Australian Government

MURRAY–DARLING BASIN AUTHORITY

2013–14 Basin Annual Environmental Watering Priorities

Overview and technical summaries

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Cover Image: Image compilation of Gwydir Wetlands (Arthur Mostead) and Southern Bell frog (Marjorie Crosby-Fairall).

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Overview of the 2013-14 Basin Annual Environmental Watering Priorities

What are Basin Annual Environmental Watering Priorities?

The Authority will prepare Basin Annual Environmental Watering Priorities (the Priorities) for the start of each water year (July to June), as required by Division 5 of Chapter 8 in the Basin Plan. All environmental watering in the Murray-Darling Basin, including the use of both held and planned environmental water, is to be undertaken having regard to the Priorities.

The purpose of the Priorities is to influence regional-scale environmental watering towards Basin-scale ecological outcomes and to promote coordinated environmental watering between environmental water holders and managers. The Priorities are not an exhaustive list of all important assets and functions throughout the Basin and hence do not exclude other watering priorities identified by environmental water holders and managers.

Setting the scene for the 2013-14 Priorities

Between 2000 and 2010 the Murray-Darling Basin endured an extended period of below average rainfall (Figure 1). This 'millennium drought', combined with the effects of river regulation, had a significant negative impact on water-dependent ecosystems throughout the Basin. Only small volumes of environmental water were available during this period owing to the limited recovery of entitlements at the time and low annual allocations. The environmental water that was available was used primarily to maintain critical drought refuges.

In 2010-11 and then again in 2011-12 the Basin experienced above average rainfall and widespread flooding. These events stimulated partial recovery of many riverine, wetland and floodplain flora and fauna communities throughout the system. Environmental water was not released during the floods, but rather was used to maintain water levels following the recession of peaks to support environmental outcomes such as bird breeding events and wetland habitat.

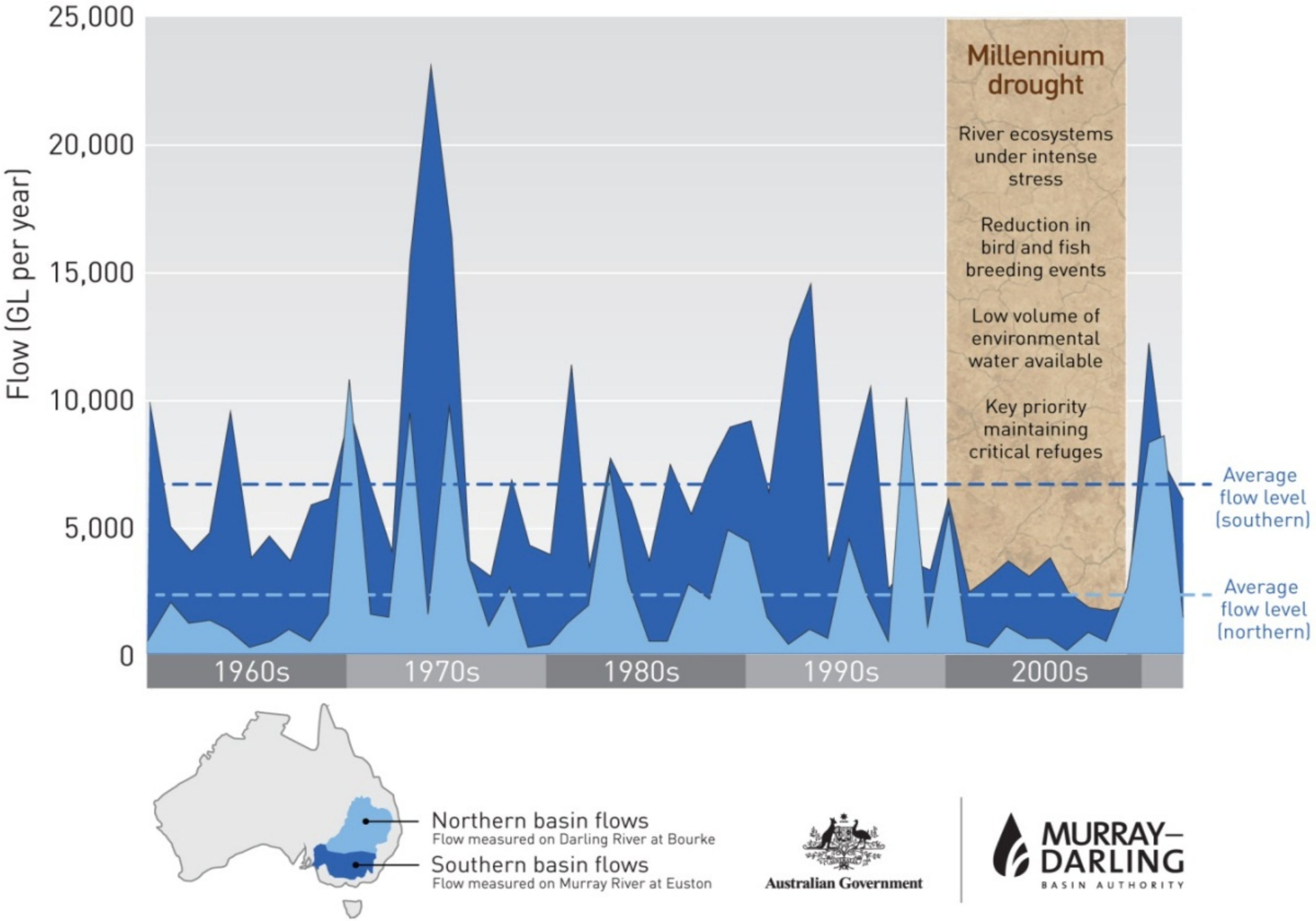

Figure 1. Annual inflows in the Northern and Southern Murray-Darling Basin

The past year (2012-2013) has been hotter and drier than usual throughout the Basin (Figure 2). In the Southern Basin, some early flooding occurred along parts of the Murray, Murrumbidgee, Goulburn and Ovens Rivers but since September 2012 there have been few rainfall events. In the Northern Basin, some catchments in Queensland and Northern New South Wales received heavy rainfall and flooding from ex-tropical cyclone Oswald in late January 2013. However, other rivers throughout central-north New South Wales and the north-western region of the Basin have experienced below average rainfall throughout the year.

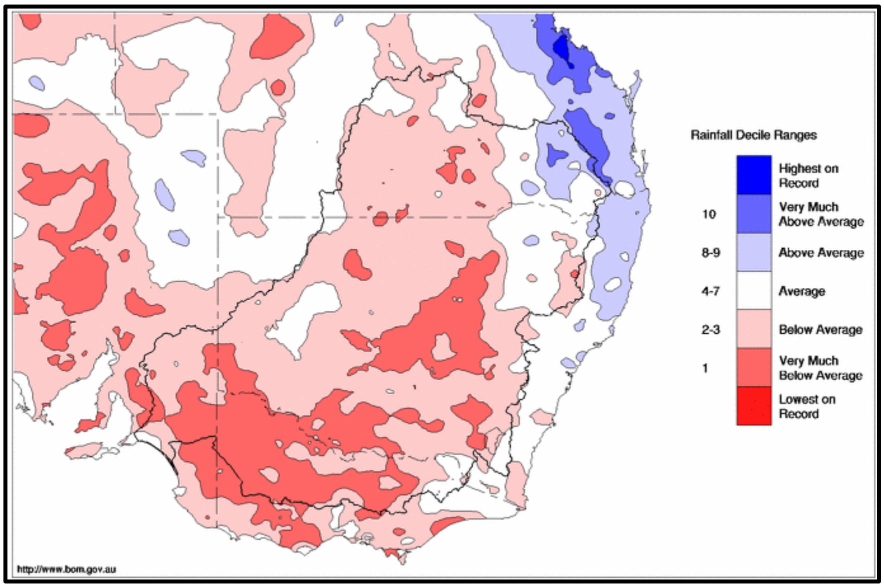

Figure 2. Rainfall throughout the Murray-Darling Basin, 1 June 2012- 31 May 2013 (Bureau of Meteorology)

Despite low inflows and high water usage in response to hotter temperatures, dam storage levels throughout the Basin still generally remain above average. This provides confidence that reasonable environmental water allocations may become available in 2013-14, however volumes will vary between catchments according to inflows. The Bureau of Meteorology rainfall outlook for the next three months (June – August 2013) indicates a wetter than normal season is more likely throughout the Basin (Figure 3).

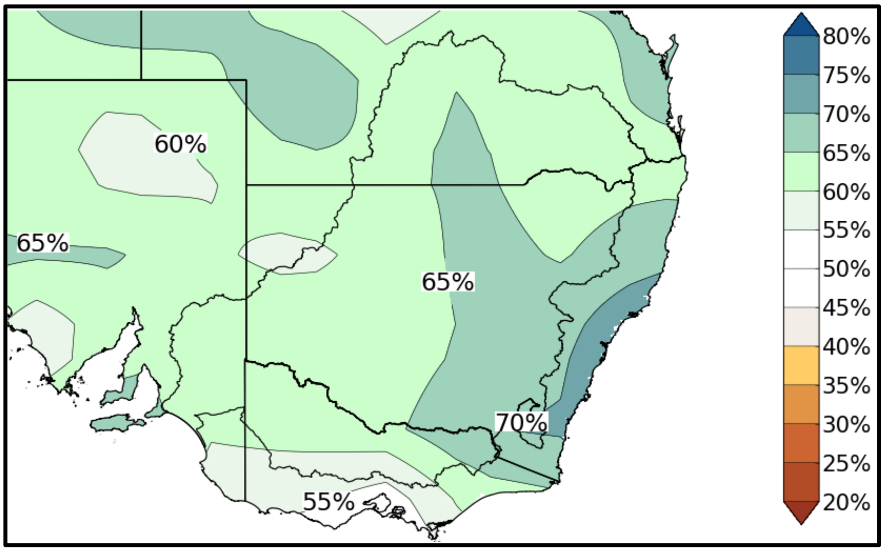

Figure 3. Chance of exceeding the median rainfall, 1 June – 31 August 2013 (Bureau of Meteorology)

Given the antecedent conditions, current climate forecasts and likely water availability, the Priorities for 2013-14 focus on the broad management outcomes aligned to the moderate to wet resource availability scenarios (Table 1). These are to maintain, and in some cases improve, ecological health and ecosystem resilience throughout the Basin.

However, due to the highly variable nature of climate and river flow across the Basin, real-time management of environmental water will be undertaken according to specific conditions in each catchment. Each Priority is supported by a rationale that describes how its implementation may vary according to prevailing conditions throughout 2013-14.

Table 1: Management outcomes for each resource availability scenario[1]

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

[1] See the statutory '*Guidelines for the method to determine priorities for applying environmental water*'.

Rationale and process

In putting together the Priorities for 2013-14, the Authority has taken a Basin-scale approach which adds value to current environmental watering activities without duplicating them. This philosophy encompasses moving the concept of environmental watering, from just the delivery of a volume of water at specific sites towards the preferred concept of a flow regime as near natural as possible within river systems.

The Priorities have been developed using both the conventional triage approach to environmental watering, whereby assets and functions are prioritised by their urgency of watering, as well as drawing on a restoration ecology approach. Restoration ecology emphasises providing environmental water to those assets and functions already in good condition where a significant positive response to environmental water is most likely.

The process is designed to facilitate outcomes that are consistent with:

(1) The objectives for water dependent ecosystems outlined in the Environmental Watering Plan (Basin Plan, Chapter 8) namely:
- Protection and restoration of water-dependent ecosystems.
- Protection and restoration of ecosystems functions of water-dependent ecosystems.
- Ensuring water- dependent ecosystems are resilient to climate change and other risks and threats.

(2) The management outcomes for the Basin Plan as a whole (Basin Plan, Chapter 5) and particularly:
- Healthy and resilient ecosystems with rivers and creeks regularly connected to their floodplains and, ultimately, the ocean.

The Authority has not attempted to prioritise the watering needs of all the ecological assets and functions throughout the Basin. Rather the final Priorities for 2013-14 reflect those considered to be of Basin-scale significance, noting that environmental watering is already occurring successfully throughout much of the Basin at the local and regional scale and that state priorities will guide watering at a more local level for each water resource plan area.

To determine the Basin annual environmental watering priorities for 2013-14 the Authority implemented an evidence-based process that combined analysis and expert judgement. The process included:

a) Application of the principles and method detailed in the Environmental Watering Plan.
b) Development of a Basin-wide view through a threats and opportunities assessment and a Basin-scale significance assessment.
c) Consultation with a range of stakeholders.

Further detail on how the Authority has identified the Priorities for 2013-14 is provided under the heading: *Preparing Basin annual environmental watering priorities for 2013-14*.

The Basin Annual Environmental Watering Priorities for 2013-14

The Priorities for 2013-14 are focussed around two themes*, Connecting rivers and floodplains* and *Supporting in-stream functions*.

To complement these Priorities, the Authority has also developed a *Guiding Philosophy* for environmental water delivery to: ***Maximise environmental outcomes by delivering environmental water in response to natural cues.***

The Priorities for 2013-14 are outlined in below and presented geographically in Figure 4. Some of these Priorities are more strategic in nature and are likely to apply for a number of years. Each Priority is supported by a rationale document outlining expected outcomes of the Priority, matters of interest, and practical issues relating to implementation.

Theme: Connecting rivers and floodplains

1. **Northern Basin wetlands:** Improve the resilience of colonial waterbird populations by supporting breeding events and improving breeding habitat in the Northern Basin wetlands.
2. **Gwydir wetlands:** Improve the condition and maintain the extent of wetland vegetation communities in the Gwydir wetlands (including Ramsar sites) by restoring hydrological connectivity and a flow regime that meets ecological requirements.
3. **Macquarie Marshes:** Improve ecosystem resilience amongst wetland vegetation communities in the Macquarie Marshes including Ramsar listed sites.
4. **Lower Lachlan wetlands:** Improve ecosystem resilience amongst wetland vegetation communities in the lower Lachlan wetlands
5. **Mid-Murrumbidgee wetlands:** Improve the condition of wetland vegetation communities in the mid-Murrumbidgee wetlands through a winter or spring fresh.
6. **Lower Murray River system:** Improve vegetation condition in wetlands and floodplains and provide cues for native fish recruitment and movement in the lower Murray River system by enhancing in-stream flow variability.

Theme: Supporting in-stream functions

7. **Barwon-Darling River:** Improve habitat and provide opportunities for migration and reproduction of native fish in the Barwon-Darling River system by increasing flow variability and hydrological connectivity.
8. **Lower Goulburn River:** Improve habitat and provide opportunities for migration and reproduction of native fish in the lower Goulburn River through re-instating a variable flow regime which includes a large ‘in-channel’ spring/summer fresh.
9. **Mid-Murray River:** Improve habitat and provide opportunities for migration and reproduction of native fish in the mid-Murray River, including the Edward-Wakool and other smaller anabranches, distributary creeks and low-lying wetlands throughout the region.
10. **Coorong, Lower Lakes and Murray Mouth:** Facilitate *Ruppia* recovery by ensuring appropriate flows into the Coorong; and maintain the connection between the Lower Lakes to improve the water quality in Lake Albert.

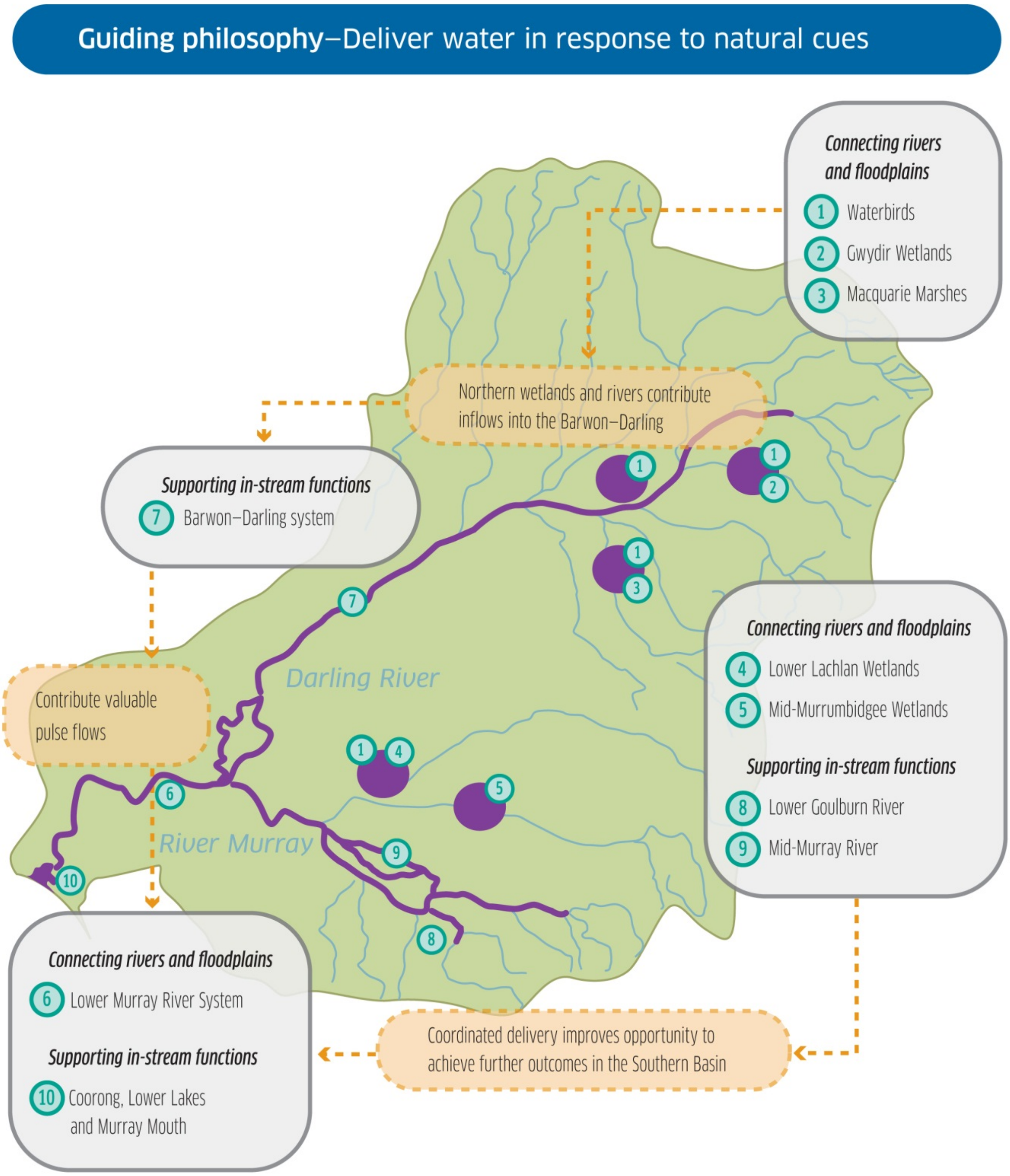

Figure 4.Geographic representation of the Basin annual environmental watering priorities for 2013-14

Guiding Philosophy

Division 6 of Chapter 8 of the Basin Plan sets out a range of principles to be applied in environmental watering. The Authority has developed a *Guiding Philosophy* for 2013-14 to highlight some of the specific issues contained within these principles. For further information, refer to *the Guiding Philosophy* document.

