Basin states, it will provide guidance to future reviews of this strategy (noting that the primary purpose of the strategy is the achievement of environmental outcomes).

Social and economic benefits of ecosystem services

It is widely recognised that water planning in Australia needs to continue to improve its understanding of the social and economic benefits provided by well-functioning ecosystems. This area of research is commonly referred to as ‘ecosystem services’ and looks at the aspects of ecosystems that contribute to human wellbeing. These include benefits that are direct and indirect, market and non-market, and use and non-use—many of which have historically been difficult to investigate and quantify. Nevertheless, it has become increasingly important that these services from healthy ecosystems are recognised and considered in water planning across the Basin.

The Basin Plan has a focus on optimising the social, economic and environmental outcomes arising from the use and management of the Basin’s water resources. During its development, the MDBA took into account a wide range of social and economic information. This included assessments of the [ecological and economic benefits of environmental water in the Murray–Darling Basin](#).

Continuing to provide high quality research and analysis on the economic and social impacts of the Basin Plan, and investigating the economic and social benefits of ecosystem services in the Basin, is a priority for the MDBA.

Northern Basin Work Program

The MDBA is undertaking a series of reviews and studies to improve the level of understanding of environmental science, water recovery modelling and social and economic assessments in the northern Basin. This work, to be synthesised in late 2015, will contribute to identifying options for water recovery in the northern shared zone and the Condamine–Balonne.

Glossary

Anabranches	Branch of a river that leaves the main stream and re-joins it downstream.
Bank-full flows	The maximum amount of water a channel can hold without overflowing—a key factor in determining the shape of a river.
Base flows	The usual, reliable, background flow levels within a river channel; maintained generally by seepage from groundwater storage, but also by surface inflows.
Blackwater	Oxygen-depleted water caused by the decay of organic matter. Localised and temporary blackwater events are a natural part of the ecology of lowland river systems during flooding.
CAMBA	China–Australia Migratory Bird Agreement.
Cease-to-flow periods	A time when there is no flow in the channel.
Cold water pollution	Occurs when relatively colder water is released from water storages into the river. This can have negative impacts on the environment by restricting the growth and reproduction of freshwater fauna.
Diadromous	Fishes spending part of their life-cycle in salt water and part in fresh water.
Ecosystem functions	The processes that arise from the interaction of biota with the physical environment and with each other, that maintain the integrity and health of an ecosystem.
Estuarine system	A coastal habitat (or body of water) characterised by the mixing of fresh and salt water. Estuaries are influenced by tide, wave and river processes.
Flood-runner	A stream that branches off and flows away from a main stream channel.
Flow components	The different volumes of water that make up a flow regime. They typically include ‘cease-to-flow’ periods, ‘base flows’, ‘freshes’, ‘bank-full flows’ and ‘over-bank flows’.
Flow regime	The description of the characteristic pattern of a river’s flow including the quantity, timing and variability.
Food web	The linking and inter-linking of multiple food chains, as may be found in a complex ecosystem (for example, river/lake/forest) with several stages in the food chains.
Freshes	A pulse of water in a river channel, usually caused by heavy rainfall upstream. Freshes deliver important nutrients and enable salt and sediment to move in the system.
Held environmental water	Water available under: a water access right, a water delivery right, or an irrigation right; for the purposes of achieving environmental outcomes (including water specified in a water access right to be for environmental use).

Hydrodynamic diversity	The way flows interact with the physical structure of rivers to create sections of fast-flowing, slow-flowing and still water habitats at local to landscape scales.
Hydrograph	A graph showing the rate of flow (discharge volume) over a period of time past a specific point in a river.
Hydrology	The study of the occurrence, distribution and movement of water.
Hydrological connectivity	The flow that links natural aquatic environments. Lateral connectivity is the flow linking river channels and the floodplain. Longitudinal connectivity relates to the consistent downstream flow along the length of rivers.
JAMBA	Japan–Australia Migratory Bird Agreement.
Over-bank flows	Flows that spill over the riverbank and onto floodplains. They benefit a broad range of biota (including floodplain vegetation communities, birds and native fish) and support important ecosystem functions.
Planned environmental water	Water that has the meaning as given by Section 6 of the Water Act 2007. In summary, it is water committed by: the Basin Plan, a water resource plan or a plan made under a state water management law, or any other instrument made under a law of a state for the purposes of achieving environmental outcomes.
Population structure	A healthy population structure has good fish numbers in a range of age and size classes (including sex ratios for some species). These populations demonstrate regular recruitment (younger classes) and good numbers of mature fish to breed future generations.
Rapid-Eye	A proprietary name for a form of satellite imagery.
Ramsar Convention	An international treaty to maintain the ecological character of key wetlands.
Recruitment	Successful development and growth of juveniles; such that they have the ability to contribute to the next generation.
Representative species	Species whose habitat requirements are 'typical' of a wider suite of species within an ecosystem, such that they can act as surrogates.
Riparian	The part of the landscape adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within them.
Riverine system	An aquatic habitat within a channel that is characterised by a downstream flow.
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement.
Submergent macrophyte	Plants that grow in the water and have roots in the soil with the majority of the plant being submerged.
Water-dependent system	An ecosystem or species that depends on periodic or sustained inundation, waterlogging or significant inputs of water for natural functioning and survival.

Appendix 1 – Basin Plan – Environmental Water Plan Targets

Intermediate targets up to 30 June 2019

- (1) There is no loss of, or degradation in, the following:
- (a) flow regimes which include relevant flow components set out in paragraph 8.51(1)(b);
 - (b) hydrologic connectivity between the river and floodplain and between hydrologically-connected valleys;
 - (c) river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions;
Note: See section 1.07 for the meaning of the terms **priority environmental asset** and **priority ecosystem function**.
 - (d) condition of the Coorong and Lower Lakes ecosystems and Murray mouth opening regime;
 - (e) condition, diversity, extent and contiguousness of native water-dependent vegetation;
 - (f) recruitment and populations of native, water-dependent species including vegetation, birds, fish and macroinvertebrates.

Longer term targets from 1 July 2019

- (2) There are improvements in the following:
- (a) flow regimes which include relevant flow components set out in paragraph 8.51(1)(b);
Note: The improvements in flow regimes will be measured by progress towards natural flow regimes, having regard to the Basin-wide environmental watering strategy.
 - (b) hydrological connectivity between the river and floodplain and between hydrologically-connected valleys;
 - (c) river, floodplain and wetland types including the condition of priority environmental assets and priority ecosystem functions;
 - (d) condition of the Coorong and Lower Lakes ecosystems and Murray mouth opening regime;
 - (e) condition, diversity, extent and contiguousness of native water-dependent vegetation;
 - (f) recruitment and populations of native water-dependent species, including vegetation, birds, fish and macroinvertebrates;
 - (g) the community structure of water-dependent ecosystems.

Note: the contents of this appendix should be considered within the context of sections 8.08 and 8.09 of the Basin Plan.

Appendix 2 – Information used to develop expected environmental outcomes and water management strategies

Hydrology and connectivity

Murray–Darling Basin Authority 2012, 'Hydrologic modelling to inform the proposed Basin Plan - methods and results', MDBA publication no: 17/12, Murray–Darling Basin Authority, Canberra.

Vegetation

Cunningham SC, Griffioen P, Mac Nally R 2014, 'Validation of stand condition mapping for floodplain forests of the Murray–Darling Basin using remote sensing', report to the Murray–Darling Basin Authority, Canberra.

Cunningham SC, White M, Griffioen P, Newell G, Mac Nally R 2013, 'Mapping floodplain vegetation types across the Murray–Darling Basin', report to the Murray–Darling Basin Authority, Canberra.

Frahn K, Nico J, Strawbridge A 2012, 'Current distribution and abundance of *Ruppia tuberosa* in the Coorong', South Australian Research and Development Institute (Aquatic Sciences), Adelaide, SARDI Publication No. F2012/000074-1, SARDI Research Report Series No. 615.

Kim DH, Brookes JD, Ganf GG, 2013, 'The effect of salinity on the germination of *Ruppia tuberosa* and *Ruppia megacarpa* and implications for the Coorong, a coastal lagoon of southern Australia', *Aquatic Botany*, <http://dx.doi.org/10.1016/j.aquabot.2013.06.008>.