River regulation has altered the natural flow regime throughout the Murray-Darling Basin. It has reduced the long-term average flow (in particular a reduction in small to medium floods), changed seasonal patterns and negatively impacted water quality, all of which has contributed to a decline of water-dependent ecosystems. By delivering environmental water in response to natural cues, environmental water holders and managers can contribute to events similar to those which would otherwise have occurred in an unmodified system. This would be expected to improve the environmental outcomes obtainable from environmental watering within the Basin.

Connecting rivers and floodplains

The first theme of the Priorities for 2013-14 relates to the protection and restoration of lateral connectivity within the Basin by connecting rivers with their floodplains. Connectivity is fundamental for maintaining the health of floodplain vegetation and for supporting ecosystem functions within aquatic ecosystems. Connecting rivers to their floodplains is also vital for the protection and restoration of declared Ramsar wetlands and for supporting species listed under international migratory bird agreements.

This group of Priorities aims to improve vegetation condition and build ecosystem resilience throughout the Basin by following up on the positive response of floodplain and wetland vegetation communities to the high flows of 2010-11 and 2011-12. Providing flows to significant wetlands and floodplains that support large numbers of colonial nesting waterbirds is also covered by this theme. In many cases promoting lateral connectivity will also provide increased carbon exchange and flows for the river channels thereby improving longitudinal connectivity between the rivers of the Basin.

Supporting in-stream functions

The second theme of the Priorities for 2013-14 is the protection and restoration of ecosystem functions that maintain in-stream and end-of-system aquatic species and communities. The significant unregulated events of 2010-11 and 2011-12 served to re-invigorate the system following the millennium drought, but they also had some negative effects. An example of this was the fish kills that arose from hypoxic blackwater, the severity of which was exacerbated owing to the length of time between floods (which meant there was a build-up of organic matter on the floodplain) coupled with the summer timing of the rainfall events.

This group of priorities aims to promote medium-high flows (within constraints) to maintain hydrologic connectivity along watercourses. This will assist the transfer of nutrients and biota throughout the system and will support the recovery of native aquatic fauna and flora across the Basin. In addition, improved in-stream function will enhance the ecological outcomes achievable when rivers and floodplains are connected.

Preparing Basin annual environmental watering priorities for 2013-14

Introduction

The Environmental Watering Plan has an environmental management framework that sets out key components of environmental water management. The environmental management framework is intended to coordinate the planning, prioritisation and use of planned and held environmental water; facilitate coordination and cooperation between the Authority, the Commonwealth Environmental Water Office and the Basin States; and enable adaptive management.

The environmental management framework sets out that the Authority must prepare Basin annual environmental watering priorities and a Basin-wide environmental watering strategy and Basin states must undertake long-term and annual environmental water planning and management, consistent with methods and principles set out in the Environmental Watering Plan.

Basin annual environmental watering priorities ('Priorities') are the first components of the environmental management framework to take effect. The Priorities may identify priority environmental assets and priority ecosystem functions that have Basin-scale significance, require complex arrangements or have potential for synergies.

How the Authority identifies Priorities

Method to determine Priorities for applying environmental water

The Authority determined Priorities for applying environmental water by following the method in Part 6 of the Environmental Watering Plan. The method has four steps:

1. Determine Resource Availability Scenario.
2. Select the management outcomes that apply to the Resource Availability Scenario.
3. Determine provisional Priorities by applying the principles in the Environmental Water Plan (Part 6, Division 1 of the Environmental Watering Plan).
4. Refine those priorities based on seasonal, operational and management considerations.

Step 1: Determine Resource Availability Scenario

The Authority considered antecedent conditions, current climate forecasts and likely water availability then made a judgement about the current Resource Availability Scenario for the Basin. The result of this assessment is described in the document '*Overview of the 2013-14 Basin Annual Environmental Watering Priorities*'.

Step 2: Select management outcomes

Determination of the Resource Availability Scenario informed the broad management outcomes which the Priorities would focus on (Table 2), taking into account differences between individual catchments.

The Authority also sought the views of a group of scientists and practitioners with environmental water experience to help determine the strategic environmental watering needs at the Basin-scale. This served to provide an initial context for the Priorities and the management outcomes that were selected. These management outcomes are described under the heading *Overview of the 2013-14 Basin Annual Environmental Watering Priorities*.

Table 2: Management outcomes for each Resource Availability Scenario[2]

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

[2] See the statutory 'Guidelines for the method to determine priorities for applying environmental water'.

Step 3: Determine provisional Priorities by applying the principles

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

1. Consistency with the principles of ecologically sustainable development and international agreements.
2. Consistency with 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.

The Authority's approach to determining the provisional priorities based on these principles has been to employ a top-down/bottom-up approach (Figure 5). The top-down element, undertaken by the Authority, identified provisional Basin annual environmental water priorities (Fig 1) by the application of two assessments that attempted to draw together the principles - a risk assessment (threats and opportunities) and a Basin-wide significance assessment. Both of these assessments were aided by expert judgement, and are described below under the heading 'assessments'.

In accordance with the Environmental Watering Plan, the Authority also needed to consider how the state annual environmental watering priorities could inform the Priorities. The bottom-up element of the approach identified regional priorities by applying the method at the region scale, and was undertaken by the Basin states.

For 2013-14 the two sets of priorities were integrated qualitatively, assessing synergies, competing demands, and the Basin-scale significance of regional priorities. This resulted in a set of Priorities with a whole-of-system focus, informed by local experience and knowledge. Leading up to the state's submission of their priorities the Authority worked closely with the states and the Commonwealth Environmental Water Office to identify priorities which would be important at a Basin-scale. The states, Commonwealth Environmental Water Office and the Authority will work together to further improve the method to ensure that there is a clear process to consider the region-scale and Basin-scale priorities together in the future.

Assessments

Risk assessment (threats and opportunities). The MDBA engaged Barma Water Resources to develop a conceptual approach to assist in identifying the provisional priorities, trialled for 2013-14 at the Hydrologic Indicator Sites. This study assessed the last time the environmental water requirements identified for the Hydrologic Indicator Sites were met, in order to identify whether they were a priority for watering. The conceptual approach examined:

- Potential contribution of each Hydrologic Indicator Site to the overall environmental objectives for water-dependent ecosystems (Part 2 of the Environmental Watering Plan).
- An assessment based on the specific flow indicators developed for the proposed Environmentally Sustainable Level of Take for surface water of the Murray–Darling

Basin. The assessment identified whether the environmental watering requirements that had been identified had been recently met or were overdue.
- Threats and opportunities for watering. This was a risk assessment of threats to delivery of environmental water and likely failure to meet overall environmental objectives for water-dependent ecosystems, as well as identifying the best opportunities to meet the objectives. A single threat, such as a river system constraint, could completely prohibit the delivery of a specific flow.

Barma Water Resources (2013) advised of assumptions, limitations and gaps inherent in the risk assessment (threat and opportunities). Due to the lack of empirical data for some Hydrologic Indicator Sites, the degree of interpretation and judgement required was such that the value of the assessment depends very much on the people using the assessment. Barma Water Resources (2013) recommended a very strong application of judgement, including consultation with on-site managers and others with good knowledge of an area (see Step 4 below).

A Basin-scale significance assessment. The Basin-scale significance assessment was used to assess the Authority's provisional priorities. The tool reflects a 'whole of Basin perspective' by adopting the responsibilities under the Environmental Watering Plan in the Basin Plan. Basin-scale significance assessment was assessed against four criteria:

- Significance of environmental benefit if priority is met.
- Risk of not listing a priority.
- Certainty / likelihood of environmental benefit.
- Synergies and multiple outcomes.

Expert judgement was important to both assessments. In the risk assessment (threats and opportunity) expert judgement was required to assess potential contribution to overall environmental objectives for water-dependent ecosystems (Part 2 of the environmental watering plan), especially for those Hydrological Indicator Sites lacking empirical data.

Step 4: Refine based on seasonal, operational and management considerations.

The provisional priorities were tested against seasonal, operational and management considerations as part of the risk assessment (threat and opportunity) described above, and through consultation with water managers and environmental water holders.

Any of the provisional priorities with environmental watering requirements that could not be delivered within the river system's delivery capacity or operating constraints were either refined or removed from further consideration.

Seasonal considerations, being influenced by climatic conditions, were considered at length by the Authority when refining the provisional priorities. However, as the climatic conditions for the coming year cannot be reliably predicted, the Authority considered how the Priorities may be implemented across all scenarios in each relevant catchment.

The rationales for each of the Priorities document MDBA's conclusions as a result of these considerations.

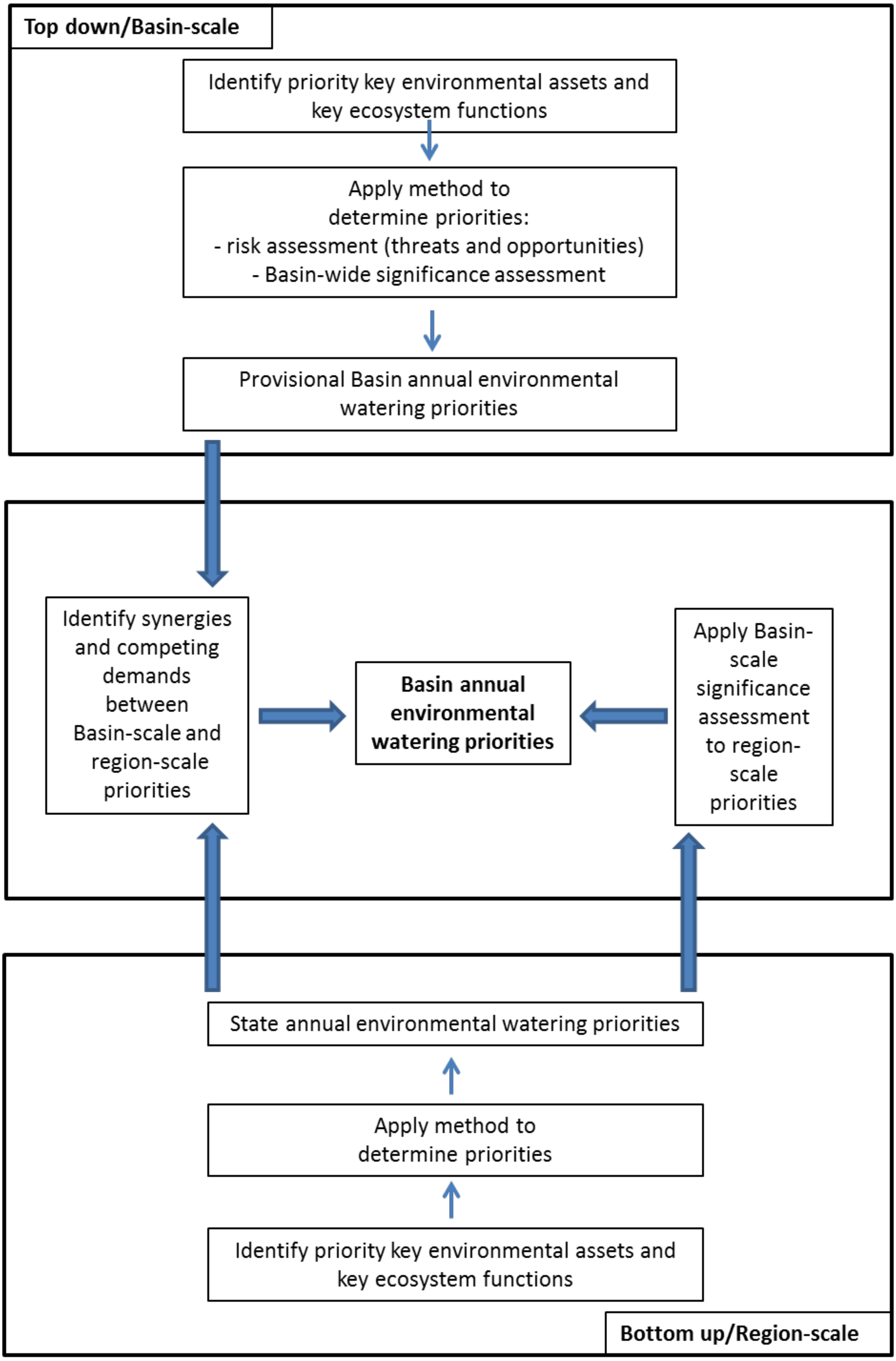

Figure 5: The top-down/bottom-up approach for preparing Basin annual environmental watering priorities.

Consultation in the development of the Priorities

In preparing Priorities, the Authority consulted with Basin states and the Commonwealth Environmental Water Office. The Authority also had regard to advice provided by river operators, and the views of local communities and persons materially affected by the management of environmental water, and Indigenous values and uses.

Informal consultation commenced in 2011 with Basin states, the Commonwealth Environmental Water Office, environmental water holders and managers in state agencies, catchment management authorities, and environmental water advisory groups. This consultation helped the MDBA to understand the approach of the Basin states and the Commonwealth Environmental Water Office to prioritisation, and commenced the discussion on some of the key issues, such as Basin-scale significance, synergies and coordination, trade-offs and competing demands for environmental water.

Formal consultation began once the Authority developed provisional Priorities. In addition to continued bilateral meetings, formal multilateral meeting were held with Basin states and the Commonwealth Environmental Water Office in April and June 2013. Input from local communities was gathered by way of the state annual environmental watering priorities, as these were developed taking advice through environmental water advisory groups.

Briefings of the Northern Basin Advisory Committee, Northern Basin Aboriginal Nations, Murray and Lower Darling Indigenous Nations, and the Advisory Committee on Social, Economic and Environmental Science were conducted in April and May 2013.

The Authority also convened a group of scientists and practitioners with environmental water experience to advise on matters of Basin-scale significance that may impede or improve the Authority's ability to set Priorities.

Next steps

Further consultation will be carried out in 2013-14 after the Priorities have been published. Feedback from this consultation, together with formal reporting from holders of held and managers of planned environmental water will be used to inform the development of Priorities for 2014-15.

In the longer term, the Authority will seek to improve the knowledge base that underpins the Priorities. In preparing Priorities for 2013-14, the Authority followed a path of assessing threats and opportunities and Basin-scale significance, based on the existing information base (Figure 6) and consultation with water managers and environmental water holders.

The Authority expects that the path will evolve over the next five years as components of the environmental watering plan are progressively implemented, and the annual and longer-term planning cycles between and within jurisdictions become better integrated.

During this time the Authority will seek to improve the information base including work in the following areas:

1. Strategic planning. Application of strategic conservation planning principles to environmental water planning will explore how the principles of 'comprehensive,

adequate and representative' can be applied to environmental water, and in particular, how it will influence the selection of key environmental assets for environmental water.

2. Inundation mapping and condition assessment. Development of flood inundation models for the Basin, along with mapping of flood-dependent vegetation, will provide information on flooding history, vegetation condition and expected response to environmental flows of many key environmental assets.

3. Environmental water requirements of Key Environmental Assets (KEA) and Key Ecosystem Functions (KEF). In 2013-14, the Authority focused on the Hydrologic Indicator Sites, which had known and consistently defined environmental watering requirements. A broader suite of sites will be added over the coming years as state long-term plans are developed, noting that delivery of environmental water consistent with the prescribed requirement will not always be practical.

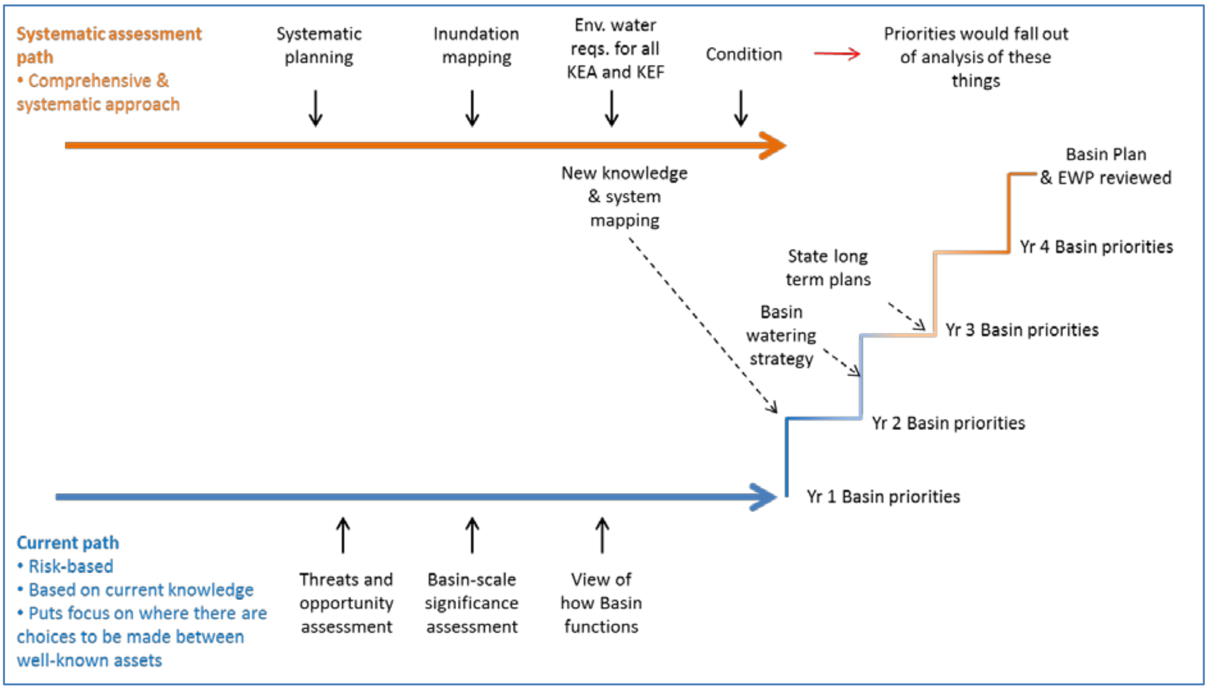

Figure 6: Steps to a more systematic method for identifying Priorities.

The work plan identified by the Authority and the completion of other Basin Plan obligations (i.e. Basin-wide environmental watering strategy, long-term watering plans and constraints management strategy) will provide a more systematic information base and approach. This approach will be underpinned by on-going consultation with community stakeholders, the Basin states and the Commonwealth Environmental Water Office.

Guiding philosophy for Basin Annual Environmental Watering Priorities

Maximise environmental benefits by delivering environmental water in response to natural cues. [3]

As the role of active management of environmental water in the Basin has grown our understanding of the importance of responding to natural flow patterns and ecologically significant events has increased. Delivering environmental water in response to natural cues has become a guiding philosophy for the management of environmental water.

It is anticipated that by following this philosophy environmental watering will contribute to meeting the Environmental Watering Plan objectives at the Basin scale and improve whole of system outcomes by:

- Maximising outcomes through effective and efficient use of water
- Reducing the negative effects of river regulation
- Meeting ecological needs which are seasonally dependent.

Feedback from key stakeholders has also identified that an inability to respond to natural cues can limit the ability to achieve environmental outcomes.

This guiding philosophy relates to Principle 3 of the 'Principles to be applied in environmental watering' in Chapter 8 of the Basin Plan. Principle 3 aims to maximise environmental outcomes through various ways including by enhancing existing flow events and mitigating or avoiding seasonal inversion of flows of which both directly relate to this philosophy.

A regulated river system

Changes to the natural flow regime due to river regulation are well documented and include reduction in long-term average flow, a reduction in small to medium floods, changes to seasonal patterns and changes to water quality (Gippel and Blackham 2002; MDBMC 1995). Alterations to the natural flow regime have resulted in a decline in the condition of water dependent ecosystems. These effects include loss of wetland and floodplain productivity, lost and altered habitats, changes in species composition, including invasion by feral species, declining numbers of waterbirds, and reduction in health, area and diversity of riparian, floodplain and wetland vegetation (Kingsford and Johnson 1998; Gerhke and Harris 2001; Young 2001; Bunn and Arthington 2002). Recovery and management of water for the environment will go some way to mitigating these effects.

Seasonal flow patterns

The effects of river regulation on seasonal flow patterns differ throughout the Murray-Darling Basin and depend on distance downstream from storages and the location of significant irrigation off-takes. In the River Murray, the seasonal flow pattern has been reversed from Hume Dam to

[3] Note this is not a Basin Annual Environmental Watering Priority, rather it's a guiding philosophy which is consistent with s8.35 of the Basin Plan (Principles to be applied in environmental watering).

Yarrawonga with the effect reduced further downstream (e.g. at Euston) due to tributary inflows and irrigation take upstream. It is evident that at Euston there is a large reduction in the winter spring flows (Figure 7). Seasonal flows are critical to fish, as much of their behaviour is synchronised with flow regimes as well as water temperature and day-length. Changes caused by river regulation to the timing of flow events are therefore likely to have a negative impact on aquatic species (Bunn and Arthington, 2002). Making releases earlier in the season in response to natural events will result in more natural seasonal flow patterns which support aquatic species.

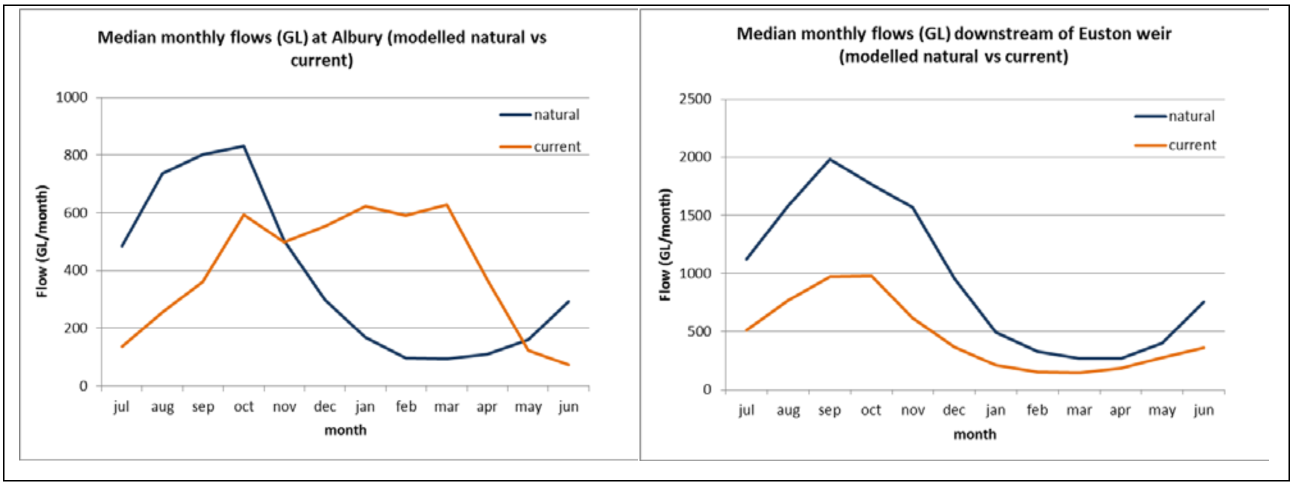

Figure 7. These graphs show the effects of river regulation on the seasonal flow patterns of the River Murray at Albury and further downstream at Euston. The graph on the left shows that modelled natural flows at Albury are higher in winter and spring and lower in summer and autumn whereas current flows at Albury are much lower during winter and have a lower more sustained peak through spring, summer and into autumn. The graph on the right demonstrates that the current flow pattern of the River Murray at Euston is similar to the modelled natural flow but has a much lower peak flow in spring.

Co-ordinating dam releases with natural events

The capture, holding and release of water through dams has multiple impacts on the environment in addition to seasonal flows including; a change in temperature of the water (as detailed below) and a reduction in connectivity both laterally between the river and floodplain and longitudinally with natural cues not being met. Often aquatic biota require certain conditions in order to survive and reproduce, these conditions may provide a natural cue for life events such as fish spawning or birds breeding, and are usually a result of many factors combining, generally though, flow, connectivity and water quality are contributing factors. Given dams interrupt and alter flows and impact on water quality they subsequently impact on the success of life events of aquatic biota.

Some dams do allow for a portion of water to be passed through the dam in response to natural events as part of the dam's operating strategy. These rules, known as translucency rules permit small to medium inflow events to be released from storage at the same time the storage is receiving the inflows.

Building on natural events has many benefits beyond supplying an event solely from a manufactured storage release. If environmental water is released in conjunction with a natural event it's a more efficient and effective use of environmental water because not as much environmental water is needed to achieve the desired flow, it also improves the capacity to increase the extent of inundation. In addition, it can also improve the ecological outcomes by utilising the productivity gains from upstream flooding and runoff which include plant and invertebrate propagules, carbon and nutrients and other chemical cues resulting from inundation of floodplain soils and plant material, eggs and larvae of fish and other organisms spawned at upstream sites (Wallace et al. 2011). Delivering water in response to natural events is one of the most effective tools in overcoming the human induced threat that river regulation has on the environment.

Following this philosophy is possible under all resource availability scenarios. In wet to very wet years responding to natural events may mean filling the gaps in the hydrograph or extending the recession (or tail) of a flow event, while in drier years it may be possible to build upon a smaller event to achieve a higher peak flow. The environment of the Murray–Darling Basin has adapted to wetting and drying cycles, and these natural cycles should also be considered in undertaking environmental watering.

Other considerations

There are some limitations to the environmental benefits that can be achieved when delivering environmental water in response to natural cues.

The construction of large dams and the release of water from the bottom of the storage reduces the temperature in rivers downstream (Walker 1985). Changes to water temperature, known as cold water pollution, are estimated to affect up to 3,000 km of river channels in the Basin (Gehrke et al. 2003). Differences in the temperature downstream of a large dam can be as much 16 ^{o}C but are usually between 8-10 ^{o}C lower than natural temperatures during the spring/summer period (Lugg and Astle unpublished; Sherman 2000). The effects of this often persist 200 km downstream and in some cases as much as 400 km downstream of a dam (Preece 2003).

The effects of cold water pollution have been summarised by Cottingham et al. (2007) as including; a decrease in the growth rates of fish, failure of fish to spawn, reduced survival of eggs and larvae and reduced rates of primary production and bacterial activity in river systems, thus reducing the carrying capacity of the affected river.

Overcoming cold water pollution is a long-term challenge and will require changes to infrastructure. The MDBA encourages the use of cold water pollution mitigation measures where they are in place and the modification of dams where they are not. The MDBA acknowledges and supports the NSW Government plans to complete the construction of mitigation measures on Burrendong Dam by the end of 2013.

Priority 1 — Connecting rivers and floodplains: Waterbirds in the Northern Basin

Basin Annual Environmental Watering Priority

Improve the resilience of colonial waterbird populations by supporting breeding events and improving breeding habitat in the Northern Basin wetlands.

Expected outcomes of this priority

It is anticipated that the above Basin Annual Environmental Watering Priority (the Priority) will facilitate the following outcomes:

- Maintain suitable habitat for colonial waterbird breeding in the Narran Lakes, Gwydir wetlands, Macquarie Marshes and lower Lachlan wetlands.
- Support reproduction and recruitment for colonially nesting water birds including those listed on Japan Australia Migratory Birds Agreement (JAMBA) and China Australia Migratory Birds Agreement (CAMBA) and the Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA).
- Assist colonially nesting waterbird populations to build resilience to extended dry periods.

Why is this a Priority?

The Authority considers this Priority to be of Basin significance because:

- The construction of dams and subsequent diversion of water from rivers and wetlands have had a substantial impact on important breeding areas for waterbirds.
- Supporting habitats and building upon recent recovery of wetlands and waterbirds provides opportunities to build resilience in waterbird populations to endure future extended dry periods.
- The key wetlands of the Narran Lakes, Gwydir Wetlands, Macquarie Marches and the wetlands in the lower Lachlan are recognised as providing many of the most important breeding habitat for large-scale colonial waterbird breeding within the Murray-Darling Basin:
  - The Narran Lakes are among the highest ranked sites in NSW for species richness, number of breeding species and total number of birds.
  - The lower Lachlan wetlands of this region have the capacity to support large-scale colonial waterbird breeding events.
  - The Gwydir Wetlands are recognised as a refuge for waterbirds in dry times, and for supporting some of the largest waterbird breeding colonies recorded in Australia.
  - The Macquarie Marshes have long been regarded as an important refuge for waterbirds during dry times, as well as supporting some of Australia’s largest recorded waterbird breeding colonies.
  - The Paroo, Warrego and Barwon Darling can also be important for bird breeding in years of large floods but as they cannot be influenced by active management of environmental flows they are not discussed in this Priority.

Significance of this priority

This Priority outlines the value of wetland sites for waterbird breeding in the Northern Basin. Its implementation will maintain and improve habitat to support waterbird breeding events.

Wetlands in the Murray-Darling Basin are a crucial component of the life cycle of waterbirds. Of the 98 species recorded in a basin wide survey, 34 species have a large component of their breeding habitat in the wetlands of the Murray-Darling Basin (Scott 1997). Although there are many important sites for waterbirds across the Basin, it is notable that very large waterbird breeding events are primarily restricted to the Northern Basin. In contrast to much of the Southern Basin, the Northern Basin retains elements of lateral hydrological connectivity between rivers, floodplains and wetlands. This connectivity is thought to enable the maintenance of key breeding sites for waterbirds in the Murray-Darling Basin. This is consistent with the findings of Colloff et al. (2010) and Reid et al. (2013) who reported a clear alignment between the colonial nesting waterbird guild (egrets, herons, ibis, spoonbills and the Australian Pelican) and catchments in moderate to good hydrological condition.

Waterbirds are useful measures of wetland health, as changes in numbers and diversity of waterbirds can be an indicator for changes in other biota, such as fish, vegetation and invertebrates (Kingsford et al. 2013; Scott 2001).

Condition of Waterbird populations

To breed successfully, colonial nesting waterbirds need a flood of sufficient size and duration (4 - 6 months) at the right time of year to provide food resources, nesting sites, and protection from terrestrial predators to allow juveniles to fledge (Scott 1997, 2001). Notably, flood magnitude is an important determinant of the size of a waterbird breeding event. For example, observations at the Macquarie Marshes indicate that the number of waterbirds breeding rapidly increases as the flood size increases (NSW NPWS & DLWC 1996; Scott 1997, 2001). Furthermore, breeding waterbirds have high nutritional and energy demands and can be expected to select foraging habitats that have a high abundance of accessible foods (Laubhan and Gammonley 2000). The very large infrequent floods not only inundate a much larger area, and hence provide a greater abundance of food but also provide a longer duration of inundation which is vital for the very large waterbird breeding events that have been reported in the Murray-Darling Basin (Richard Kingsford pers. comm, cited in Scott 1997).

The construction of dams and subsequent diversion of water from rivers and wetlands has major impacts on core breeding areas for waterbirds (Kingsford and Johnson 1998,). Reid et al. (2013) notes that colonial nesting waterbirds are the group of birds most adversely affected by river regulation and water diversions. River regulation and extraction affects the hydrology of the rivers and associated wetlands by: reducing the average duration and extent of inundation in wetlands; reducing the heights and frequency of small to medium floods; permanently flooding intermittent wetlands; and, changing the seasonality of inundation (Briggs 1990; Pressey 1990; MDBMC 1995). Aerial surveys of waterbirds across eastern Australia have been undertaken since 1983. Results from these surveys indicate that there is a decline in the abundance of some species of waterbirds along with the reduction in wetland area (Scott 1997).

The 'millennium drought' resulted in a long period where there were very few opportunities for waterbird breeding in the Murray-Darling Basin. For the three years prior to 2012-13 the Northern Basin experienced very wet conditions which caused flood flows to rivers and floodplains. This contributed to the recovery of some wetlands and also significant waterbird breeding events in key wetland sites such as Narran Lakes, Macquarie Marshes, Gwydir Wetlands and the lower Lachlan wetlands. The Authority considers that should a bird breeding event begin in response to a natural watering event, water managers should consider options for extending the event to allow sufficient time for breeding events to conclude and thus assist in building waterbird numbers resilience in populations to endure future extended dry periods.

Description of Key Wetlands

The Northern Basin contains nationally and internationally recognised wetlands that support large numbers of waterbirds. These include; Macquarie Marshes in the Macquarie catchment, Gwydir Wetlands in the Gwydir catchment and the Narran Lakes in the Lower Balonne. The lower Lachlan wetlands in the Lachlan catchment are not hydrologically connected to the Northern Basin, however it is also recognised as a wetland which has the capacity to support large numbers of breeding waterbirds. The key wetlands are not linked hydrologically, however their geographical proximity and potential to support major waterbird breeding events suggests a strong ecological connection. The catchments which support these systems cover very large geographical areas with varying climatic conditions therefore presenting the opportunity to allow for seasonal inundation patterns.

Macquarie Marshes, Gwydir Wetlands and Lower Lachlan Wetlands

Details regarding location and ecological significance of Macquarie Marshes, Gwydir Wetlands and the lower Lachlan wetlands, have been outlined in the other 2013-14 watering Priorities information sheets.

Narran Lakes

The Narran Lakes are located at the end of the Narran River which is a distributary of the Balonne River. They are situated approximately 50km southwest of Lightening Ridge in north central New South Wales (Figure 8). The Narran Lakes system is about 278 km^2 and comprises four distinct structural features — a complex network of river channels (channelised floodplain), floodplain lakes, ephemeral wetlands and a broader floodplain surface. There are four main lakes or water bodies, which are surrounded by a large floodplain area and these fill sequentially with Narran Lake filling in the largest events (Thoms et al. 2007). The Narran Lakes are among the highest ranked sites in NSW for species richness, number of breeding species and total number of birds.