Murray–Darling Basin Authority 2012, 'Hydrologic modelling to inform the proposed Basin Plan - methods and results', MDBA publication no: 17/12, Murray–Darling Basin Authority, Canberra.

Murray–Darling Basin Authority 2012, 'Assessment of environmental water requirements for the proposed Basin Plan', series publication nos: 19/12 to 25/12, accessible at: <http://www.mdba.gov.au/what-we-do/basin-plan/development/bp-science/assessing-environmental-water-requirements>.

Murray–Darling Basin Authority 2012, 'Assessment of environmental water requirements for the proposed Basin Plan: The Coorong, Lower Lakes and Murray Mouth', MDBA Publication No: 34/12.

Rogers DJ and Paton DC 2009, 'Changes in the distribution and abundance of *Ruppia tuberosa* in the Coorong', CSIRO Water for a Healthy Country National Research Flagship, Canberra.

Note re vegetation data: Initially data were acquired using Landsat7. Unfortunately this data was corrupted and alternative data were acquired through '*Rapid Eye*'. Landsat8 will be available for future data collection. This will improve the extent and accuracy of the data and will allow for condition of river red gums, black box and coolibah to be scored within five categories with confidence, Basin-wide.

Waterbirds

Bino G, Kingsford RT, Brandis K, Porter J 2014, 'Setting waterbird objectives and priorities for the Basin-wide environmental watering strategy', report to the Murray–Darling Basin Authority. Centre for Ecosystem Science, University of New South Wales.

Brookes JD, Lamontagne S, Aldridge KT, Bengner S, Bissett A, Bucater L, Cheshire AC, Cook PLM, Deegan BM, Dittmann S, Fairweather PG, Fernandes MB, Ford PW, Geddes MC, Gillanders BM, Grigg NJ, Haese RR, Krull E, Langley RA, Lester RE, Loo M, Munro AR, Noell CJ, Nayar S, Paton DC, Revill AT, Rogers DJ, Rolston A, Sharma SK, Short DA, Tanner JE, Webster IT, Wellman NR and Ye Q 2009, 'An Ecosystem Assessment Framework to Guide Management of the Coorong', final report of the CLLAMM ecology Research Cluster, CSIRO: Water for a Healthy Country National Research Flagship, Canberra.

Kingsford RT, Bino G, Porter J, Brandis K 2013, 'Waterbird communities in the Murray–Darling Basin 1983–2012', report to Murray–Darling Basin Authority, Australian Wetlands, Rivers and Landscapes Centre, University of New South Wales.

Murray–Darling Basin Authority 2011, 'The proposed “environmentally sustainable level of take” for surface water of the Murray–Darling Basin: Methods and outcomes', MDBA publication no: 226/11, Murray–Darling Basin Authority, Canberra.

Paton, DC 2010, 'The end of the river', ATF Press, South Australia.

Rogers DJ, Paton DC 2009, 'Spatiotemporal variation in the waterbird communities of the Coorong', CSIRO: Water for a Healthy Country National Research Flagship, Canberra.

Native fish

Jackson P and Bice C 2014, 'Murray–Darling Fishes and Flows – summary of current knowledge and thinking', report prepared for the Murray–Darling Basin Authority for internal use only.

Koehn J, Stuart I, Bamford H, Bice C, Hodges K, Jackson P, Lieschke J, Lovett S, Mallen-Cooper M, Raadik T, Thiem J, Todd C, Tonkin Z, Zampatti B 2014, 'Quantifiable environmental outcomes for fish', unpublished client report for Murray–Darling Basin Authority, Arthur Rylah Institute for Environmental Research, Department of Environment and Primary Industries, Heidelberg, Victoria.

Mallen-Cooper M and Zampatti B 2014, Background Paper: 'Use of life history conceptual models in flow management in the Murray–Darling Basin', report prepared for the Murray–Darling Basin Authority.

Mallen-Cooper M and Zampatti B 2014, Background Paper: 'The Natural Flow Paradigm and managing flows in the Murray–Darling Basin', report prepared for the Murray–Darling Basin Authority.

Mallen-Cooper M and Zampatti B 2014, 'Flow-related fish ecology in the Murray–Darling Basin: a summary guide for water management, report prepared for the Murray–Darling Basin Authority.

NSW Department of Primary Industries 2014, 'Development of Quantifiable Environmental Outcomes and watering strategies to support the fish theme in the Northern Basin', report prepared for the Murray–Darling Basin Authority, NSW Department of Primary Industries, Tamworth.

Other sources:

The MDBA also ran nine workshops with subject matter experts from government, academia and private consulting firms. These were:

- vegetation expert workshops, held on 20 February 2014 in Adelaide and 15 April 2014 in Canberra
- waterbirds expert workshops, held on 14 October 2013 in Canberra and 13 March 2014 in Canberra
- native fish expert workshops, held on 11–12 February 2014 in Canberra; 25–26 March 2014 in Heidelberg (SA); 27–28 May 2014 in Brisbane; 5 June 2014 in Adelaide, and 23–24 September 2014 in Canberra.

Appendix 3 – Expected vegetation outcomes by region

The table below identifies the current best estimate of areas where outcomes are expected to be able to be managed within current constraints and operational works and measures. The removal of constraints would result in greater outcomes because the area of forest and woodland receiving flows would increase. Naturally-occurring high flows (that are not affected by the Basin Plan) will also contribute to the outcomes listed below, subject to climatic variables.

Environmental assets and outcomes listed below must be considered in regional long-term watering plans (in addition to regionally significant sites). This assessment is based on the best information available on the relationship between different flows and inundation of the river corridor and well-defined constraints. Areas could change if better information becomes available in the future.

Table 3 Expected extent outcomes for communities of water-dependent vegetation as a result of the Basin Plan

Basin region	Outcomes for water-dependent vegetation	Area of river red gum (ha)*	Area of black box (ha)*	Area of coolibah (ha)*	Shrublands	Non-woody water dependent vegetation
Paroo	Maintain extent and condition** of water-dependent vegetation near river channels and on the floodplain	2,300	38,300	22,800		Closely fringing or occurring within the Paroo River
Warrego	Maintain extent and condition** of water-dependent vegetation near river channels and on the floodplain	7,300	80,400	121,400		Closely fringing or occurring within the Warrego, Langlo, Ward & Nive rivers
Nebine	Maintain extent and condition** of water-dependent vegetation near river channels and on the floodplain	200	28,800	15,400		Closely fringing or occurring within the Nebine Creek
Condamine–Balonne	Maintain extent and condition** of water-dependent vegetation near river channels and on areas of the floodplain	11,500#	36,100**	62,900**	Lignum in Narran Lakes	Closely fringing or occurring within the Condamine, Balonne, Birrie, Bokhara, Culgoa, Maranoa, Merivale & Narran rivers
Moonie	Maintain extent and condition** of water-dependent vegetation near river channels and on the floodplain	2,200	2,500	7,900		Closely fringing or occurring within the Moonie River
Border Rivers	Maintain extent and condition** of water-dependent vegetation near river channels and on areas of the floodplain	10,700	3,800	35,200	Lignum in the lower Border rivers region	Closely fringing or occurring within the Barwon, Dumaresq, Macintyre rivers & Macintyre Brook
Gwydir	Maintain extent and condition** of water-dependent vegetation near river channels and on low-lying areas of the floodplain.	4,500**	600**	6,500**	Lignum in the Lower Gwydir	Closely fringing or occurring within the Gwydir River and marsh club-rush and water couch in the Gwydir Wetlands
Namoi	Maintain extent and condition** of water-dependent vegetation near river channels.	6,100	800	4,200		Closely fringing or occurring within the Namoi River