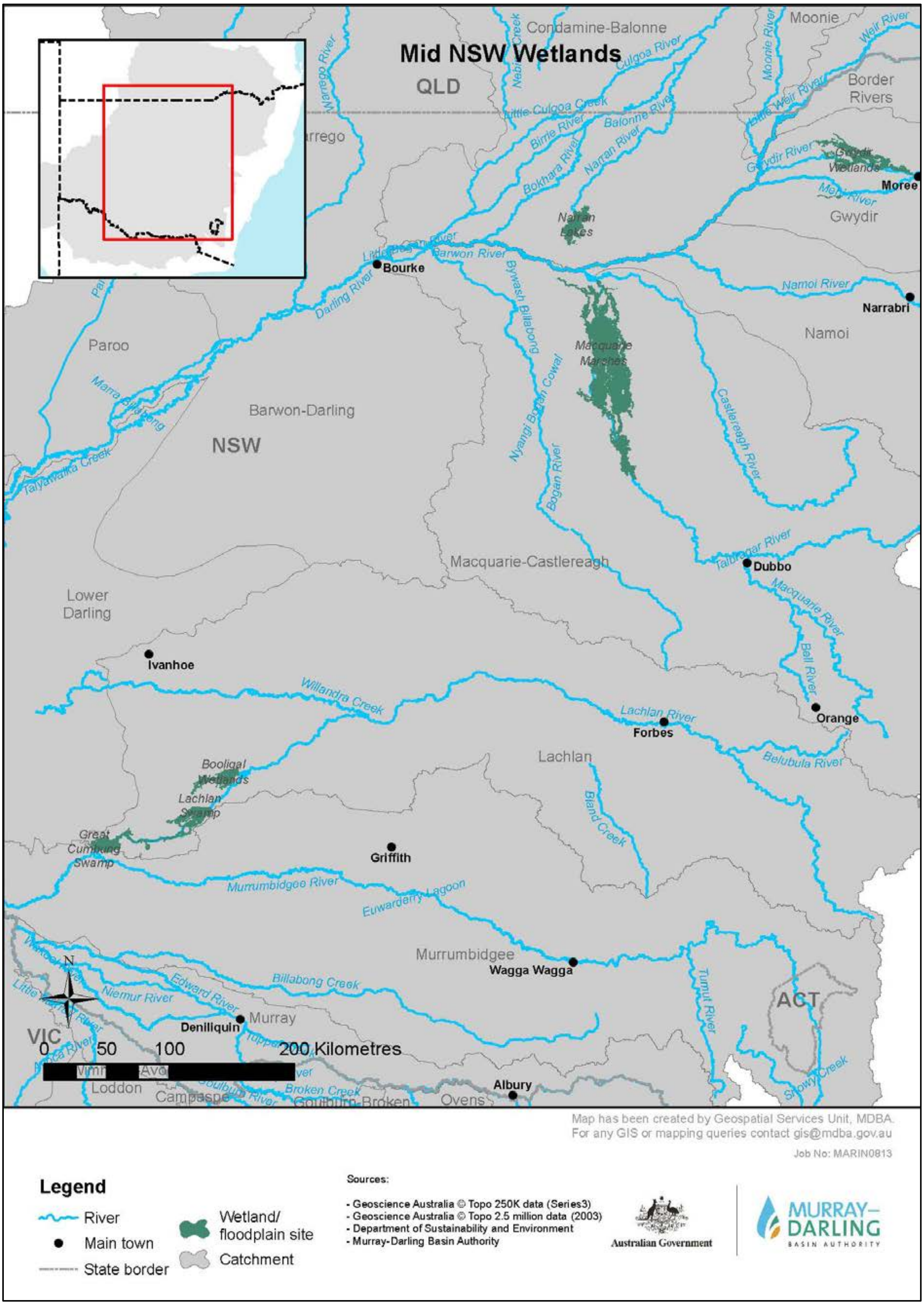

Figure 8: Map of the key wetland sites for waterbird breeding.

Three of the Lakes (Clear Lake, Back Lake and Long Arm) are part of the Narran Lakes Nature Reserve Ramsar site, which has areas of extensive, frequently available breeding and feeding habitat for numerous waterbird species. Ibis, spoonbills, cormorants, pelicans and several waterfowl species breed in fringing lignum with river cooba used for nesting and roosting by egrets, herons, spoonbills, cormorants and darters. Sixty-five species of waterbirds have been recorded in the Narran Lakes system of which 46 breed in the Lakes (Thoms et al. 2002).

The Narran Lakes system includes a variety of vegetation types including ecologically significant populations of sedges and ephemeral herbfields, lignum (*Muehlenbeckia florulenta*), reeds (*Phragmites australis*), river red gum (*Eucalyptus camaldulensis*), coolibah (*Eucalyptus coolabah*), black box (*Eucalyptus largiflorens*) and river cooba (*Acacia stenophylla*). These vegetation communities support the wide variety of birdlife, but are vulnerable to alteration in the frequency of flood events that result from water resource development in the upper catchment (Thoms et al. 2002).

There is a strong relationship between bird breeding events and inflows at Narran Lakes. Annual inflows to the Narran Lakes wetlands are highly variable with 85% of flooding occurring in summer and autumn (Smith 1993). All breeding events have occurred when annual flows in the Narran are in excess of 100,000 ML (MDBA 2012a). Rayburg and Thoms (2008) note that breeding events have historically occurred every two and half years.

There has been a substantial change in the hydrology of the Narran River as a result of water resource development in the Condamine-Balonne catchment. The level of water abstraction has reduced the median annual flow down the Narran River, reducing the frequency of small to medium flood events and changing the nature of the flood pulse into the Lakes (Thoms et al. 2002). This has reduced the opportunity for successful breeding events.

Implementation of the Priority

The Authority does not anticipate that environmental flows will be designed to stimulate waterbird breeding. Rather any watering activities to support waterbird breeding events in the Narran Lakes, Macquarie Marshes, Gwydir Wetlands and lower Lachlan wetlands would only be in response to a bird breeding event commencing naturally. If an event does occur water managers should determine if the event requires support by either extending or magnifying inundation to facilitate success.

Factors to be considered in deciding to provide water to support waterbird breeding events include:

- Antecedent conditions.
- Resource availability scenario (RAS).
- Timing of the event.
- Location and accessibility of breeding sites.
- Magnitude of the breeding event.
- The likely success of the breeding event and the extent to which river regulation and water extraction impacts this success.

The provision of environmental water to these wetland sites will also improve the ecosystem resilience of permanent and semi-permanent wetland vegetation and hence maintain and support waterbird habitat. Implementation of this Priority builds upon and complements the implementation of the *Gwydir Wetlands*, *Macquarie Marshes and lower Lachlan wetlands* Priorities. These Priorities hinge around a foundation of supporting ecosystem functioning in these wetlands encouraging the continued recovery of inundation dependent communities and hence support important breeding habitat for waterbirds in the Northern Basin. Reid et al. (2013) note that the provision of environmental flows to improve wetland health ensures breeding and population maintenance of colonial nesting waterbirds.

The key sites are discussed below.

Implementation in the Narran Lakes

The Authority notes the limited capacity under the present policy/legislative framework to actively manage held environmental water in the Condamine Balonne River. The Condamine Balonne River is largely unregulated by in-stream storages and environmental water entitlements are unable to be ordered from a publicly regulated water storage. Water entitlements are based on the ability to pump certain volumes in a range of unregulated flow events. Unregulated or unsupplemented water licences recovered by the Commonwealth in the Condamine Balonne have resulted in a greater proportion of certain flow events remaining in the river for environmental benefit as the environmental water is left in the river. These entitlements will contribute to connectivity and variability in the Narran River and assist in supporting vegetation condition and resilience in the Narran Lakes. However as these entitlements cannot be actively managed, they are of limited use in the support of bird breeding events.

Water may also be provided to the Narran Lakes through the provision of appropriate rules in water resource planning. Presently the Condamine Balonne Water Resource Plan contains rules to support bird breeding in Narran Lakes. These rules limit water extraction where a flow occurs which would be sufficient to fill Narran Lakes. However, this rule only applies in cooler months, which is generally not seasonally appropriate for birds breeding in Narran Lakes. Until the review of Water Resource Plans, there may be limited opportunities to deliver planned environmental flows to support bird breeding.

The Commonwealth and State Governments have explored several options for restoring natural flow variability and connectivity in unregulated systems to support bird breeding in Narran Lakes. For example, a breeding event was triggered in the Narran Lakes as a result of natural inundation for January 2008. This was the largest event at Narran Lakes for nine years and the most significant in the Murray-Darling Basin in that period. In March water levels started to recede. In order to prevent mass desertion of nests, the Murray-Darling Basin Commission purchased water from private storages which supported the event to completion (Cummins and Duggan 2009). It should be noted that such water management strategies require the support of river operators and the community to ensure the protection of recovered flows as they move through the system. Other water management strategies for improving ecological outcomes in unregulated systems are discussed in the *Barwon-Darling River* Priority.

It is likely that a bird breeding event may commence under a moderate to very wet RAS. However, it is possible that an unregulated event of sufficient magnitude may initiate a breeding event in a dry RAS. Water managers should consider options to support bird breeding events under moderate to very wet RAS, if the opportunity is presented.

Implementation in the Macquarie Marshes

The Macquarie Marshes supported substantial numbers of waterbirds in the 2010-11 and 2011-12, as a result of unregulated events and the supply of environmental water. In the 2010-11 event, held environmental water was critical to the success of the bird breeding event as unregulated flows started to recede midway through the breeding event. Held environmental water (contributed by both the NSW and Commonwealth governments) followed on from the unregulated flow maintaining flood levels until the fledging period.

It is likely that a bird breeding event may commence under a moderate to very wet RAS. Given the drying antecedent conditions, it is very unlikely that in a dry RAS, birds will commence breeding. In addition, during a dry RAS there is unlikely to be sufficient quantities of managed environmental water to support a large breeding event.

For further information on the Macquarie Marshes refer to the Macquarie Marshes Priority.

Implementation in the Gwydir Wetlands

The Gwydir Wetlands supported substantial numbers of waterbirds in 2011-12, as a result of unregulated events. NSW Environmental Contingency Allowance environmental water was critical to the success of the bird breeding event. As unregulated flows started to recede midway through the breeding event, deliveries of environmental water maintained flood levels until the fledging period.

It is likely that a bird breeding event may commence predominantly under a wet RAS, however there have been exceptions to this in the Gwydir when in 2005 a significant waterbird breeding event occurred under a dry RAS. Sufficient held environmental water is likely to be available to support a breeding event regardless of the RAS, however water managers would need to assess all variables (as listed above) when determining the capacity to support any breeding events.

For further information on the Gwydir Wetlands refer to the Gwydir Wetlands Priority.

Implementation in the lower Lachlan Wetlands

The lower Lachlan wetlands supported large-scale colonial waterbird breeding events in 2010-2011 at several sites as a result of unregulated flows and the supply of environmental water. These events produced 120,000 straw-necked ibis fledglings. There have been no recordings of large colonial bird breeding events since 2010-11 in the lower Lachlan wetlands). A large environmental watering event commenced in the lower Lachlan River in June 2013. This event is likely to promote suitable nesting and foraging habitat for waterbirds. Depending on further inflows, a waterbird breeding event may occur in spring 2013-14. Water managers should support such bird breeding events to their completion if environmental water holdings allow.

For further information on the lower Lachlan wetlands refer to the lower Lachlan wetlands Priority.

Priority 2 — Connecting rivers and floodplains: Gwydir Wetlands

Basin Annual Environmental Watering Priority

Improve the condition and maintain the extent of wetland vegetation communities in the Gwydir wetlands (including Ramsar sites) by restoring hydrological connectivity and a flow regime that meets ecological requirements.

Expected outcomes of this Priority

It is anticipated that the above Basin Annual Environmental Watering Priority (the Priority) will facilitate the following outcomes:

- Improve the condition and extent of permanent and semi-permanent wetland vegetation communities.
- Maintain habitat suitable for colonial waterbird breeding.
- Protect and restore endangered ecological communities.
- Contribute to restoration of the ecological character of the Ramsar sites.
- Promote lateral and longitudinal connectivity between wetland-floodplain-river.
- Enable growth, reproduction and recruitment for a diverse range of permanent and semi-permanent wetland vegetation.
- Maintain wetland refuges and adequate soil moisture in core wetland to allow rapid biotic response to water deliveries.
- Assist the recovery of marsh club rush and water couch to compete with invasive species such as *lippia*.

Why is this a Priority?

The Authority considers this Priority to be of Basin significance because:

- The Gwydir catchment consists of a mosaic of wetland types, ranging from semi-permanent marshes and waterholes to floodplain woodlands. These wetland types include nationally and internationally important wetlands.
- The Gwydir Wetlands are Ramsar listed and, are recognised as supporting:
    - Some of the largest waterbird breeding colonies recorded in Australia
    - Habitat for native fish (Murray cod)
    - Critically endangered ecological community (marsh club rush sedge land).
- There has been a reduction in the average annual volume of water entering the wetlands by 42% and an 85% reduction in the extent of wetland vegetation.
- Environmental water can be delivered to support the Priority, if physical and seasonal constraints are addressed. This will reconnect key habitat components of the Gwydir wetlands, promote longitudinal and lateral connectivity and support vegetation recovery and recruitment opportunities for a range of waterbird and native aquatic species.

Significance of site

The Gwydir catchment is in the north west of NSW. Copeton Dam was completed in 1976 on the Gwydir River and is the largest regulated water storage in the catchment. The dam supplies water to users on the Gwydir River (including the Mehi River, Carole Creek, Gil Gil Creek, and Moomin Creek) and replenishment flows to the Lower Gwydir, Gingham Watercourse and Mallowa Creek.

The Gwydir Wetlands lie in the downstream reaches of the Gwydir River, west of Moree in Northern NSW (Figure 9). The wetlands consist of a mosaic of wetland types, ranging from semi-permanent marshes and waterholes to floodplain woodlands. These wetland types include nationally and internationally important wetlands with 4 sites listed as internationally significant under the Ramsar Convention. Three of these sites are privately owned and the largest has been declared a Nature Reserve and is managed by the NSW Government.

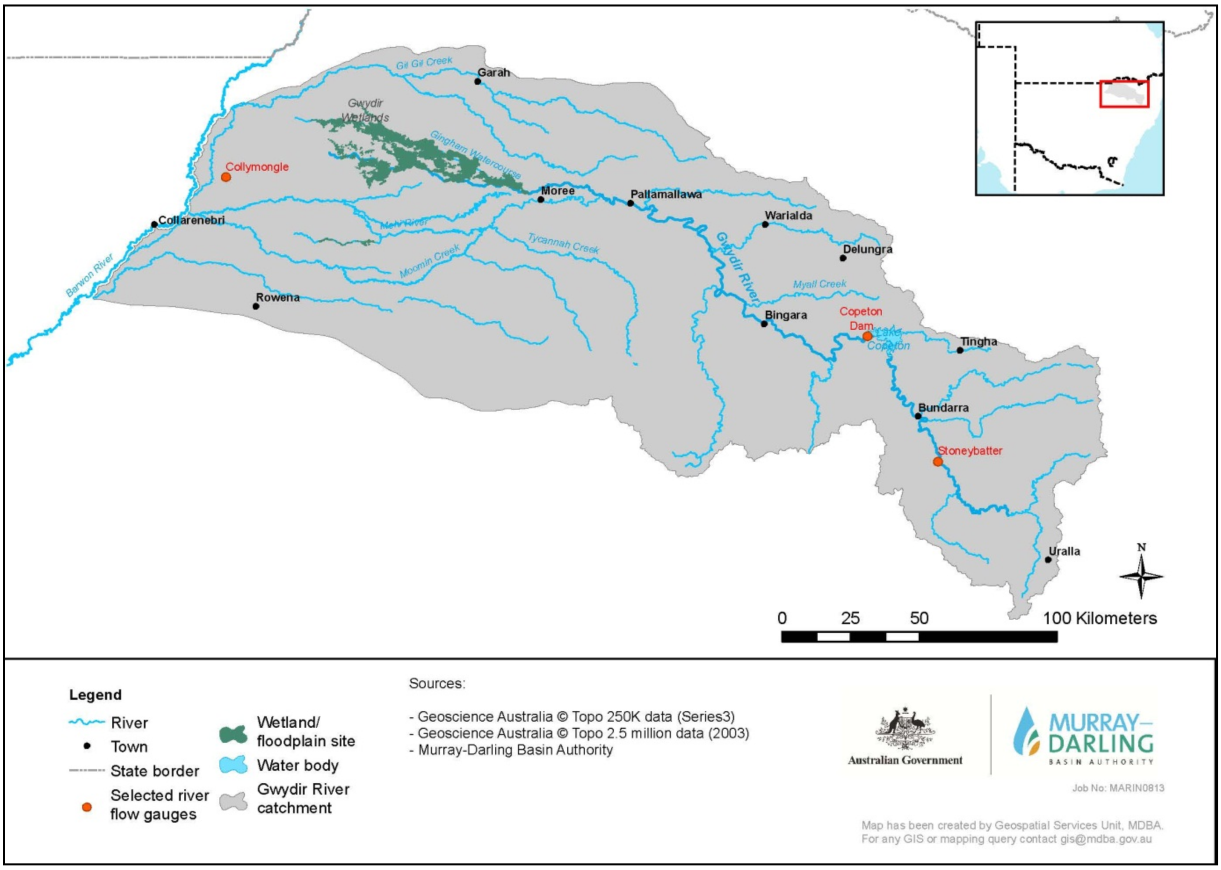

Figure 9: Map of the Gwydir catchment

The Gwydir Wetlands are a major site for waterbird breeding in Australia (Morse 1922; McCosker 1996). They are recognised as a refuge for waterbirds in dry times, and for supporting some of the largest waterbird breeding colonies recorded in Australia (Green and Bennett 1991). There have been 75 waterbird species recorded in the Gwydir Wetlands (Spencer 2010). They include species listed as threatened both in NSW and nationally, and species listed on the JAMBA, CAMBA and ROKAMBA migratory bird agreements (Spencer 2010). Records of major breeding events date back to the 1920's when the Gwydir Wetlands were thought to hold the largest heronry in NSW with hundreds of thousands of breeding birds (Morse 1922). A separate Priority supports bird breeding events in the Gwydir and other northern Basin wetlands.