Basin region	Outcomes for water-dependent vegetation	Area of river red gum (ha)*	Area of black box (ha)*	Area of coolibah (ha)*	Shrublands	Non-woody water dependent vegetation
Macquarie–Castlereagh	Maintain extent and condition** of water-dependent vegetation near river channels and on low-lying areas of the floodplain	58,200	57,100	32,200	Lignum in the Macquarie Marshes	Closely fringing or occurring within the Bogan, Castlereagh, Macquarie and Talbragar rivers; and common reed, cumbungi and water couch in the Macquarie Marshes
Barwon–Darling	Maintain extent and condition** of water-dependent vegetation near river channels and on low-lying areas of the floodplain	7,800**	11,700**	14,900**		Closely fringing or occurring within the Darling River
Lachlan	Maintain extent of water-dependent vegetation near river channels and on low-lying areas of the floodplain. Improve condition ⁱ of black box and river red gum	41,300	58,000		Lignum in the Lower Lachlan	Closely fringing or occurring within the Lachlan River and Willandra Creek; and common reed and Cumbungi in the Great Cumbung Swamp
Murrumbidgee	Maintain extent of water-dependent vegetation near river channels and on low-lying areas of the floodplain. Improve condition ⁱ of black box and river red gum	68,300	38,900		Lignum in the Lower Murrumbidgee	Closely fringing or occurring within the Murrumbidgee River, Billabong and Yanco creeks
Lower Darling	Maintain extent of water-dependent vegetation near river channels and on low-lying areas of the floodplain. Improve condition ⁱ of black box and river red gum	10,300	38,600	600	Lignum swamps in the Lower Darling region	Closely fringing or occurring within the Darling River, Great Darling Anabranch and Talyawalka Anabranch
Ovens	Maintain extent and condition** water-dependent vegetation near river channels and on the floodplain	10,200	<100			Closely fringing or occurring within the Ovens River
Goulburn–Broken	Maintain extent of water-dependent vegetation near river channels and on low-lying areas of the floodplain. Improve condition ⁱ of black box and river red gum	19,800	500			Closely fringing or occurring within the Broken Creek, Broken and Goulburn rivers
Campaspe	Maintain extent and condition** of water-dependent vegetation near river channels	1,900	<100			Closely fringing or occurring within the Campaspe River
Loddon	Maintain extent and condition** of water-dependent vegetation near river channels	2,200	700			Closely fringing or occurring within the Loddon River

Basin region	Outcomes for water-dependent vegetation	Area of river red gum (ha)*	Area of black box (ha)*	Area of coolibah (ha)*	Shrublands	Non-woody water dependent vegetation
Murray	Maintain extent of water-dependent vegetation near river channels and on low-lying areas of the floodplain. Improve condition ⁱ of black box and river red gum.	90,600	41,700		Lignum along the Murray River from the junction with the Wakool River to downstream of Lock 3, including Chowilla and Hattah Lakes	Closely fringing or occurring within the Murray, Edward, Kiewa, Mitta Mitta, Niemur and Wakool rivers and Tuppall Creek; <i>Ruppia tuberosa</i> in the Coorong and Moira grasslands in the Barmah–Millewa Forest
Wimmera–Avoca	Maintain extent of water-dependent vegetation near river channels. Improve condition ⁱ of black box and river red gum.	6,500	3,100			Closely fringing or occurring within the Avoca, Avon, Richardson and Wimmera rivers
Eastern Mt Lofty Ranges	Maintain extent and condition of water-dependent vegetation near river channels	<100	<100			

*Area (ha) (+/- 10%) is based on Cunningham SC, White M, Griffioen P, Newell G and Mac Nally R 2013, 'Mapping Floodplain Vegetation Types across the Murray–Darling Basin', Murray–Darling Basin Authority, Canberra.

Condition parameters is based on Cunningham SC, Read J, Baker PJ and Mac Nally R 2007, 'Quantitative assessment of stand condition and its relationship to physiological stress in stands of *Eucalyptus camaldulensis* (Myrtaceae) in south-eastern Australia', *Australian Journal of Botany*, **55, 692–699.

#the extent and area of forests and woodlands for the lower Condamine–Balonne, Barwon–Darling and Gwydir regions, and the Bogan River, are considered to be an underestimate due to current technical limitations in determining the lateral extent achieved through implementation of the Basin Plan.

ⁱCondition is scored from 0–10 and classified within five categories for river red gum and two categories for black box in the Lachlan, Murrumbidgee, Lower Darling, Goulburn–Broken and Wimmera–Avoca. As the data capture improves across the Basin, five categories of condition will be used across the Basin.

Table 4 Current condition of black box trees in the Lachlan, Murrumbidgee, Lower Darling, Murray, Wimmera–Avoca and Goulburn–Broken

Basin region	Vegetation with a condition ⁱ score 0 – 6	Vegetation with a condition ⁱ score >6 – 10	Percent of vegetation assessed (within the managed floodplain) ⁱⁱⁱ
Lachlan	72%	28%	45%
Murrumbidgee	54%	46%	73%
Lower Darling	72%	28%	85%
Murray	33%	65%	28%
Wimmera–Avoca	42%	58%	26%
Goulburn–Broken	28%	72%	77%

Table 5 Current conditionⁱⁱ of river red gum trees in the Lachlan, Murrumbidgee, Lower Darling, Murray, Wimmera–Avoca and Goulburn–Broken

Basin region	Vegetation with a condition ⁱ score 0 – 2	Vegetation with a condition ⁱ score >2 – 4	Vegetation with a condition ⁱ score >4 – 6	Vegetation with a condition ⁱ score >6 – 8	Vegetation with a condition ⁱ score >8 – 10	Percent of vegetation assessed (within the managed floodplain) ⁱⁱⁱ
Lachlan	3%	8%	21%	41%	26%	93%
Murrumbidgee	3%	8%	22%	40%	27%	93%
Lower Darling	11%	5%	7%	41%	35%	92%
Murray	2%	1%	10%	51%	35%	51%
Wimmera–Avoca	3%	5%	18%	60%	13%	20%
Goulburn–Broken	1%	2%	7%	34%	55%	89%

Notes:

ⁱ Condition is scored from 0–10 and classified within five categories for river red gum and two categories for black box in the Lachlan, Murrumbidgee, Lower Darling, Goulburn–Broken and Wimmera–Avoca. As the data capture improves across the Basin, five categories of condition will be used across the Basin.

ⁱⁱ Condition is scored from 0–10 and classified within five condition categories, being: 0–2 ‘severely degraded’; >2–4 ‘degraded’; >4–6 ‘poor’; >6–8 ‘moderate’; >8–10 ‘good’.

ⁱⁱⁱ The area of vegetation where condition has been assessed is based on the existing extent of RapidEye™ imagery purchased for this assessment because Landsat 7 data were corrupted. In future, the condition assessment will be extended to include the total managed floodplain through the use of Landsat 8.

Appendix 4 – Important Basin environmental assets for waterbirds

The MDBA's purpose in compiling this list has been to identify the environmental assets that are needed to achieve a sustainable population of waterbirds. Outcomes at these sites will not only be achieved through the use of environmental water, but through natural events and consumptive water. Environmental water holders and managers should use this list as an input into identifying those environmental assets that can be managed with environmental water (termed priority environmental assets by the Basin Plan). More detail on the criteria for inclusion is provided below.

MDBA note that drought refuges were identified as priorities when setting representation targets during dry times. Some of these sites are wetland complexes (e.g. Lowbidgee floodplain) that can be managed for environmental outcomes; whereas some are storages or water transfer basins (e.g. Waranga Basin) that can't be managed for environmental outcomes, but nonetheless provide refuge for some species.

Table 6 Important Basin environmental assets for waterbirds

Environmental asset	Water resource plan area	Total abundance and diversity	Drought refuge	Colonial waterbird breeding	Shorebird abundance
1. Currawinya Lakes	Warrego–Paroo–Nebine	*			
2. Narran lakes	Intersecting streams	*		*	*
3. Cuttaburra channels	Intersecting streams	*		*	*
4. Paroo overflow lakes	Intersecting streams	*		*	*
5. Yantabulla	Intersecting streams	*			
6. Upper Darling River	Barwon–Darling Watercourse	*	*		
7. Gwydir wetlands	Gwydir	*		*	
8. Macquarie Marshes	Macquarie–Castlereagh	*		*	*
9. Booligal wetlands	Lachlan	*		*	
10. Great Cumbung Swamp	Lachlan	*		*	
11. Lake Brewster	Lachlan	*		*	
12. Lake Cowal	Lachlan			*	
13. Fivebough Swamp	Murrumbidgee	*	*		*
14. Lowbidgee floodplain	Murrumbidgee	*	*	*	*

Environmental asset	Water resource plan area	Total abundance and diversity	Drought refuge	Colonial waterbird breeding	Shorebird abundance
15. Gunbower–Koondrook–Perricoota	NSW Murray and Lower Darling			*	
16. Kerang wetlands	Victorian Murray	*		*	
17. Menindee lakes	NSW Murray and Lower Darling	*		*	
18. River Murray & Euston Lakes	NSW Murray and Lower Darling		*		
19. Talywalka system	NSW Murray and Lower Darling	*			
20. Darling Anabranh	NSW Murray and Lower Darling	*			
21. Lindsay–Walpolla–Chowilla	NSW Murray and Lower Darling/ Victorian Murray/ SA River Murray	*			
22. Barmah–Millewa	NSW Murray and Lower Darling/ Victorian Murray	*		*	
23. Kiewa River	Victorian Murray		*		
24. Corop wetlands	Northern Victoria	*	*		
25. Winton wetlands	Northern Victoria		*		
26. Waranga Basin	Northern Victoria		*		
27. Noora evaporation Basin	South Australian Murray Region	*			
28. Pyap Lagoon	South Australian River Murray		*		
29. Hattah Lakes	Wimmera–Mallee			*	
30. Lake Albacutya	Wimmera–Mallee	*			
31. Lake Buloke	Wimmera–Mallee	*			
32. Lake Hindmarsh	Wimmera–Mallee	*			
33. Coorong, Lower Lakes and Murray Mouth	SA River Murray/ SA Murray Region/ Eastern Mount Lofty Ranges	*		*	*

Note: Inclusion of an environmental asset on the list above means that they are important for maintaining total waterbird abundance and diversity and as a drought refuge, for colonial waterbird breeding, and for shorebirds.

Further information on categories of sites identified in Table 7

Total waterbird abundance and diversity: environmental assets listed in this category represent a desired conservation target of 80% representation for abundance, of each waterbird species recorded in surveys. The decision on representation target was grounded on accumulated waterbird data suggesting that 80% of waterbird species were present in only about 30 of the wetlands surveyed each year. This analysis was run on the Aerial Waterbird Survey of South Eastern Australia dataset (1983–2012), and separately on The Living Murray survey and the Hydrologic Indicator Site survey (2010–2012). The analysis prioritised each environmental asset by giving them an ‘irreplaceability score’. For those environmental assets surveyed by the Aerial Waterbird Survey of South Eastern Australia, the criteria to be included in the list above was an irreplaceability score greater than 0.8 and total waterbird abundance greater than 60,000 individuals. For those environmental assets surveyed by The Living Murray survey and the Hydrologic Indicator Site survey, criteria to be included in the list above was an irreplaceability score greater than 0.8.

Drought refuge: environmental assets listed in this category are sites that were identified as priorities when setting representation targets during dry times. Some of these sites are wetland complexes (e.g. Lowbidgee floodplain) that can be managed for environmental outcomes. Some storages or water transfer basins that can’t be managed for environmental outcomes are nonetheless important refuge for some species during drought—for example, Coolmunda Dam, Split Rock Reservoir and Burrendong Dam. Dry times were defined by examining water availability across the entire Basin over the 30 years and selecting those years in the bottom 25 percentile (2003, 2005–2009). This analysis was run on the Aerial Waterbird Survey of South Eastern Australia dataset.

Colonial waterbird breeding: environmental assets listed in this category are wetland complexes that have had colonial waterbird breeding events in the historical record. Source data was the Australia Colonial Waterbird Breeding Database, which is a long-term dataset (1899–2012) of colonial waterbird breeding and distribution. It collates records for nine species: Australian pelican (*Pelecanus conspicillatus*), great cormorant (*Phalacrocorax carbo*), pied cormorant (*Phalacrocorax varius*), white-necked heron (*Ardea pacifica*), intermediate egret (*Ardea intermedia*), little egret (*Egretta garzetta*), straw-necked ibis (*Threskiornis spinicollis*), glossy ibis (*Plegadis falcinellus*) and royal spoonbill (*Platalea regia*).

These species breed in single or multi-species colonies of tens to hundreds of thousands of individuals. These species were chosen to be representative of colonial waterbird breeding to analyse the distribution, frequency and diversity of colonial waterbird breeding in the Murray–Darling Basin.

Shorebirds: environmental assets listed in this category represent a desired conservation target of 80% representation targets for abundance of shorebirds as a functional group. The criteria to be included in the list above was an irreplaceability score greater than 0.8. Analysis was also run for other functional groups but the results are not presented here.

For a fuller account of this work, see: Bino G, Kingsford RT, Brandis K and Porter J, 2014, ‘Setting waterbird objectives and priorities for the Basin-wide environmental watering strategy’, report to the Murray–Darling Basin Authority, Centre for Ecosystem Science, University of New South Wales.

Appendix 5 – Basin native fish communities

The southern and northern fish communities follow catchment divisions outlined [Figure 9](#) in the main text (river flows and connectivity). The Lachlan and Paroo catchments are grouped with the northern community, and the Wimmera catchment with the southern community.

The Lachlan catchment has characteristics of both southern and northern fish communities and represents a transition zone between the two systems. For the purposes of this strategy, the Lachlan is grouped with the northern fish community as it is characterised by semi-arid conditions and flow management arrangements similar to the northern Basin.

Southern Basin community

Most fish in the southern Basin exist in a highly modified environment, particularly in and around the River Murray. Much of this habitat still supports important fish populations, such as iconic riverine specialists Murray cod, trout cod, silver perch and golden perch. The region still has important unregulated systems that support remnant populations of threatened species and are important for overall fish biodiversity. The southern Basin is dominated by naturally high rainfall in winter and spring; however, river regulation has reversed or inverted some of this seasonality. High flows now occur in summer in some locations, with low flows (even drying) in winter.

Fish in the southern Basin are found in a wide variety of habitats. Large bodied and long-lived species such as Murray cod, trout cod, silver perch and golden perch are all riverine specialists. On the other hand, small-bodied species such as southern purple-spotted gudgeon, southern pygmy perch, flat-headed galaxias, and Murray hardyhead each require access to inundated floodplains to complete their life cycles. Other freshwater habitats such as creeks, wetlands, forest flood-runners, billabongs, and permanent lakes are also important for native fish.

Estuarine fish community

The estuarine fish community supports the highest fish diversity in the Basin as a result of the dynamic nature of the estuary environment. Many species use the estuary including true estuarine species as well as migratory species, marine and freshwater species. The estuarine fish community includes important recreational and commercial fish species such as black bream, greenback flounder, yellow-eye mullet, golden perch, and mulloway. Species like sandy sprat and small-mouthed hardyhead are also essential food sources for predatory fish and waterbirds in the region.

Connectivity, productivity and salinity are the three major factors that regulate fish populations in the estuarine community. Each of these is heavily influenced by freshwater inflows to the Coorong, largely originating from the River Murray. Connectivity between the ocean, the estuary and the river is essential for many species. This connectivity is now restricted and fish must use constructed fishways and the barrages—making flows that operate these structures particularly important. In addition to connectivity, freshwater inflows also carry nutrients from upstream and contribute to estuarine productivity; and interact with tides to create a salinity gradient (a gradual change from freshwater to hyper-saline water) that influences the distribution and health of fish species.

Northern Basin fish community

The northern Basin is important in maintaining the overall biodiversity of fish in the whole Basin. Its fish community includes 25 resident species—including populations of nationally-listed Murray cod and silver perch. The northern Basin is also a stronghold for many species that are threatened in the south. It has important remnant populations of olive perchlet, southern pygmy perch and freshwater catfish; and unique populations of northern river blackfish in the uplands of the Condamine River. A number of species that are not present in the south, i.e. Rendahl's tandan, Hyrtl's tandan, spangled perch, Darling River hardyhead and desert rainbowfish, exist in the north.

With very variable rainfall, many of the river flows in the northern Basin are highly intermittent. Therefore, natural wetting and drying cycles have a strong influence on fish communities. Survival through drying phases governs the long-term persistence of native fish in this region. Survival heavily depends on quality refuge habitat during dry times and the ability to recolonise habitats when moderate to high flow conditions return.