The Gwydir Wetlands provide critical habitat for native fish. Surveys conducted in 2007 and 2008 recorded 11 species of native fish (including Murray cod *Maccullochella peelii peelii*) (Spencer 2010).

The Gwydir Wetlands are also notable for having one of the largest known stands of the wetland plant marsh club rush (*Bolboschoenus flubiatilis*) in NSW (Green and Bennett 1991; McCosker and Duggin 1993). The marsh club rush sedgeland is currently listed as a Critically Endangered Ecological Community under the NSW Threatened Species Conservation Act (1995).

Condition of environmental assets and functions

From 2010 to 2013, the Northern Basin experienced a series of floods after receiving significantly more than average rainfall. Unregulated flows inundated large areas of the Gwydir Wetlands and only small scale deliveries of Commonwealth and NSW held environmental were required to core wetland areas. These flows resulted in some recovery of wetland and floodplain vegetation, and supported large numbers of colonial nesting waterbirds (predominantly ibis and egrets) to breed in the Wetlands. However, wetland and floodplain communities continue to recover from disturbances experienced over the previous decades including severe drought and habitat loss.

The flow regime in the Gwydir catchment has been significantly altered by river regulation and increased water consumption. There has been an increase of 75% in the average period between flood events and a 64% increase in the maximum period between events (a rise from 7 to 11.5 years). The reduction in frequency means that the average annual flooding volume has been reduced by 42 % (CSIRO 2007a). These changes are consistent with the stressed ecological condition of the wetlands (CSIRO 2007a).

Historically, the Gwydir wetlands covered an area of around 220,000 hectares (Green and Bennett 1991). However within the Lower Gwydir and Gingham Channel, the extensive drought, changed water regime and changed land use have reduced the area of the wetlands by 85% (Bowen and Simpson 2009). From 1997 to 2011 the area of land opportunistically cropped in the Gwydir Wetlands is estimated to have increased by more than 70,000 hectares (EcoLogical 2012). Consequently there has been significant decline of both semi-permanent and floodplain wetland within the Gingham and Lower Gwydir Watercourses (Bowen and Simpson 2009). Figures 10 and 11 demonstrate the change in native vegetation extent between 1996 and 2008.

Loss of connection and flow paths

Remnant wetland areas are now largely fragmented by areas of land developed for cultivation. The encroachment of dry land cropping and other intensive agriculture in the Gwydir wetlands has reduced wetland habitat and affected connectivity by limiting the movement of floodwaters throughout the system. Many of the cropped areas are in and around flow paths and in some instances are protected by flood levee banks which affect water distribution. The loss of wetland habitat and changes to flow distribution threatens both the ecological values and functioning of the Gwydir Wetlands.

Given the recent historical reduction in the extent of the Gwydir wetlands there is a significant risk of further loss of the wetlands if flood pathways and more natural flow regimes are not maintained or reinstated. The trend of conversion of native vegetation to opportunistic cropping is a significant threat to the ecological functioning of these wetland systems.

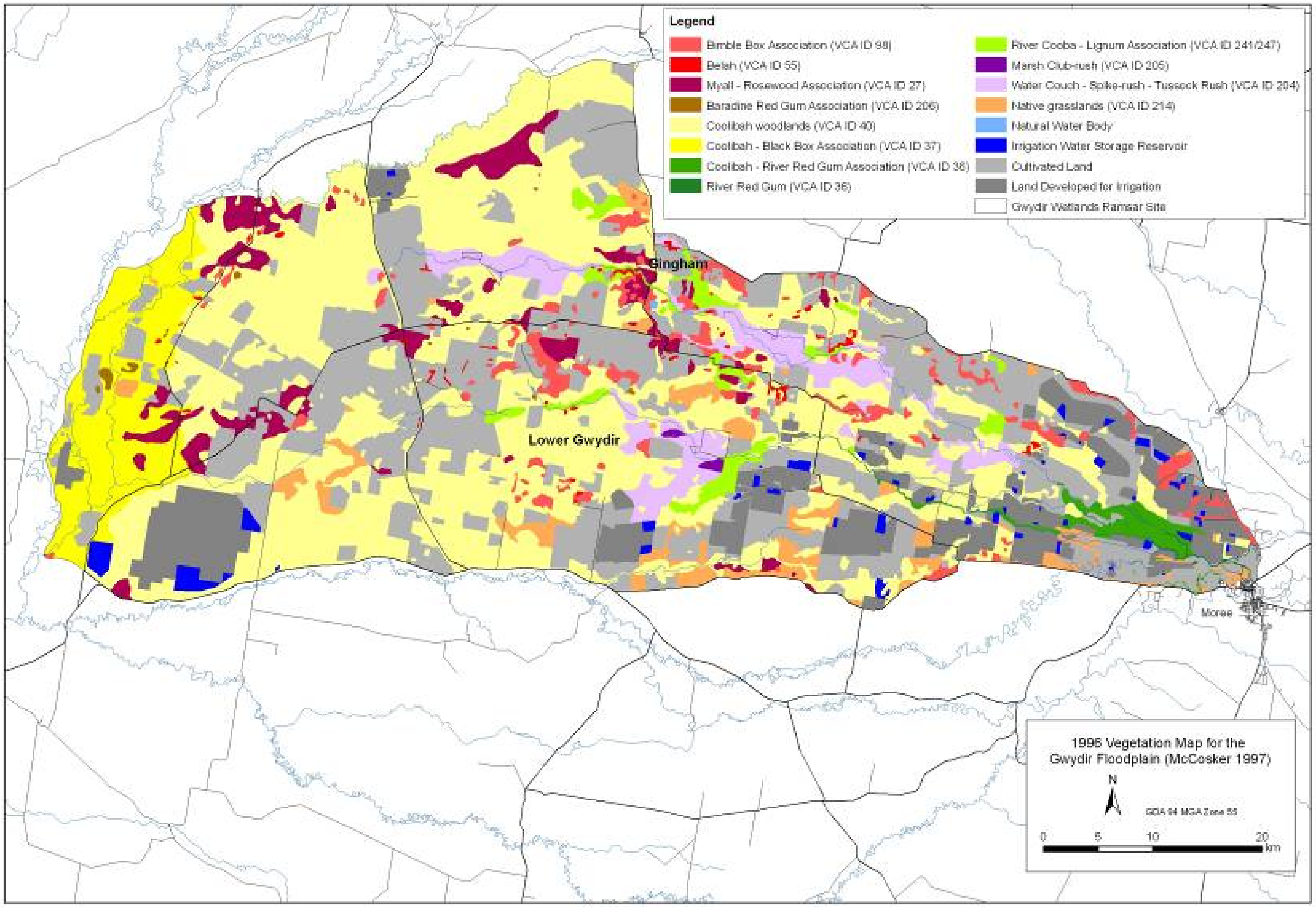

Figure 10: Native vegetation map 1996 (Bowen and Simpson 2009)

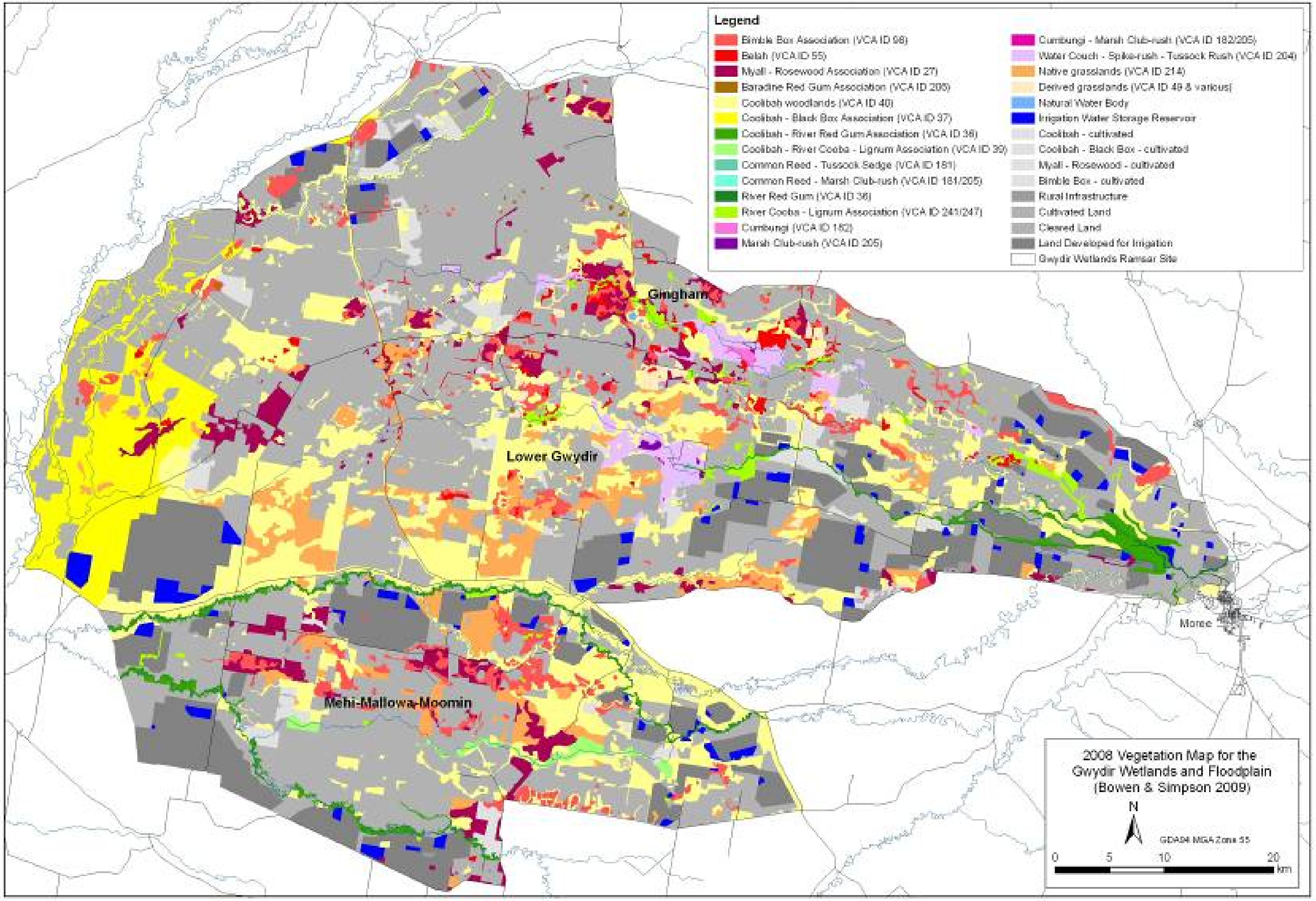

Figure 11: Native vegetation map 2008 (Bowen and Simpson 2009)

Matters of Interest

Natural flow regimes

Natural timing for inundation of the Gwydir Wetlands is linked to rainfall in the upper catchment. November to March and June to July are the main periods of flooding (NSW DECCW 2011; EcoLogical 2012). Increased wetland plant growth is seen during spring-summer floods with warm moist soils providing optimal conditions for germination and seed growth. Winter floods are important for replenishing soil moisture and establishing suitable conditions for plant growth in the warmer months (CEWO 2012a).

Late-winter and spring floods also enable adult fish to feed and grow before they spawn (Humphries et al. 2002). Native fish species in the Gwydir Wetlands and Lower Gwydir River typically spawn during spring and early summer associated with an increase in flow and temperatures (Spencer 2010; NSW DECCW 2011). Flows that target in-channel habitat in September to October coincide with the smaller spawning 'window' (water temperature related) of Murray cod and freshwater catfish (*Tandanus tandanus*); larvae and juveniles of these species have been recorded in fish surveys in late September-early October in northern Basin valleys (Wilson et al. 2009).

Presently in the Gwydir there are limitations on environmental watering in the winter cropping season between April and December (EcoLogical 2013). Limiting the seasonality of environmental watering presents challenges to supporting the ecological assets and functions.

Implementation of the Priority

Restoring connectivity and natural flow regimes in the Gwydir catchment is critical to improving the condition and extent of permanent and semi-permanent wetland vegetation communities. This Priority may be met with water from a variety of sources used in combination. The provision of held environmental water in combination with small to moderate unregulated base flows and freshes would support the natural inundation of floodplains and wetlands, promote connectivity between wetlands, support vegetation recovery and recruitment opportunities for a range of waterbird and native aquatic species.

Several categories of environmental water are available in the Gwydir Valley. The Water Sharing Plan provides for a 45 GL environmental contingency allowance used to support the wetlands and waterbird breeding events. In addition the Commonwealth and NSW government together hold 127 GL of regulated environmental water in entitlements. The Gwydir Wetlands receive unregulated flows from tributaries downstream of Copeton Dam under the Water Sharing Plan for the Gwydir Regulated River Water Source.

As inundation of the Gwydir Wetlands is linked to rainfall in the upper catchment, the provision of environmental water could be delivered in response to natural cues (See Guiding Philosophy – *Deliver water in response to natural cues*). The Resource Availability Scenario (RAS) will change over the course of 2013–14 as the season progresses and new allocation announcements are made. Likewise, the scale of connectivity and inundation will vary through the different inflow scenarios.

Due to the relatively large amount of carryover of environmental water allocation in 2013-14, the Gwydir Priority is relevant in all RAS. In wet to very wet scenarios, unregulated flow will achieve the Priority. In dry to moderate scenarios a combination of unregulated flow and held environmental water can be delivered to contribute to achieving the Priority. This could include supporting the post drought recovery of core wetland vegetation communities which commenced in late 2010, so that aquatic flora and fauna can increase their chances of persisting through any future consecutive dry scenarios. In very dry inflows a drying scenario may be indicated, and environmental water managers may choose not to deliver held environmental water.

A factor influencing the capacity of held environmental water to meet this Priority is that during periods of peak demand consumptive orders may dominate available channel capacity which can limit the ability of held environmental water to contribute to the objectives of the Priority.

Maximising Outcomes

Re-establishing natural flow paths is necessary to reconnect important habitat of the Gwydir wetlands. There are presently barriers to restoring connectivity and a flow regime that meets ecological requirements in the Gwydir. This will require close cooperation with individual landholders to understand the opportunities and constraints at a property level.

As required by the Basin Plan, the Authority is currently developing a Constraints Management Strategy in consultation with Basin states and the public. The strategy to be completed in 2013, will identify constraints throughout the basin, including within the Gwydir catchment, which restrict the delivery of environmental water. The strategy will make recommendations for the remediation of key constraints, including the identification of mechanisms to mitigate any third party impacts.

To the extent that constraints on the management of held environmental water can be resolved, river operators and environmental water holders/managers will have opportunities to increase the range of outcomes targeted under this Priority and improve the condition of these wetlands in the future.

Priority 3 — Connecting rivers and floodplains: Macquarie Marshes

Basin Annual Environmental Watering Priority

Improve ecosystem resilience amongst wetland vegetation communities in the Macquarie Marshes including Ramsar listed sites

Expected outcomes of this Priority

It is anticipated that the above Basin Annual Environmental Watering Priority (the Priority) will facilitate the following outcomes:

- Improve the condition and extent of permanent and semi-permanent wetland vegetation communities.
- Maintain habitat suitable for colonial waterbird breeding.
- Improve the ecological character of Macquarie Marshes Ramsar sites.
- Enable growth, reproduction and recruitment for a diverse range of permanent and semi-permanent wetland vegetation.
- Support continued drought recovery of semi-permanent vegetation communities.
- Assist the recovery of permanent wetland communities to compete with invasive species such as *Lippia*.
- Support mobilisation, transport and dispersal of biotic and abiotic material (e.g. sediment, nutrients and organic matter) through lateral connectivity between the floodplain and river channel and connectivity through the length of the Marshes.

Why is this a Priority?

The Authority considers this a Priority to be of Basin significance because:

- The Macquarie Marshes are recognised as a wetland site of international significance both in terms of size and diversity of wetland vegetation types. It provides important refuges for water birds during dry times as well as supporting very large colonial bird breeding events in wetter times.
- The condition of permanent and semi-permanent wetland vegetation was significantly impacted by the millennium drought. The subsequent wet years provided an opportunity to commence recovery.
- The below average rainfall experienced in New South Wales over the past 12 months has resulted in the Macquarie Marshes drying out. Water is required in the permanent wetland communities to promote continued recovery and resilience of this area.

Significance of site

The Macquarie Marshes are located in the lower reaches of the Macquarie River in central west New South Wales, and stretch north of the township of Warren (Figure 12). They cover approximately 200,000 hectares, and form one of the largest freshwater wetlands in the Murray-Darling Basin. The system contains a variety of wetland types, ranging from semi-permanent wetlands which require frequent inundation through to ephemeral wetlands inundated by only the largest floods (NSW OEH 2013a).

The Macquarie Marshes are rare in terms of both size and diversity of wetland types (NSW DECC 2009). Most of the Macquarie Marshes are privately owned, with the exception of approximately 21,000 hectares which is listed as Nature Reserve and managed by the NSW National Parks and Wildlife Service. Part of the Macquarie Marshes are listed as a wetland of international importance under the Ramsar convention.

The Macquarie Marshes have long been regarded as an important refuge for waterbirds during dry times, as well as supporting some of Australia's largest recorded waterbird breeding colonies (Kingsford and Auld 2005). Most breeding sites are located in semi-permanent wetland vegetation and river red gum forest and woodland. The Macquarie Marshes also provide habitat for migratory wading birds listed under CAMBA, JAMBA and Bonn convention (Kingsford and Auld 2005) including the eastern great egret (*Ardea modesta*), glossy ibis (*Plegadis falcinellus*), Latham's snipe (*Gallinago hardwickii*, and the cattle egret (*Ardea ibis*).