Appendix 6 – Supporting detail for native fish outcomes

Table 7 gives information for short-lived, moderate- to long-lived and estuarine species targeted by this strategy. Species-specific recruitment requirements are outlined (see recruitment frequency column) and detail provided on the links between species life history and flow. Some threatened species are not included in the table owing to insufficient information on their flow requirements. This table provides details in relation to expanding distributions of native fish by 2024. Table 8 (which follows) provides priorities for increasing the distribution of these species. Both tables are based on the best information currently available. Future application of this information can consider more recent data, if available.

It is important to note that short-lived species have increased vulnerability to successive years of recruitment failure. Therefore, they require frequent recruitment events to sustain populations—annually and biennially depending on their longevity. For moderate- to long-lived species, populations are often dominated by a few strong or very strong cohorts (large recruitment events) with fewer individuals from smaller recruitment events in most remaining year classes. For many species, years with strong recruitment coincide with good flow (quantity and quality of flows).

Table 7 Details for short-lived species, moderate to long-lived species, and estuarine species of fish

Species	Longevity	Recruitment frequency	Threatened spp. status	Importance (other)	Links between life history and flow needs	Fish community
Murray hardyhead (<i>Craterocephalus fluviatilis</i>)	Short-lived	Annual	Australia NSW, Vic, SA		The main conservation issue is the amount and quality of inflows to riverine and non-riverine wetlands. Regulation and water extraction influences the amount and quality of inflow to the floodplain, riverine and lake habitats. Specifically, off-channel habitats in the lower River Murray dry out due to low river flows and extraction. Reduced connectivity (including secondary connectivity) between the main river channel and floodplain habitat for dispersal. Associated with aquatic vegetation, possibly for spawning. In particular, this species is associated with stands of <i>Ruppia</i> in saline habitats.	Southern Basin
Olive perchlet (<i>Ambassis agassizii</i>)	Short-lived	Annual	SA, NSW (endangered population) (Vic extinct)		Heavily impacted across most of its distribution, although good remnant populations exist in Queensland. Largely a wetland species with heavy dependence on off-channel lagoons and wetlands during the life-cycle—therefore heavily impacted by river regulation and infrastructure that disconnects off-channel habitats and the creation of deep pools that drown-out in-channel emergent vegetation. As aquatic vegetation (particularly emergent vegetation) is vital; flows to sustain healthy and diverse aquatic vegetation are important. Artificially prolonged, elevated flows should be avoided as these can kill off aquatic vegetation. Secondary connection events between rivers and lagoons and wetlands are required to enable recruits to enter the river. Suitable refuges are required during summer low flows. Require stable water levels during spawning season.	Southern & Northern Basin

Species	Longevity	Recruitment frequency	Threatened spp. status	Importance (other)	Links between life history and flow needs	Fish community
Southern pygmy perch (<i>Nannoperca australis</i>)	Short-lived	Annual	NSW, SA, Vic		Heavily impacted. Largely a wetland species with strong relationships with in-channel submerged macrophytes such as ribbon weed, and with off-channel habitat. Therefore, highly impacted by the loss of macrophytes and off-channel habitats. This species is strongly associated with floodplain environments and most commonly inhabits wetlands and billabongs. Secondary connection events between rivers and lagoons and wetlands are required to enable recruits to enter the river. Increased persistence of drought refuges important.	Southern Basin
Yarra pygmy perch (<i>Nannoperca obscura</i>)	Short-lived	Annual	Australia Vic, SA		Heavily impacted. Largely a wetland species. River regulation and water extraction influence the amount and quality of inflow to the floodplain, riverine and lake habitats—specifically, drying out off-channel habitats in the lower River Murray. Aquatic vegetation (particularly emergent vegetation) is important for this species; therefore flows to sustain healthy and diverse aquatic vegetation are important. Artificially prolonged, elevated flows should be avoided as these can kill off aquatic vegetation. Secondary connection events between rivers and lagoons and wetlands are required to enable recruits to enter the river.	Southern & Northern Basin
Southern purple-spotted gudgeon (<i>Mogurnda adspersa</i>)	Short-lived	Biennial	NSW, SA, Vic	Aquarium species	Heavily impacted wetland species. River regulation/extraction have exacerbated water availability—creating habitat loss through drying. Generally found in small, shallow pools or backwaters. High site fidelity to permanent pools in unregulated streams. In NSW, remnant populations often found in small high-order streams and off-stream habitats (particularly wetlands with dense macrophytes)—management of this habitat aspect is critical. Particular habitat requirement for spawning—requires hard substrates or macrophytes. Visual displays are important for breeding. Appear to breed around August in the northern Basin prior to increased summer flows—releasing large amounts of water at this time might reduce the chance of breeding events. Broadscale factors are important—including spring inundation and a summer low-flow period—combining to create suitable local habitat condition and heterogeneity. Spring water rises inundate edge vegetation, allowing fish access to shallow dense habitat and food resources. These benefit the first pulse of larvae as adults come into peak spawning with the return of warmer water temperatures. Secondary connection events between rivers and lagoons and wetlands are required to enable recruits to enter the river.	Southern & Northern Basin

Species	Longevity	Recruitment frequency	Threatened spp. status	Importance (other)	Links between life history and flow needs	Fish community
Silver perch (<i>Bidyanus bidyanus</i>)	Moderate to long-lived	8 years in 10	Australia ACT, NSW, Vic, SA, Qld	Formerly a recreational species but take is now restricted due to threatened status.	Heavily impacted channel specialist. Flow-cued spawning. Flows govern recruitment strength in this species, with spawning and recruitment enhanced by spring/summer flooding and high within-channel flow pulses. Spawn and recruit in flowing habitats. Flows stimulate movement of both adults and juveniles. Large-scale movement requirements that are interrupted by loss of flows and barriers to connectivity: <ul style="list-style-type: none"> • flows (current velocity) disperse early life stages (larval drift) • large scale spawning migrations. 	Southern & Northern Basin
Golden Perch (<i>Macquaria ambigua</i>)	Moderate to long-lived	8 years in 10	No (but a no-take population in Vic)	Key recreational target species. Important economic asset.	Impacted channel specialist. Flow-cued spawning. Flows govern recruitment strength in this species, with spawning and recruitment enhanced with spring/summer flooding and high within-channel flow pulses. Spawn and recruit in flowing habitats Flows stimulate movement Flows (current velocity) disperse early life stages. Golden perch have more flexibility in spawning and recruitment than silver perch.	Southern & Northern Basin
Murray cod (<i>Maccullochella peelii peelii</i>)	Moderate to long-lived	8 years in 10	Australia Vic, SA	Iconic species. Key recreational target species & key economic asset. High importance to aboriginal peoples. Formerly a commercial species before fishery declined.	Heavily impacted channel specialist. Large-scale movements that are critical in the life-cycle (e.g. spawning migrations and larval drift) are interrupted by loss of flows and barriers to connectivity. Requires access to fast and moderate flowing in-channel habitat of good quality. Spawn and recruit in flowing habitats—loss of these habitats has major impacts on this species. Seasonally appropriate flows (with rising water levels) are required to stimulate migration. Flows also increase productivity and available habitat. Highly impacted by blackwater events—flow is important to maintain water quality. Spawning is independent of flooding but recruitment can be enhanced by elevated flows. Nesting species that requires stable water depths for the duration of nesting to ensure adults do not abandon nests. Requires flowing water during this time period to maintain water quality. Flow (current velocity) then disperses larval stages.	Southern & Northern Basin

Species	Longevity	Recruitment frequency	Threatened spp. status	Importance (other)	Links between life history and flow needs	Fish community
Trout cod (<i>Maccullochella macquariensis</i>)	Moderate to long-lived	8 years in 10	Australia ACT, NSW, Vic, SA	Formerly a recreational species but take is now restricted due to threatened status.	<p>Heavily impacted channel specialist species. Requires access to fast and moderate flowing in-channel habitat of good quality. Spawns and recruits in flowing habitats—loss of these habitats has major impacts on this species. Seasonally appropriate flows (with rising water levels) are required to stimulate migration. Flows also increase productivity and available habitat.</p> <p>Spawning is independent of flooding but recruitment can be enhanced by elevated flows. Increasing flow is often required to stimulate migration, for productivity and to increase available habitat. Flow is important to maintain water quality—blackwater events can have major impacts on this species.</p> <p>Nesting species that requires stable water depths for the duration of nesting to ensure adults do not abandon nests. Requires flowing water during this time period to maintain water quality. Flow (current velocity) then disperses larval stages.</p>	Southern & Northern Basin
Macquarie perch (<i>Macquaria australasica</i>)	Moderate to long-lived	8 years in 10	Australia ACT, NSW, Vic, SA	Formerly a recreational species but take is now restricted due to threatened status.	<p>Heavily impacted by water extraction, particularly smaller riverine populations. Require flowing water (that retains stable depths) in conjunction with riffle and pool habitats containing cobble and gravel substrates for spawning. Flowing water is also required to disperse eggs and larvae. However, late spring flushes may negatively impact recruitment by disturbing eggs.</p> <p>Macquarie perch spawn in aggregations – barriers may prevent access to suitable spawning habitat or other adult fish. Suitable flows for connectivity are required. Natural freshes are required to scour fine sediment and prepare spawning habitats.</p> <p>Flow is important to maintain water quality. Maintenance of base flows and refuge pools during summer and autumn. They are vulnerable to loss of suitable refuge habitat either through water extraction or flow regulation. This reduces the number and quality of refuge pools during low flow conditions.</p>	Southern & Northern Basin