The Macquarie Marshes support a variety of flood-dependent vegetation types that include extensive water couch (*Paspalum distichum*) and common reed (*Phragmites australis*) grassland. They support regionally important areas of river red gum (*Eucalyptus camaldulensis*) forest and woodland. These vegetation communities provide habitat for 15 frog species and 77 waterbird species including the nationally vulnerable Australian painted snipe (*Rostratula australis*) and superb parrot (*Polytelis swainsonii*) (NSW OEH 2013a). Forty-two species of waterbird have been recorded breeding in the Macquarie Marshes.

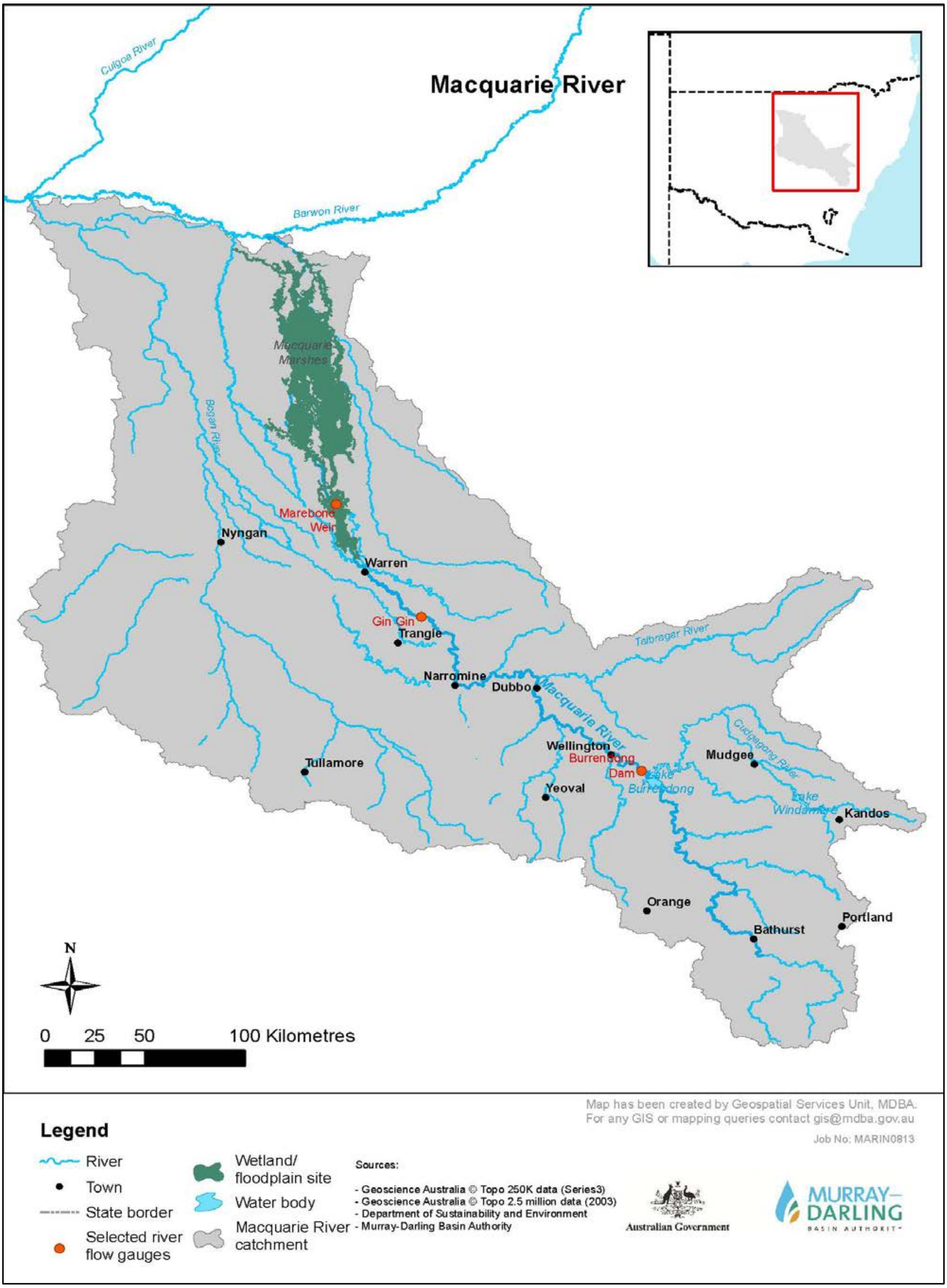

Figure 12: Macquarie catchment outlining the Macquarie Marshes

Condition of environmental assets and functions

The condition of the Macquarie Marshes has been declining for decades (NSW DECCW 2010a). Vegetation mapping undertaken in 2008 (Bowen and Simpson 2010) demonstrated significant areas of wetland vegetation in poor condition and the large loss of semi-permanent and permanent wetland vegetation communities. Many areas of river red gum demonstrated a substantial decline in canopy condition, with more than half the area showing more than 40% dead canopy and a considerable increase in chenopod (dryland) understory (Bowen and Simpson 2010). In 2009, the Ramsar listed sites were the subject of an Article 3.2 notification under the Ramsar Convention as being likely to have undergone a fundamental change in their ecological character as a result of an altered flooding regime (NSW OEH 2013a).

A combination of natural flooding and managed environmental water releases between 2010 and 2013 has resulted in large inflows to the Macquarie Marshes, and inundation of permanent and semi-permanent wetland vegetation. Wetland managers consider the Macquarie Marshes to be showing signs of recovery (NSW OEH 2012a). It was noted that ongoing recovery will depend on sufficient water being available to ensure protracted drying can be avoided and the water needs of dependent vegetation can be met (NSW OEH 2012a).

Matters of interest

Wetland community water requirements

In the Macquarie Marshes flooding is the primary source of water for the permanent and semi-permanent vegetation communities. There is a close association between the health of mature red gum trees, the establishment of seedlings, and the duration, frequency and timing of floods (Armstrong et al. 2009).

Large-scale seedling establishment tends to be in response to major floods, and results in large areas with trees of a similar age (Roberts and Marston 2011). Field observations in the Macquarie Marshes indicate river red gum communities in these systems deposited large volumes of seed during the major floods of 2010-2012, with many seeds having now germinated and developed into seedlings. Seedling establishment is the critical life history phase of river red gums (Roberts & Marston 2011). A follow-up flood event for river red gum seedlings in these systems in 2013-14 would be highly desirable to support the resilience of river red gum woodland and forest.

Permanent and semi-permanent wetland vegetation communities require regular, frequent and prolonged flooding. Open water, reed and water couch communities require watering every year or two, hence continued watering in 2013-14 will be important to build resilience in these communities. The MDBA (2012b) analysis used to develop the Basin Plan Environmental Water Requirements for the Macquarie Marshes outlines a number of hydrological indicators which have been most impacted by water resource development and which will be conducive to improving ecological outcomes. These requirements include the provision of 100 GL in 80% of years.

In the past 12 months, central New South Wales has experienced below average rainfall. As a result the Macquarie Marshes have experienced a drying phase (D. Love pers. comm. May 2013). Follow-up flooding is required particularly in permanent wetland communities to promote continued recovery in the Macquarie Marshes.

Implementation of the Priority

Within the Macquarie catchment, large volumes of environmental water were delivered throughout 2012-13 for the purposes of the restoration of the Macquarie Marshes. Approximately 120 GL of managed environmental water will be carried over into 2013-14. Due to the influence of carryover, it is anticipated that the Priority could be met across the full range of Resource Availability Scenarios (RAS). However, the scale of a watering event will vary with the RAS. In a very dry or dry scenario there will be limited opportunities to combine managed environmental water with unregulated events, hence the extent of inundation will be less, and river red gum communities are unlikely to be inundated. In these scenarios it is anticipated that core permanent wetland communities will be targeted with managed flows. In moderate and wet scenarios there will be a greater capacity to combine held environmental water with an unregulated event, which will increase the capacity of water managers to target a broader range of wetland communities including river red gums.

Flows from the Macquarie River have been identified as an important contributor to environmental outcomes in the Barwon-Darling River, and as such outcomes within the Macquarie Marshes should also be considered in conjunction with other Priorities and potential outcomes in the Barwon-Darling.

Priority 4 — Connecting rivers and floodplains: lower Lachlan wetlands

Basin Annual Environmental Watering Priority

Improve ecosystem resilience amongst wetland vegetation communities in the lower Lachlan wetlands

Note: For the purposes of this Basin Annual Environmental Watering Priority (the Priority) any wetland and floodplain assets downstream of Lake Brewster may be considered as part of the lower Lachlan wetlands.

Expected outcomes of this Priority

It is anticipated that the above Priority will facilitate the following outcomes:

- Maintain and improve the health of native riparian, floodplain and wetland vegetation communities by providing opportunities for growth and recruitment.
- Support mobilisation, transport and dispersal of biotic and abiotic material (e.g. sediment, nutrients and organic matter) through lateral connectivity between the floodplain and river channel.
- Maintain habitat suitable for colonial waterbird breeding.
- Support native vegetation communities' recovery from drought.

Why is this a Priority?

Although the Lachlan system is largely disconnected from other major rivers in terms of surface-water flow, it nonetheless provides an important ecological link with adjoining catchments and the overall Basin. The Authority considers this Priority to be of Basin significance because:

- The Lachlan Catchment supports approximately 470,000 ha of wetlands including key sites such as Booligal wetlands, Lachlan Swamp and the Great Cumbung Swamp.
- Following limited rainfall in the past year, wetland vegetation communities in the lower Lachlan are in need of watering in order to capitalise on the improvement in their condition after the 2010-12 floods.
- Maintaining and improving vegetation condition in the lower Lachlan wetlands serves to provide vital habitat for colonial nesting waterbirds.

Significance of site

The Lachlan River is approximately 1,450 km long, flowing west from the Great Dividing Range near Gunning through to the wetland system of the Great Cumbung Swamp near Oxley in New South Wales (Figure 13). The Lachlan Catchment supports approximately 470,000 ha of wetlands, most of which are located on the lower Lachlan floodplain including key sites such as Booligal wetlands, Lachlan Swamp and the Great Cumbung Swamp (Armstrong et al. 2009b). These three sites are each listed as nationally significant in the *Directory of important wetlands in Australia* (Environment Australia (2001)

The lower Lachlan wetlands contain an extensive range of native riparian, floodplain and wetland vegetation including river red gum (*Eucalyptus camaldulensis*), black box (*Eucalyptus largiflorens*) and river cooba (*Acacia stenophylla*) communities (LRWG 2010). The wetlands of this region provide valuable habitat for native fish and frogs, and have the capacity to support large-scale colonial waterbird breeding events (>40,000 nests) (LRWG 2010).

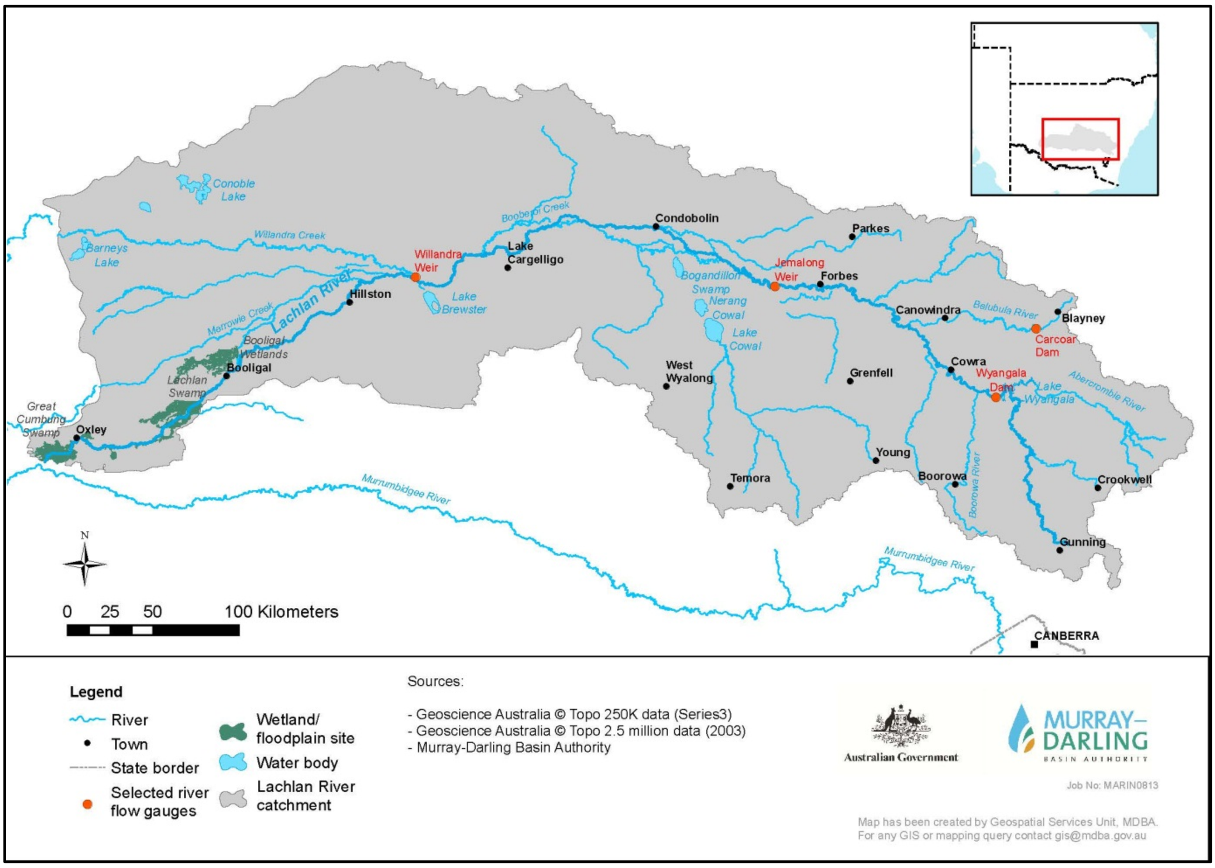

Figure 13: Map of the Lachlan catchment

Condition of environmental assets and functions

The millennium drought caused significant impacts on the health and composition of vegetation communities in the lower Lachlan wetlands. In particular, large areas of river red gums became extremely stressed and extensive tree deaths were recorded (NSW DECCW 2010b). The drought was broken in the summer of 2010-11 by the fifth wettest summer on record in NSW (BOM 2011).

From 2010-11 to mid-2012, wetland and riverine assets in the lower Lachlan catchment all experienced two or more episodes of substantial extent and duration of inundation (NSW OEH 2012b). Wetland vegetation communities that were previously suffering from a marked decline are now demonstrating early signs of recovery (P. Packard pers. comm. 26 February 2013). However, the condition of individual sites continues to vary significantly (NSW OEH 2013b; Driver et al. 2013).

Since the last significant rainfall event in March 2012, central New South Wales – like much of the Basin – has experienced below average rainfall. As a result the soil profile throughout the lower Lachlan catchment has dried considerably (P. Packard pers. comm. 26 February 2013). Follow-up flooding is needed in some areas to promote continued recovery in this system.

Matters of Interest

River red gum recruitment

Flooding is the primary source of water for river red gums, and there is a close association between the health of mature red gum trees, the establishment of seedlings, and the duration, frequency and timing of floods (Armstrong et al. 2009). Roberts and Marston (2011) indicate that optimal growth of river red gum forest requires an inundation frequency of between one to three years, whilst river red gum woodland requires inundation every two to four years.

Large-scale seedling establishment tends to be in response to major floods, and results in large areas with trees of a similar age (Roberts & Marston 2011). Field observations in the lower Lachlan catchment indicate river red gum communities in this system deposited large volumes of seed during the major floods of 2010-2012, with many seeds having now germinated and developed into seedlings (P. Packard pers. comm. 26 February 2013).

Seedling establishment is the critical life history phase of river red gums (Roberts & Marston 2011). Inundation of river red gum seedlings in this system in 2013-14 would be highly desirable to recharge soil moisture and promote their ongoing survival.

Colonial bird breeding

The lower Lachlan wetlands have been recognised as providing important habitat for large-scale colonial waterbird breeding within the Murray-Darling Basin (LRWG 2013). The wetland vegetation outcomes identified within this Priority are intrinsically linked with the colonial waterbird breeding outcomes outlined within the *Waterbirds Priority*.

Implementation of the Priority

Whilst the above section provides details on the inundation requirements of river red gums, the aim of this Priority is to build resilience amongst wetland vegetation communities throughout the lower Lachlan system more generally. By delivering environmental water to the lower Lachlan, it is also anticipated that additional in-stream benefits will be achieved along the broader Lachlan River channel.

At the time of writing in June 2013, the Commonwealth Environmental Water Office and NSW Office of Environment and Heritage were soon to commence a large environmental watering action in the Lachlan River targeting the environmental water needs identified in this Priority. The extended travel times for water spreading through parts of the lower Lachlan wetlands means that this event will straddle both the 2012-2013 and 2013-14 water years (NSW OEH 2013b). The Authority notes that this watering event is consistent with the lower Lachlan wetlands Priority for 2013-14.

This Priority is likely to be achievable regardless of the prevailing Resource Availability Scenario (RAS) in the coming year. If a wet scenario eventuates early on in the water year, environmental water could be managed to increase the overall duration of flows to the lower Lachlan wetlands. A wet scenario in 2013-14 may also trigger a colonial bird breeding event in the lower Lachlan that environmental water holders and managers may support subject to water resource availability (see *Waterbirds Priority*). Under a dry scenario the large environmental watering action commenced in June 2013 will be completed as planned. Beyond this there may be limited opportunities to provide overbank flows to the lower Lachlan wetlands through the remainder of the water year.

Priority 5 — Connecting rivers and floodplains: Mid-Murrumbidgee Wetlands

Basin Annual Environmental Watering Priority

Improve the condition of wetland vegetation communities in the mid-Murrumbidgee wetlands through a winter or spring fresh.

Expected outcomes of this Priority

It is anticipated that the above Basin Annual Environmental Watering Priority (the Priority) will facilitate the following outcomes:

- Maintain and improve the health of inundation dependent vegetation communities by providing opportunities for growth and recruitment.
- Support mobilisation, transport and dispersal of biotic and abiotic material (e.g. sediment, nutrients and organic matter) through lateral connectivity between the low-lying floodplain wetlands and the Murrumbidgee River channel.
- Support native vegetation communities' recovery from drought.
- Increase habitat for fish, frogs, birds and turtles.

Why is this a Priority?

The Authority considers this Priority to be of Basin significance because:

- The mid-Murrumbidgee wetlands contribute to the ecological functioning of the second longest river in the Basin. The wetlands are particularly important to the reach of river between Wagga Wagga and Hay, where they collectively represent almost all of the floodplain assets that can still connect to the Murrumbidgee River in that reach.
- The wetlands provide important habitat for rare and threatened species as well as migratory bird species listed under international agreements including Japan-Australia Migratory Bird Agreement, China-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement and the Bonn Convention.
- The condition of the wetlands suffered greatly during the drought, and, despite improvement due to recent watering events, is still in a recovery phase. Watering in 2013-14 is important to assist with recovery and build resilience of inundation dependent vegetation communities to help ensure they can withstand future droughts and provide refuge habitat.

Significance of the site

The mid-Murrumbidgee wetlands are an assemblage of lagoons and billabongs located on the floodplain of the Murrumbidgee River between Wagga Wagga and Carrathool (Figure 14). The mid-Murrumbidgee wetlands are good examples of inland river and lagoon wetlands of which a selection is listed in *the Directory of Important Wetlands of Australia* (Environment Australia 2001). These wetlands support the functioning of the Murrumbidgee River, the second longest River in the Murray-Darling Basin, by providing an important input of carbon and nutrients as well as important habitat for fish, frogs, turtles and birds.

The mid-Murrumbidgee wetlands support many rare and threatened fauna species including the Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act) listed endangered trout cod (*Maccullochella macquariensis*), the vulnerable southern bell frog (*Litoria raniformis*) and numerous bird species. The wetlands also support internationally listed migratory species such as the cattle egret (*Ardea ibis*), eastern great egret (*Ardea modesta*), glossy ibis (*Plegadis falcinellus*), Latham's snipe (*Gallinago hardwickii*) and the white-bellied sea-eagle (*Haliaeetus leucogaster*) (MDBA 2010c).

Condition of environmental assets and functions

As demonstrated in Figure 15, the Murrumbidgee River went through an extended period of low flows between the years 2000 and 2010, resulting in minimal lateral connectivity between the mid-Murrumbidgee wetlands and the Murrumbidgee River. The critical threshold for connection for a number of low-lying wetlands is a flow of 26,850 ML/day at Narrandera, with many more wetlands requiring larger flows to be connected. Figure 15 demonstrates that a large proportion of mid-Murrumbidgee wetlands did not naturally connect with the Murrumbidgee River throughout the period 2000-2010, with only a small number connecting in 2005. The prolonged period of low flows was followed up in 2010/11 and 2012 by consecutive years of high flows, resulting in widespread inundation and lateral connectivity.

In 2009, after many years of low flows, the condition of the mid-Murrumbidgee wetlands was considered critical and declining (SKM 2011). While the subsequent high flow events improved the condition of the wetlands, they are still in a recovery phase (Wassens et al. 2012). Aquatic vegetation cover in the mid-Murrumbidgee wetlands is still relatively low compared to 2000-2004 levels. Recovery is particularly slow within wetlands which have experienced an extensive dry period such as those wetlands which remained dry between 2000 and 2010 (Wassens et al. 2012).

Under modelled 'without development' conditions, wetlands with commence to flow rates of 26,850 ML/day would have a maximum dry period of 5 years (MDBA 2012c). However the majority of these wetlands experienced 10 years without inundation. To assist in the recovery of the wetlands it is important to build upon recent high flows to build resilience in these wetlands and ensure they can withstand future droughts and provide refuge habitat.

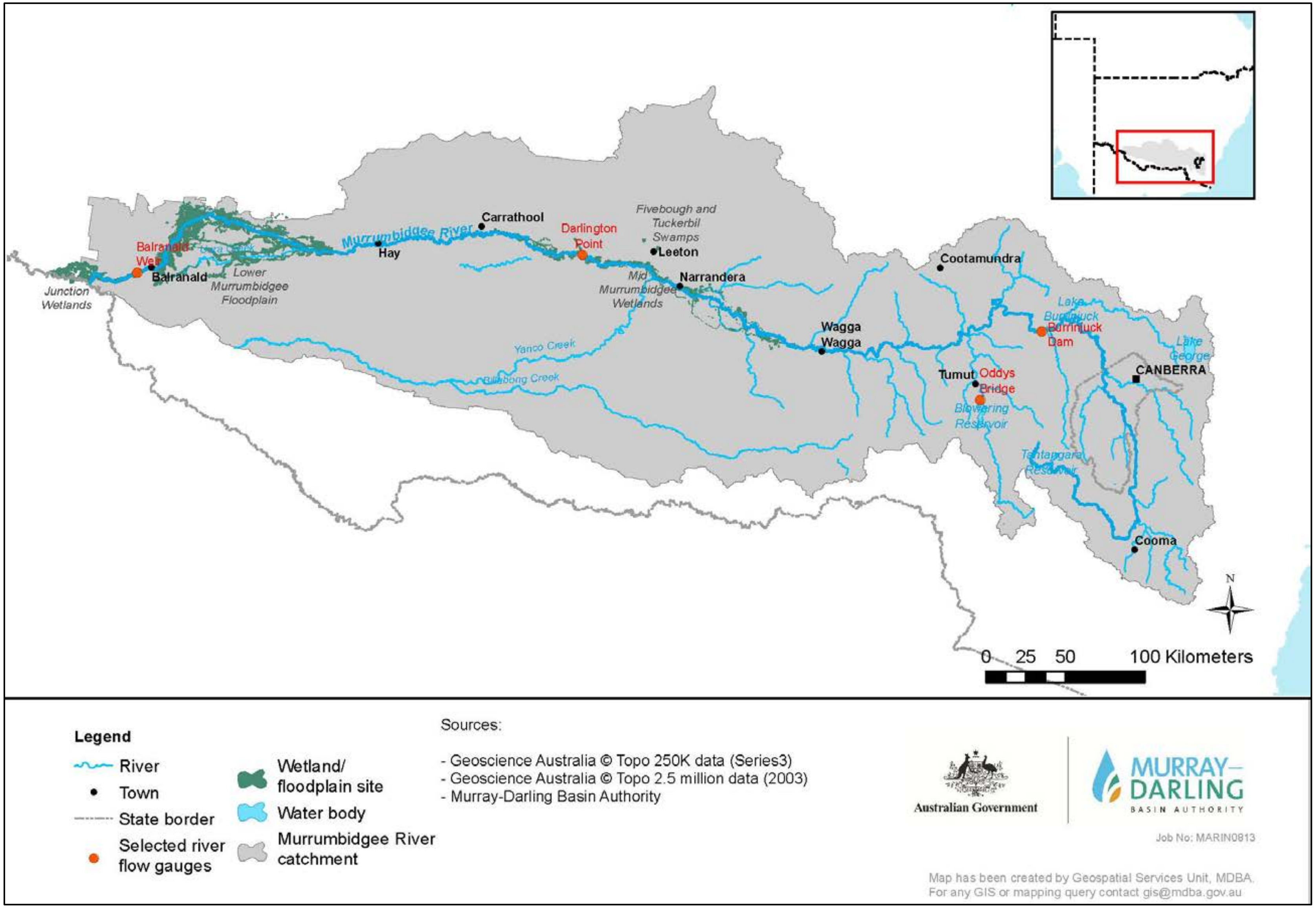

Figure 14. Map of the Murrumbidgee Catchment

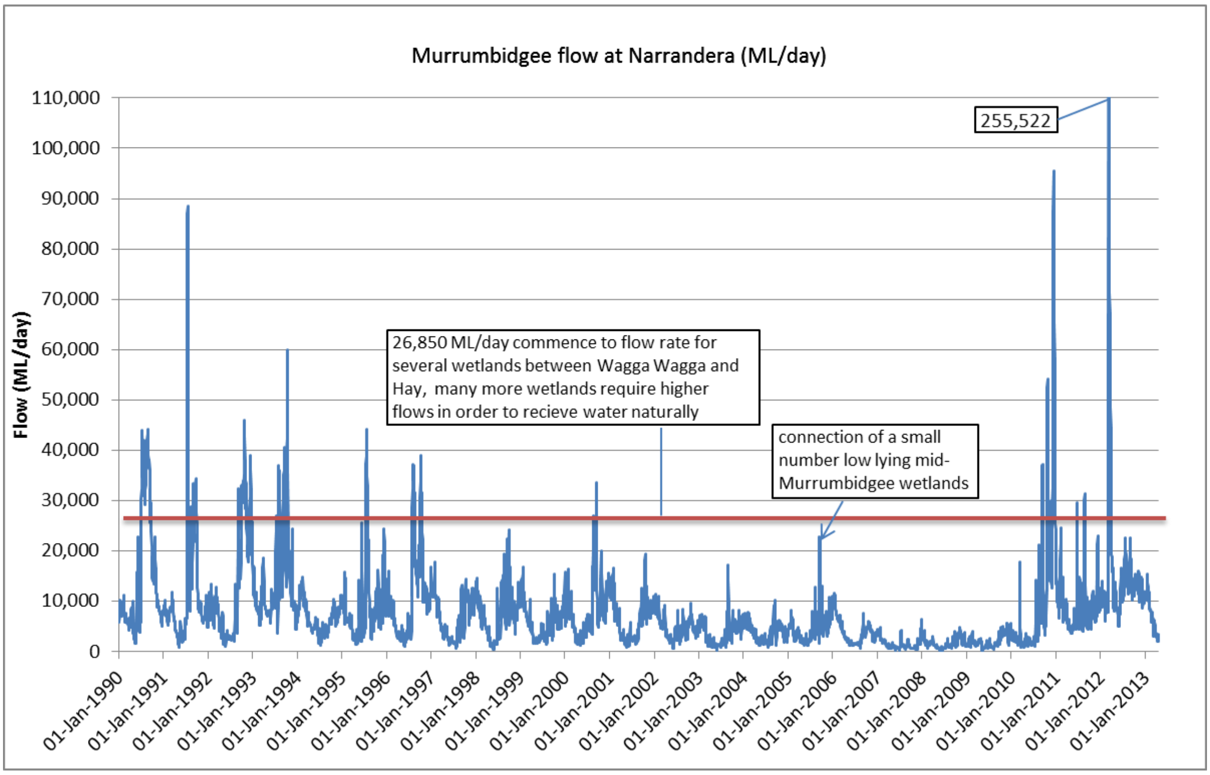

Figure 15. Flow rates of the Murrumbidgee River at Narrandera from 1990 to April 2013, showing one of the critical thresholds for inundation of mid-Murrumbidgee wetlands as specified in the Assessment of environmental water requirements for the proposed Basin Plan: Mid-Murrumbidgee River Wetlands (MDBA 2012d).(note: the flow rate of 26,850 ML/day gives an indication of when many wetlands begin to receive water, the rating table for Narrandera is currently under review and likely to change as such the flow rate required to fill wetlands may change)

Matters of interest

Aquatic vegetation

Slow recovery of the aquatic vegetation in the mid-Murrumbidgee wetlands is an important consideration. Healthy and diverse aquatic vegetation helps maintain water quality and provides important habitat for waterbirds and frogs including, the ‘vulnerable’ southern bell frog. The long-term persistence of aquatic vegetation is dependent on the maintenance of a viable seed bank, which can be affected by:

- Time since the seed bank was last replenished. The viability of seed declines over time (Casanova and Brock 2000), with seed banks progressively depleting if the wetland remains dry for longer than about six years (Roberts and Marston 2011). The replenishment of the seed bank can be influenced by:
    - Watering and the hydrologic pathways for dispersal of seeds and propagules (Roberts and Marston 2011), for instance connectivity by floodwater facilitates dispersal and re-colonisation of wetlands by aquatic species (Sheldon et al. 2002).
    - The condition of plants and their ability to produce seed and germinate.
- Disturbances such as grazing and cultivation (Tuckett et al. 2010).
- Hydrologic characteristics of a wetland filling event (e.g. depth, duration and oxygen) (Casanova and Brock 2000).

Given the above, a further watering event in 2013-14 connecting wetlands with the Murrumbidgee River will increase the likelihood of aquatic vegetation recovery, improving seed banks and thus the resilience of aquatic vegetation in the Murrumbidgee Valley. Consideration should also be given to opportunities to implement other wetland management strategies to help maximise outcomes including grazing management strategies.

Implementation of the Priority

Ability to meet the Priority under changing resource availability scenario

The seasonal rainfall outlook for southeast Australia is a wetter than normal season for the period between June to August 2013 (BOM 2013). Water allocations in the Murrumbidgee Valley for the start of the water year are forecast to be 95% for High Security licences and under average inflow conditions, a forecast allocation of 44% for General Security (NSW Office of Water 2013).

Given current and forecast conditions and expected environmental water holdings at July 2013, it is anticipated that there will be sufficient environmental water available to meet this Priority however the ability and means of meeting the Priority will depend on the resource availability scenario as outlined below.

Under a dry scenario it is still likely that there will be enough environmental water to support the Priority however there will be reduced opportunity and capacity. There is likely to be reduced occurrence of natural higher flows and fewer opportunities to piggy-back to achieve or extend inundation. There will also be reduced water availability, and potentially reduced outlet capacity with lower water levels in Burrinjuck Dam.

Wetter conditions (i.e. moderate to wet scenario) will increase the likelihood of being able to undertake environmental activities to support this Priority. There would be higher flows and more opportunities to piggy-back on events to achieve inundation or to extend the recession of naturally occurring inundation. There is also increased water availability and greater outlet capacity with higher water levels in Burrinjuck Dam. It may also be possible to provide additional water to wetlands later in the season.

It is understood that there are multiple constraints to delivering higher regulated flows in the Murrumbidgee Valley and that the delivery of environmental water needs to be consistent with the rules outlined in the Water Sharing Plan for the Murrumbidgee Regulated River Water Source. Depending on conditions, inundation through lateral connectivity may not be possible for all wetlands.

Downstream opportunities

Flows from the Murrumbidgee River have been identified as an important contributor to environmental outcomes in the mid to lower reaches of the Murray River, and as such this Priority for outcomes within the Murrumbidgee should also be considered in conjunction with the Priorities for the *mid-Murray River*, *lower Murray River system, Coorong, Lower Lakes and Murray Mouth* and other environmental outcomes in the southern-connected Basin.

Consideration should be given to coordinating flows to water the ‘Junction wetlands’. The ‘Junction wetlands’ are a group of creeks and wetlands located on the western side of the Murrumbidgee River at its confluence with the Murray River (Figure 14). Watering of the ‘Junction wetlands’ requires concurrent high flows in both the Murray (flows of 10,000 ML/day at Barham) and Murrumbidgee (flows of 5,000 ML/day downstream of Balranald weir) rivers (SKM 2011). While there is relatively little known about the ‘Junction wetlands’ they are known to support a number of rare and threatened species (SKM 2011). The ‘Junction wetlands’ have experienced similar conditions to the mid-Murrumbidgee wetlands in that they received flows during 2010-2012, and no flows between 2000 and 2010, consequently the condition of the wetlands and creeks is still recovering.

Priority 6 — Connecting Rivers and Floodplains: lower Murray River system

Basin Annual Environmental Watering Priority

Improve vegetation condition in wetlands and floodplains and provide cues for native fish recruitment and movement in the lower Murray River system by enhancing in-stream flow variability.

Note: For the purposes of this Basin Annual Environmental Watering Priority (the Priority) the lower Murray River system includes the Lower Darling River, Darling Anabranch and lower Murray River.

Expected outcomes of this Priority

It is anticipated that the above Priority will facilitate the following outcomes:

- Increase the condition, abundance and diversity of native riparian, wetland and floodplain vegetation.
- Complement natural cues to benefit wetland and floodplain communities by increasing duration and extent of inundation or facilitate a drying cycle.
- Provide cues for native fish spawning, movement and recruitment.
- Protect and restore connectivity longitudinally in the lower Murray River system and laterally between the main river channels and their associated wetlands and floodplains.
- Allow pathways for dispersal, migration and movements of native water dependent biota.
- Improve wetting and drying cycles in wetlands and floodplains.

Why is this a Priority?

The Authority considers this Priority to be of Basin significance because:

- For 2013-2014 the inundation of wetlands in the lower Murray River system is a priority to build on the positive ecological response to recent floods and improve vegetation condition.
- The lower Murray River and associated wetlands, floodplains and groundwater systems has been nominated as a threatened ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).
- The lower Murray River system has significant billabongs, floodplain depressions, wetlands, lakes and shallow creek channels that support internationally and nationally listed sites and species.
- The occurrence of small to medium floods in the lower Murray River reach has been markedly reduced following river regulation. This element of the flow regime is important for maintaining and restoring floodplain and in-stream communities.
- The Priority can be achieved by co-ordinating water delivery from upstream tributaries including the Murray River and Barwon-Darling Rivers.

Significance of site

Lower Darling River and Darling Anabranch

The Lower Darling River extends for 450km from downstream of the Menindee Lakes to its junction with the Murray River at Wentworth in New South Wales (Figure 16). The billabongs, floodplains, lakes and shallow creek channels along the Lower Darling River provide feeding and roosting sites for waterbirds listed under the international Japan-Australia Migratory Bird Agreement or China-Australia Migratory Bird Agreement and support an important population Murray cod (*Maccullochella peelii*) (Shaikh et al. 2001; MDBA 2012f; National Murray Cod Recovery Team 2010).