Species	Longevity	Recruitment frequency	Threatened spp. status	Importance (other)	Links between life history and flow needs	Fish community
Freshwater catfish (<i>Tandanus tandanus</i>)	Moderate to long-lived	8 years in 10	SA, Vic, NSW (endangered population)	Important recreational species in Queensland. Formerly a recreational species in the southern Basin but take is now restricted due to threatened status.	Heavily impacted by reduced connectivity, particularly as low and medium flow events have reduced (in frequency and magnitude). In Queensland and northern NSW, catfish are still present in the main channel of rivers and creeks. More abundant in unregulated rivers and often found in deep waterholes. Impacted by reduced opportunities for longitudinal and lateral movement, particularly reduced low and medium flow events. This species is vulnerable to loss of suitable refuge habitat, either through water extraction or flow regulation. This reduces the number and quality of refuge pools during low flow conditions. Flow events enhance recruitment in this species. Secondary connection events between rivers and lagoons and wetlands are required to enable recruits to enter the river. Nesting species that requires stable water depths for the duration of nesting to ensure adults do not abandon nests. Rapidly reducing water levels may cause them to abandon nests. This is an issue in both regulated and unregulated systems. Pumping from pools is an issue.	Southern & Northern Basin
Hyrtl's tandan (<i>Neosilurus hyrtlii</i>)	Moderate to long-lived	8 years in 10	no	Highly restricted localities in the northern basin (Queensland). Rare in Basin context.	Impacted by water extraction in the northern Basin which reduces the number and quality of refuge pools during low-flow conditions. Spawning and adult (upstream) and juvenile (downstream) migration is driven by high flow events in summer. This species requires lateral connectivity between lagoons and tributaries. Adults also migrate into lagoon habitats and tributaries. Drought refugia are important and require protection.	Northern Basin
Rendahl's tandan (<i>Porochilus rendahli</i>)	Moderate to long-lived	8 years in 10	no	Highly restricted localities in the Nthn Basin (Qld). Rare in Basin context.	Migration of adults into lagoons and tributaries is driven by high-flow events in summer. Drought refugia require protection. Probable link with good stands of aquatic vegetation (as it is most abundant in vegetated areas outside the Murray–Darling Basin)—loss of this habitat may restrict its abundance across its Basin-wide range.	Northern Basin
Northern river blackfish (Qld population) (<i>Gadopsis marmoratus</i>)	Moderate to long-lived	8 years in 10	Qld (listed as a no-take species)	Highly restricted localities in the Nthn Basin (Qld.)	Impacted channel specialist. Requires protection of flows to maintain levels and water quality in drought refuges. Usually occurs in areas of perennial water flows, good physical cover and good water quality. Spawns in response to increasing temperature. Pumping from pools during summer can be an issue, leading to reduction in available habitat and lethal water temperatures.	Northern Basin

Species	Longevity	Recruitment frequency	Threatened spp. status	Importance (other)	Links between life history and flow needs	Fish community
River blackfish (<i>Gadopsis marmoratus</i>) and Two-spined blackfish (<i>Gadopsis bispinosus</i>)	Moderate to long-lived	8 years in 10	NSW, Vic, SA ACT		These species are vulnerable to loss of suitable refuge habitat either through water extraction or flow regulation. This reduces the number and quality of refuge pools during low-flow conditions. <i>Note: Recent genetic work has potentially identified six candidate species across the current taxa under Gadopsis marmoratus and Gadopsis bispinosus. This may require adapting outcomes and approaches for management of these species.</i>	Southern & Northern Basin
Estuarine species						
Mulloway (<i>Argyrosomus japonicus</i>)	Moderate to long-lived	5 years in 10	no	Important recreational and commercial target species. Iconic species. Key apex predator in the Coorong estuary.	Impacted marine migrant species. Requires freshwater flows as a cue for spawning as river discharge cues aggregations of adults at the Murray mouth. The estuary is an important nursery habitat for juveniles (0–5 years old), providing high quality protection from predation during years with prolonged seasonal freshwater inflow conditions. Strong recruitment age classes in this species are linked to these years of good freshwater flows, whereas poor recruitment or even recruitment failure is recorded in years of poor inflow. <i>Note: the Coorong estuary likely provides the largest area of protected juvenile habitat for mulloway in southern Australia.</i>	Estuarine
Black bream (<i>Acanthopagrus butcheri</i>)	Moderate to long-lived	8 years in 10	no	Important recreational and commercial target species. Iconic estuarine resident species.	Estuarine-resident species. Distribution within the Coorong is influenced by freshwater flows – this influences the salinity gradient which governs the amount of estuarine habitat available. Spawn during spring/early summer – a suitable salinity gradient is critical for larval survival and development. Variability of freshwater inflows is a key factor influencing recruitment success, with good recruitment occurring during years of intermediate river flows and poor recruitment following periods of very low or high flows.	Estuarine
Greenback flounder (<i>Rhombosolea tapirina</i>)	Moderate to long-lived	8 years in 10	no	Important recreational/ commercial target species. Iconic estuarine resident species.	Estuarine-resident species. Distribution within the Coorong is influenced by freshwater flows – this influences the salinity gradient which governs the amount of estuarine habitat available. Spawn during autumn/winter. Freshwater flows to estuaries influence recruitment success through affecting salinities (suitable habitat) and productivity (food availability). Increased freshwater flows are linked to good recruitment and extensive distribution of juvenile fish across the Coorong.	Estuarine

Species	Longevity	Recruitment frequency	Threatened spp. status	Importance (other)	Links between life history and flow needs	Fish community
Sandy sprat (<i>Hyperlophus vittatus</i>)	Short-lived	Annual	no	Key food species in the estuary for predatory fish (e.g. Australian salmon, black bream and juvenile mullet) and waterbirds (e.g. little penguins and little terns).	Freshwater flows, particularly through productivity, drives population abundances of this species. Most abundant during years of high freshwater inflows to the estuary.	Estuarine
Small-mouthed hardyhead (<i>Atherinosoma microstoma</i>)	Short-lived	Annual	no	Key food species in the estuary for predatory fish & waterbirds.	Salinity and productivity in the estuary drives population abundances. This is an indicator species for salinity conditions in the estuary.	Estuarine
Diadromous species						
Congolli (<i>Pseudaphritis urvilli</i>)	Moderate to long-lived	8 years in 10 – maintaining stable sex ratios	SA		Heavily impacted by reduced connectivity among habitats in the Coorong. This species <u>must</u> move between freshwater and marine environments to complete its lifecycle. To maintain stable sex ratios, segregation of the sexes during breeding seasons must be avoided. Spring–summer upstream movements of juvenile congolli and winter downstream movement of female adult congolli are key requirements for the species. Freshwater discharge and associated connectivity enhance population abundance. Major improvements in population abundance linked to consecutive years of good freshwater flows.	Estuarine
Common galaxias (<i>Galaxias maculatus</i>)	Short-lived	Annual			Heavily impacted by reduced connectivity among habitats in the Coorong. This species <u>must</u> move between freshwater and marine environments to complete its life-cycle. Spring–summer upstream movement of juvenile common galaxias is critical. Reduced connectivity can lead to segregation of the sexes of this species, which inhibits breeding. Congolli populations are significantly improved by successive years of good freshwater inflows into the estuary.	Estuarine

Species	Longevity	Recruitment frequency	Threatened spp. status	Importance (other)	Links between life history and flow needs	Fish community
Short-headed lamprey (<i>Mordacia mordax</i>)	Moderate to long-lived	8 years in 10	SA		Heavily impacted by reduced connectivity among habitats in the Coorong. This species <u>must</u> move between freshwater and marine environments to complete its life-cycle. Large-scale migrations of adults are required to complete the life-cycle. Winter upstream movements of adult lamprey are critical.	Estuarine
Pouched lamprey (<i>Geotria australis</i>)	Moderate to long-lived	8 years in 10	SA		Heavily impacted by reduced connectivity among habitats in the Coorong. This species <u>must</u> move between freshwater and marine environments to complete its life-cycle. Winter upstream movements of adult lamprey are critical.	Estuarine

Priorities for increasing the distribution of native fish

Increasing the distribution of native fish relies on expansion of existing populations (see range extension) and/or the establishment of new populations (see additional populations), facilitated by improved water management and flows. Table 9 suggests candidate sites where this outcome can increase distribution of native fish species. Agencies may also consider additional or substitute sites in their planning. In some instances, complementary stocking of threatened species may be needed where flow-mediated range expansion is not feasible. This stocking can provide an initial population that could then be expanded.

For many species, existing distributions are confined to discrete locations (e.g. a river or river reach, specific wetlands). Interpretation of this outcome in relation to the overall distribution of some species is more difficult. These species can be widely distributed, but are highly fragmented, and now absent or no longer common across large parts of their range. For those species (e.g. silver perch), the intent of this outcome is to expand what now constitutes a 'core range' of the species. The core range is considered to be where populations are in reasonable condition and abundance. Expansion efforts are directed towards increasing their frequency in areas where they are currently rare (particularly where they used to be common).

Table 8 Detailed species information in relation to outcomes for distributions of native fish by 2024

Species	Priorities for increasing distribution in the Southern Basin	Priorities for increasing distribution in the Northern Basin
Macquarie perch	<p><u>Range extension:</u> Expand at least two current populations (candidate sites include Cotter River, Murrumbidgee above Cooma, Adjungbilly Creek, King Parrot Creek, Hughes Creek, and Hollands Creek).</p> <p><u>Additional populations:</u> Establish at least four additional riverine populations (candidate sites include mid-Goulburn River, Ovens River, Kiewa River and Goodradigbee River).</p> <p><i>Note: Ovens River & Goulburn populations – attempts to re-establish have commenced</i></p>	<p><u>Range extension:</u> The distribution of Macquarie perch in the Northern Basin is limited to the Lachlan catchment. Range expansion of at least 2 current populations is a priority.</p> <p><u>Additional populations:</u> Establish 1–3 additional riverine populations within the Lachlan catchment.</p>
Trout cod	<p><u>Range extension:</u> Expand the range of trout cod up the Murray upstream of Lake Mulwala and into the Kiewa River. For the connected population of the Murrumbidgee–Murray–Edwards: continue downstream expansion.</p> <p><u>Additional populations:</u> Establish at least two additional populations (candidate sites include the Macquarie River and mid-Goulburn River).</p> <p><i>Note: Macquarie River and mid-Goulburn populations – attempts to re-establish have commenced</i></p>	<p><u>Range extension:</u> The distribution of trout cod in the Northern Basin is limited to the Macquarie catchment downstream of Burrendong Dam. Range expansion of the current population is a priority.</p> <p><u>Additional populations:</u> Establish 1–3 additional populations (candidate sites are primarily within the Macquarie catchment; within the Lachlan, a candidate site is downstream of Wyangla Dam).</p>
Silver perch <i>* note this is about improving core range of this species (southern & northern)</i>	<p><u>Range extension:</u> Expand the core range within the River Murray (Yarrawonga–Euston) and populations within the Edward–Wakool, lower Murrumbidgee and Goulburn Rivers. Expand upstream of Lake Mulwala and into the Ovens River, increase up the lower Goulburn River.</p> <p><u>Additional populations:</u> Improve core range in at least two additional locations – (candidate sites include Gunbower Creek, Broken Creek, the lower Loddon, lower Darling, Billabong–Yanco system and Campaspe Rivers, ACT reaches of the Murrumbidgee).</p>	<p><u>Range extension:</u> Expand the core range of at least 2 existing populations (candidate sites include populations in the Namoi, Barwon–Darling and Macquarie catchments)</p> <p><u>Additional populations:</u> Improve core range (candidate sites are the Warrego, Paroo and Condamine Rivers (including Oakey Creek).</p>
Freshwater catfish <i>* note this is about improving core range of this species (southern & northern)</i>	<p><u>Range extension:</u> Expand the core range of at least two current populations (candidate sites include Columbo–Billabong Creek and Wakool system and Wimmera River).</p> <p><u>Additional populations:</u> Improve core range in at least three additional locations (candidate sites include the Avoca River, Loddon River upstream Laanecoorie Reserve, Merran Creek area in NSW).</p>	<p><u>Range extension:</u> Expand the core range of at least 3–5 existing populations (candidate sites include the Gwydir, Namoi, Border Rivers, Macquarie, Warrego and Condamine catchments and the Paroo River)</p>

Species	Priorities for increasing distribution in the Southern Basin	Priorities for increasing distribution in the Northern Basin
Southern pygmy perch	<p><u>Range extension:</u> Expand the range of at least two current populations (candidate sites include Barmah-Millewa and other mid-Murray wetlands).</p> <p><u>Additional populations:</u> Establish 3–4 additional populations (candidate sites include the lower Murrumbidgee wetlands and Lower Lakes).</p>	<p><u>Range extension:</u> Expand the range of the Lachlan populations.</p> <p><u>Additional populations:</u> Establish 1–3 additional populations in the Lachlan catchment.</p>
Olive perchlet <i>* note this is about improving core range of this species in Qld parts of the northern Basin</i>	<p>Olive perchlet are considered extinct in the southern Basin*.</p> <p>Reintroduction using northern populations is the main option for recovery. Candidate sites may result from improved flow that reinstates suitable habitat in River Murray and mid-Murrumbidgee wetlands).</p> <p>* as the Lachlan populations are included in the northern Basin in this document</p>	<p><u>Range extension:</u> Expand the range (or core range) of at least 3 existing populations (candidate sites include the Border Rivers, Lachlan River and middle Condamine River).</p> <p><u>Additional populations:</u> Establish or improve the core range of 2–4 additional populations (candidate sites include the Macquarie and Namoi Rivers, Gowrie Creek and Oakey Creek (Condamine tributaries).</p>
Southern purple-spotted gudgeon <i>* note this is about improving core range of this species in Qld parts of the northern Basin</i>	<p><u>Range extension:</u> Expand the range of at least two current populations (candidate sites include the Jury Swamp populations).</p> <p><u>Additional populations:</u> Establish 3–4 additional populations (candidate sites include the Murrumbidgee in Adjungbilly and Adelong Creeks and Murray wetlands).</p>	<p><u>Range extension:</u> Expand the range (or core range) of at least 3 existing populations (priority catchments Border Rivers/Gwydir, Macquarie and Condamine).</p> <p><u>Additional populations:</u> Establish or improve the core range of 2–5 additional populations – (priority catchments Border Rivers/Gwydir, Macquarie, Namoi, Barwon–Darling, Lachlan and Condamine in Oakey Creek).</p>
Yarra pygmy perch	<p><u>Range extension:</u> Expand the range of at least two current populations (candidate sites include the Lower Lakes/Coorong region).</p> <p><u>Additional populations:</u> Establish 3–4 additional populations.</p>	Not present
Murray hardyhead	<p><u>Range extension:</u> Expand the range of at least two current populations.</p> <p><u>Additional populations:</u> Establish 3–4 additional populations, with at least two of these to be within the lower Murray conservation unit, one in the mid-Murray conservation unit and a further population potentially within the Kerang Lakes region.</p>	Not present

Species	Priorities for increasing distribution in the Southern Basin	Priorities for increasing distribution in the Northern Basin
River blackfish #	<p><u>Range extension:</u> Expand the range of at least two current populations (candidate sites include the Murrumbidgee River and from the Mulwala canal).</p> <p><u>Additional populations:</u> Establish 1–3 additional populations (candidate sites include downstream of the Loddon and Campaspe Rivers).</p>	<p><u>Range extension:</u> Expand the range of at least two current populations (candidate sites include tributaries of the Condamine and upland systems of the Border Rivers, Gwydir and Namoi).</p> <p><u>Additional populations:</u> Establish 1–3 additional populations.</p>
Two-spined blackfish ²¹	<p><u>Range extension:</u> Expand the range of at least two current populations (candidate sites include the Kiewa/Ovens population and upper Goulburn tributaries).</p> <p><u>Additional populations:</u> Establish 1–3 additional populations.</p>	Not present
Flathead galaxias	<p><u>Range extension:</u> Expand the core range in the wetlands of the River Murray.</p> <p><u>Additional populations:</u> Improve core range in 1–2 additional locations (candidate sites include Murrumbidgee, Goulburn, Kiewa and Mitta Mitta Rivers and suitable wetlands in these systems).</p>	Flathead galaxias are considered extinct in the northern Basin; therefore the focus for this species is likely to be in the southern Basin. However, reintroduction using southern populations may be an option for recovery in the northern Basin in the longer term. Candidate sites may be considered within their former range in the Lachlan and Macquarie catchments.
Diadromous species (Congolli, short-headed and pouched lamprey)	<p><u>Range extension:</u> Upstream expansion facilitated through flows to operate fishways.</p>	Not present

²¹ Recent genetic studies on these two blackfish species has potentially identified six candidate species across river blackfish and two-spined blackfish. For example, Goulburn River system sites are genetically different. This may require adapting outcomes and approaches for management of these species.

Appendix 7 – Important Basin environmental assets for native fish

MDBA's purpose in compiling this list has been to identify broad-scale locations that are of basin significance for native fish. Outcomes at these locations can be achieved through the use of environmental water in conjunction with natural events and consumptive water. Where active management is not possible, the primary purpose for listing as an environmental asset is to ensure no loss or degradation of their condition. Environmental water managers should use this list as an input into identifying those environmental assets that can be managed with environmental water (termed priority environmental assets by the Basin Plan). Further management of regional and local-scale assets (not explicitly identified in the below table) will also need to be considered in planning and management, particularly to achieve outcomes for threatened species.

Table 9 Important Basin environmental assets for native fish

Environmental asset	Key movement corridors	High Biodiversity	Site of other Significance	Key site of hydrodynamic diversity	Threatened species	Dry period / drought refuge
Southern Basin						
1. Coorong, Lower Lakes and Murray Mouth	*	*	*		*	*
2. Swamps on the lower Murray channel, between Wellington and Mannum (swamp geomorphic region)		*			*	
3. Kerang Lakes					*	*
4. Katarapko anabranch	*			*		
5. Pike anabranch	*			*		
6. Lower River Murray main channel (from Darling junction downstream)	*	*	*		*	*

Environmental asset	Key movement corridors	High Biodiversity	Site of other Significance	Key site of hydrodynamic diversity	Threatened species	Dry period / drought refuge
7. Murray main channel (from Hume dam to Darling junction)	*	*	*	*	*	*
8. Chowilla anabranch	*	*	*	*	*	*
9. Lindsay–Walpolla–Mularoo Creek	*	*	*	*	*	*
10. Lower Darling main channel	*	*	*	*	*	*
11. Darling anabranch			*			*
12. Hattah Lakes			*			*
13. Euston Lakes (including Washpen and Taila Creeks)					*	
14. Lowbidgee Floodplain			*			
15. Murrumbidgee main channel (including upland reaches)	*		*		*	
16. Upland Murrumbidgee main channel	*		*		*	
17. Cotter River			*		*	
18. Koondrook–Perricoota	*	*	*	*	*	
19. Gunbower	*	*	*	*	*	
20. Barmah–Millewa	*	*	*	*	*	*

Environmental asset	Key movement corridors	High Biodiversity	Site of other Significance	Key site of hydrodynamic diversity	Threatened species	Dry period / drought refuge
21. Edward–Wakool system	*		*	*		*
22. Werai Forest			*	*		
23. Billabong–Yanco–Columbo Creeks		*	*	*	*	*
24. Lake Mulwala	*		*	*	*	*
25. Ovens River	*	*	*	*	*	*
26. Lower Goulburn River	*	*	*	*	*	*
27. Upper Mitta River			*		*	
28. King River		*		*	*	*
29. Broken River	*	*	*		*	*
30. Broken Creek					*	*
Northern Basin						
31. Warrego (Darling to Ward Rivers)	*	*		*	*	*
32. Anabranches laterally connecting the Paroo and Warrego River (including Bow, Gumholes and Cuttaburra Creeks)	*					

Environmental asset	Key movement corridors	High Biodiversity	Site of other Significance	Key site of hydrodynamic diversity	Threatened species	Dry period / drought refuge
33.Barwon–Darling (Menindee to Mungindi)	*	*		*	*	*
34.Namoi (Gunnedah to Walgett)	*	*	*	*	*	*
35.Culgoa junction to St George (including lateral connectivity to the floodplain)	*	*			*	*
36.Macintyre River – floodplain lagoons between Goondiwindi and Boomi	*	*	*		*	*
37.Macquarie River – below Burrendong Dam to Warren	*	*			*	*
38.Macquarie Marshes to Barwon, including lateral connectivity at the marshes	*				*	*
39.Lower Bogan River to junction with the Darling River	*				*	*
40.Talyawalka anabranch	*			*		*
41.Lower Moonie River to Barwon River	*	*		*		*
42.Condamine River – Surat to Oakey Creek, including lower Oakey Creek	*	*		*	*	*
43.Floodplain lagoons between Condamine and Surat	*	*	*		*	*

Environmental asset	Key movement corridors	High Biodiversity	Site of other Significance	Key site of hydrodynamic diversity	Threatened species	Dry period / drought refuge
44.Lachlan River – Condobolin to Booligal	*	*	*	*	*	*
45.Macintyre River – Mungindi to Severn in NSW	*	*		*	*	*
46.Paroo River	*	*			*	*
47.Condamine headwaters and Spring Creek upstream of Killarney				*	*	*
48.Severn River within Sundown National park		*		*	*	*
49.Peel River downstream of Chaffey Dam		*		*	*	*
50.Namoi River upstream of Keepit Dam		*		*	*	
51.Charley's Creek and tributaries (upstream from Chinchilla)		*	*	*	*	*

Notes:

Sites of significance – includes areas that have high natural abundance of native species and/or are recruitment hotspots.

This table has been compiled using expert opinion and information provided for the assessment of key ecological assets for the development of the Basin Plan.

Appendix 8 – Consultation process

During preparation of the draft of this strategy, the MDBA worked with the Basin Plan Implementation Committee (an inter-jurisdictional group with representation from all the Basin governments), and its environmental watering working group. We also held workshops with environmental water practitioners and obtained technical assistance from numerous consultants, experts and scientists.

When finalised, the draft strategy was opened for review by interested parties. This process included:

- a public comment period from 21 August to 26 September 2014, with submissions accepted via our website, by email, post and in person (see next two points)
- briefings to peak organisations, representing:
 - Aboriginal Nations
 - farming and irrigation interests
 - conservation groups
- additional briefings to:
 - environmental watering advisory committees and water delivery customer service committees where requested, e.g. Goondiwindi, Dubbo and Bourke
 - committees that we regularly consult with (the Basin Consultative Committee, the Northern Basin Advisory Committee and the Advisory Committee on Social, Economic and Environmental Sciences)
- a range of public meetings (Goolwa, Murray Bridge, Renmark, Mildura, Shepparton, Deniliquin, Griffith and Dirranbandi).

At the meetings, MDBA joined with the Commonwealth Department of the Environment, the Commonwealth Environmental Water Office, state governments and local natural resource management organisations to provide updates. Information discussed included not only the Basin-wide environmental watering strategy, but also the status of Basin Plan implementation and the work of the various agencies' programs.

Outcome

All submissions were considered, including those received after the closing date of 26 September.

We had 41 responses (in addition to the information provided to us at the meetings and briefings). Most respondents gave permission for their feedback to be [published](#). A separate report summarises this feedback and can be found on the MDBA website.

We took the feedback into account when finalising this strategy.