The Darling Anabranch flows westward downstream of Menindee Lakes into the Murray River between Lock 9 and 10, 15km west of Wentworth (Figure 16). The Darling Anabranch spreads over approximately 630,000 ha and includes the anabranch channel, lakes and floodplain environments (MDBA 2012f). The majority of lakes fill via a feeder channel from the anabranch and one lake is directly connected to the anabranch channel (Jenkins and Briggs 1995).

The Lower Darling River and Darling Anabranch support important species listed in international agreements such as the Ramsar Convention and include vulnerable and endangered species (MDBA 2012f).

Lower Murray River

The lower Murray River for the purpose of this Priority is defined from the junction of the Darling River at Wentworth in New South Wales to Wellington in South Australia (Figure 16). This area includes the Ramsar Riverland wetland complex (includes Chowilla Floodplain and the Lindsay-Wallpolla Islands) and Banrock Ramsar site. They provide key habitat for migratory water birds listed under the international Japan-Australia Migratory Bird Agreement or China-Australia Migratory Bird Agreement (MDBC 2006; MDBA 2012e). In addition there are many national and state listed species of fish, vegetation, vertebrates, invertebrates and crustaceans (MDBC 2006; MDBA 2012e).

The lower Murray River and associated wetlands, floodplains and groundwater systems has been nominated for listing as a threatened ecological community under the *EPBC Act* (DSEWPaC 2013a, b).

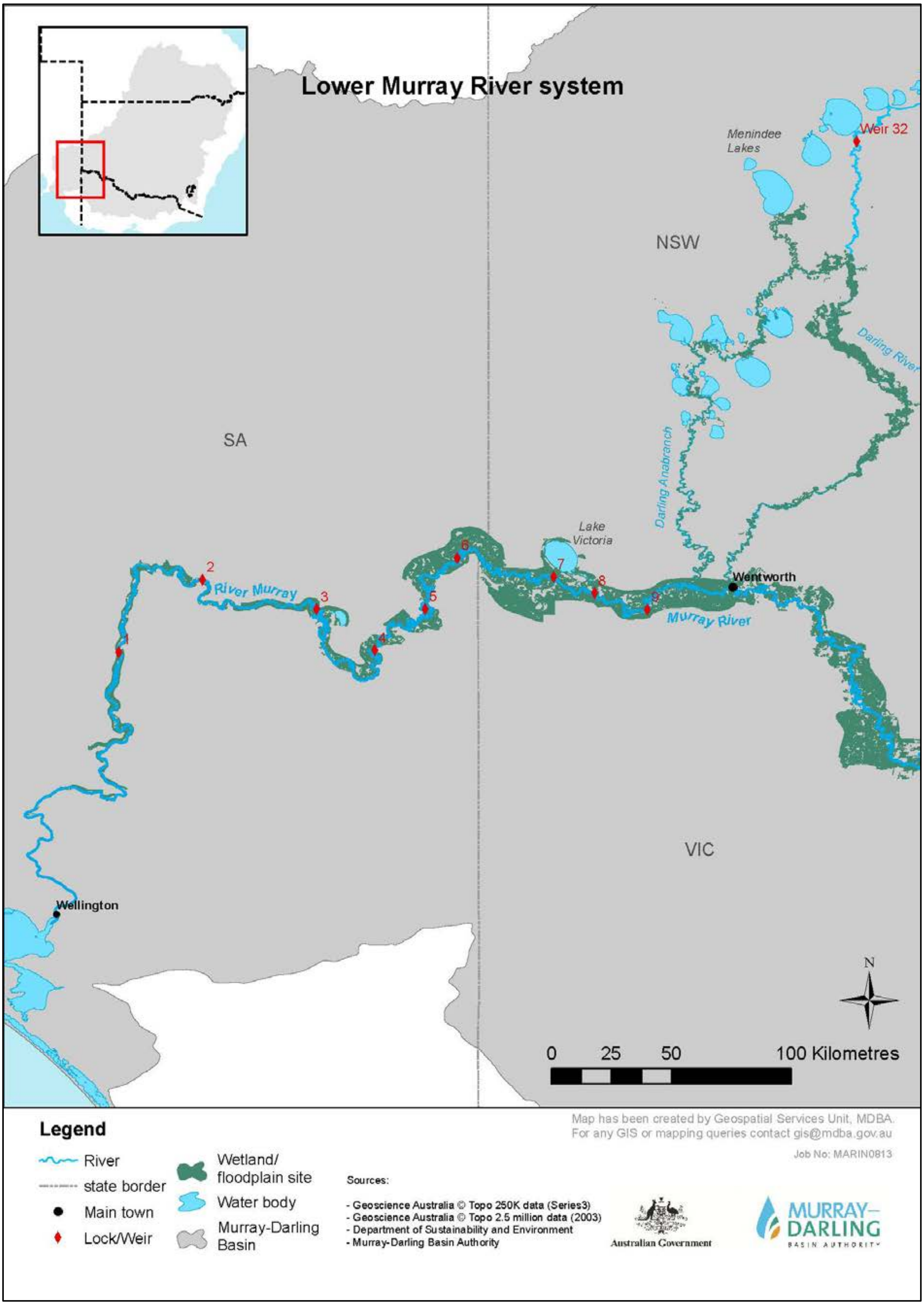

Figure 26. Map of the lower Murray River system

Condition of environmental assets and functions

As demonstrated in Figures 17 and 18, the lower Murray and Lower Darling Rivers received minimum flows during 2001-2011 and very few low lying wetlands were inundated. There were also fewer small to medium flows, which caused a reduction in wetland flooding, decline in long-lived vegetation, a lack of recruitment events, disconnection of the floodplain from the river channel and reduced vital processes such as nutrient exchange. Opportunities for successful spawning and recruitment by large-bodied native fish species were also reduced (MDBA 2013a).

Drought-breaking inflows occurred during 2010-2011 and 2011-2012 (Figures 17 and 18). This flooded and connected many floodplains and wetlands, anabranches and creeks in the lower Murray River system and triggered native fish spawning and movement. However, further flooding is required in 2013-14 to build the resilience and condition of the system (MDBA 2013a).

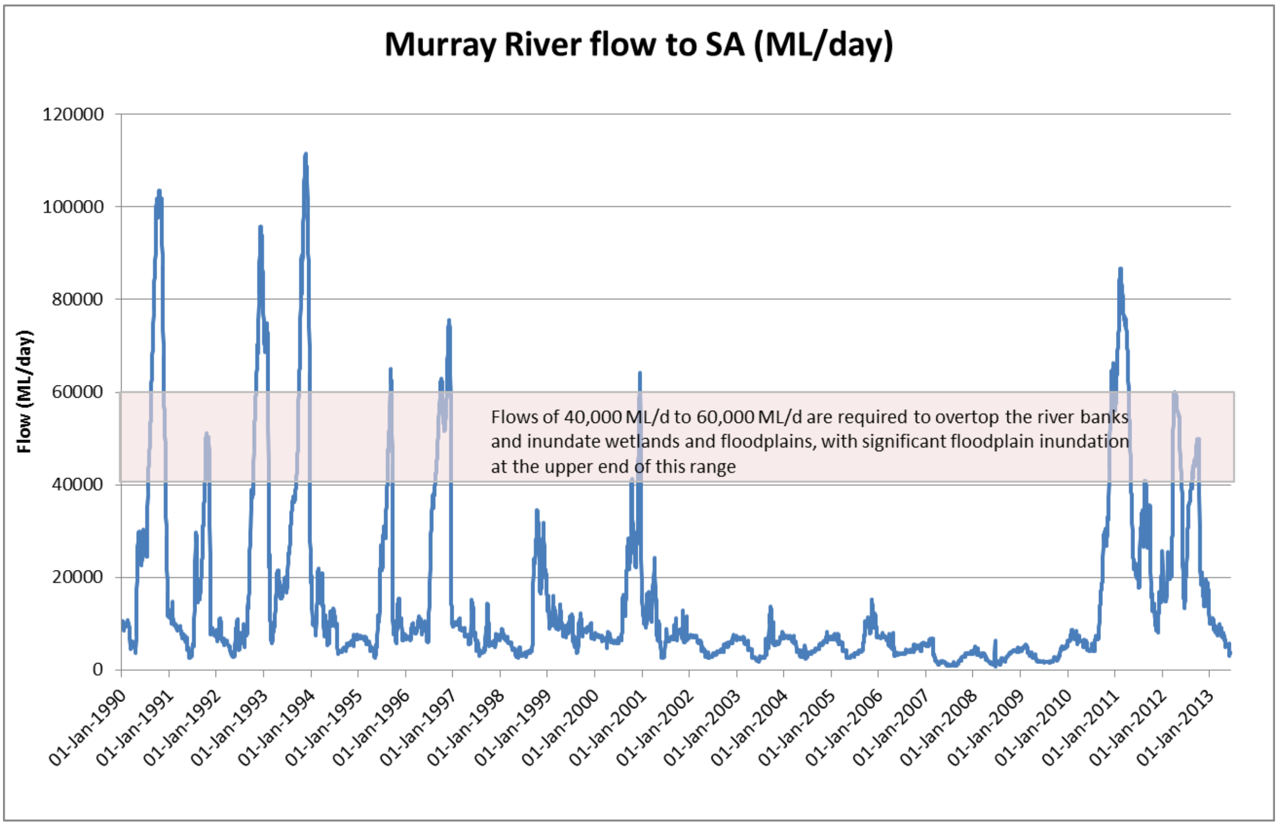

Figure 17: Flow rates of the Murray River at the South Australian border from 1990 to May 2013, showing the indicative flow ranges required for significant floodplain inundation.

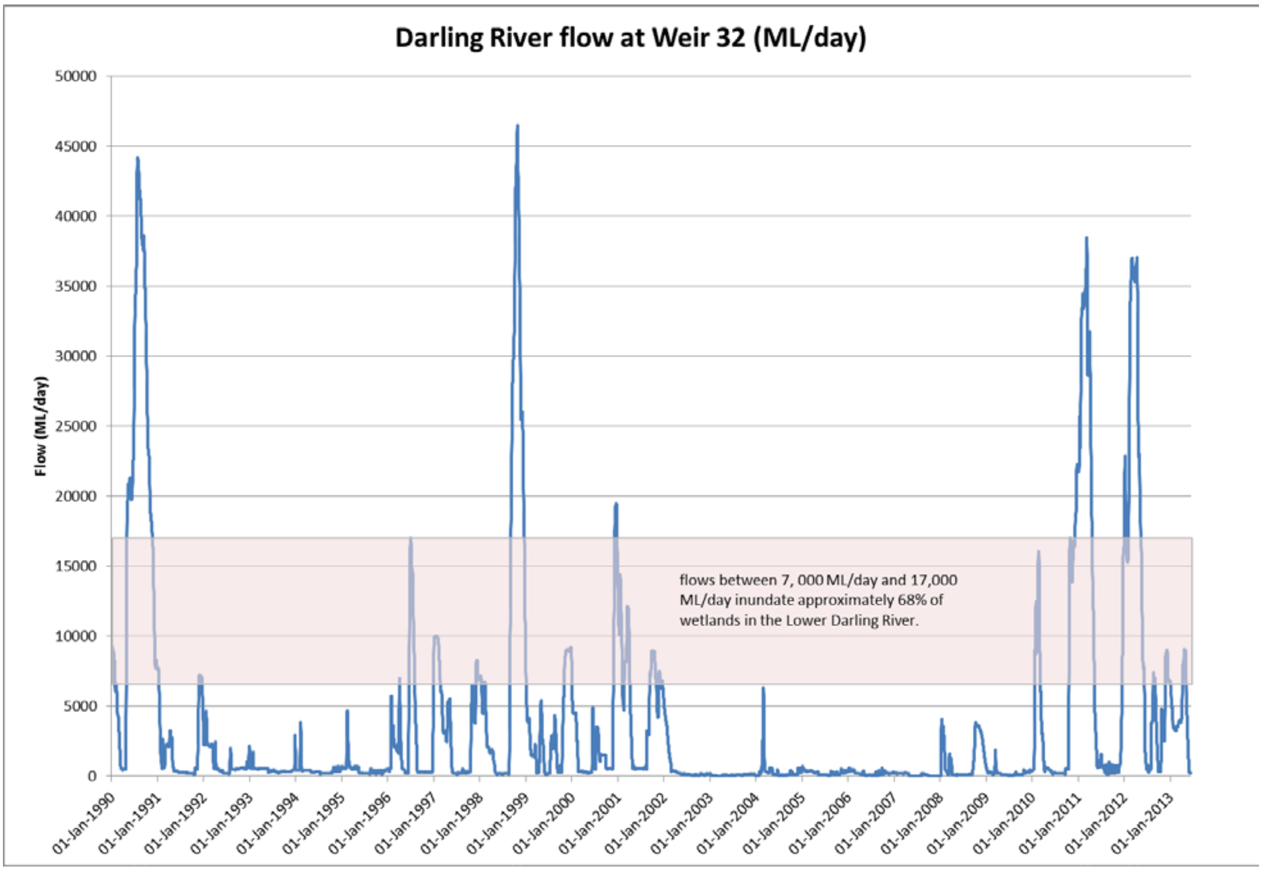

Figure 18: Flow rates of the Lower Darling River at Weir 32 from 1990 to May 2013, showing the indicative flow ranges for required wetland inundation.

Matters of interest

The restoration of the lower Murray River system is important as it connects the wetlands and floodplains to the river channel. This allows water to inundate key habitat in-channel features, improves water quality, moves sediment downstream, ensures movement of native fish species and allows for dispersal and re-colonisation of flora species through the river systems (Humphries et al. 1999; Cottingham et al. 2003; Cottingham et al. 2010).

Wetland and floodplain vegetation

Watering of floodplains and wetlands raises the surface and soil moisture levels and results in successful regeneration and a wider diversity and abundance of water dependent vegetation (Ecological Associates 2010; Roberts and Marston 2000). Therefore, the hydrology of the lower Murray River system plays a critical role in the health of vegetation communities of the area (MDBA 2012g).

There are many species of water dependent vegetation that is valuable habitat for fauna in the lower Murray River system. For example, river red gums (*Eucalyptus camaldulensis*) typically grow in floodplains and they provide key habitat for ground foraging and hollow nesting birds, lizards and small mammals. To maintain and improve the health of river red gums along the lower Murray River lateral surface water movement and groundwater recharge is required into adjacent creeks and wetlands (Doody et al. 2012; Roberts and Marston 2000). Importantly, wetlands and floodplains between 30m to 90m from the river channel and feeder creeks play a critical role in maintaining the health of river red gums compared to sites beyond 120m from the channel (Doody et al. 2012). This highlights the utility of small-moderate floods in maintaining river red gum health and population resilience.

Water dependent sedge and rush vegetation on the littoral fringe of wetlands is important nesting, breeding and shelter habitats for native fish such as the Murray hardyhead (*Craterocephalus fluviatilis*), frogs, waterbirds and macroinvertebrates. Larger emergent macrophytes such as *Phragmites* and *Typha* provide key habitat for waterbirds. Stands of *Typha* in permanent swamps and wetlands are valuable refugia habitat for water birds and other aquatic fauna such as turtles and frogs (Roberts and Marston 2000). Lignum swamps on floodplains and on the banks of the Murray River in South Australia creates important nesting habitat for colonial waterbirds. Flooding at the right time is important for germination and establishment (Roberts and Marston 2000).

Native fish

Eleven native fish species of national or state conservation significance have been recorded in the lower Murray River (Ecological Associates 2013). The lower Murray River and Lower Darling River are important regions for maintaining the long-term survival and recovery of the Murray hardyhead and Murray cod (Hammer et al. 2009; National Murray Cod Recovery Team 2010).

The Murray hardyhead is a freshwater fish endemic to the lower Murray River and Lower Darling River (Hammer et al. 2009). It is now extinct in New South Wales and survives in only a few isolated locations in Victoria and South Australia. The Murray hardyhead is listed as nationally vulnerable under *EPBC Act*, endangered on the International Union for Conservation of Nature Redlist for threatened species and critical under the South Australian Freshwater Fishes Action Plan (Hammer et al. 2009). Murray hardyhead are often found in permanent open-water wetlands with higher salinity levels, silty or sandy substrates and emergent and flood dependent fringing vegetation (such as *Cumbungi* and *Juncus* species and macrophytes) (Backhouse et al. 2008).

The Murray cod is the largest freshwater fish in Australia and had a widespread distribution throughout the majority of the Murray-Darling Basin. In the lower Murray River, flow regulation, habitat modification and heavy commercial fishing activities have reduced population numbers (Ye et al. 2000). The Murray cod is listed as vulnerable under the *EPBC Act* and is listed as endangered under the South Australian Freshwater Fishes Action Plan (Hammer et al. 2009). To ensure the survival of the Murray cod populations in the lower Murray River system it is critical to maintain and improve connectivity within and between the main channel, floodplains, wetlands and connecting streams.

Many native fish species (including the Murray hardyhead and Murray cod) rely on seasonal flow patterns to support successful spawning and recruitment, which can done by delivering water in response to natural cues (see Guiding Philosophy to *deliver water in response to natural cues*). Increased flows during spring and summer can enhance fish recruitment by triggering spawning, benefit the survival of larvae and juvenile fish by providing greater access to habitat and food and encouraging upstream migration (Beesley et al. 2011; Ecological Associates 2010; Ye et al. 2000). Evidence also suggests that the provisions of flows that connect the river channel to the floodplain as well as in-channel flow variability are critical to sustaining native fish populations (Beesley et al. 2011).

Significant places

There are many significant wetlands, floodplains and rivers that sustain valuable water dependent vegetation communities and are key for the success of native fish populations in the lower Murray River system. Examples of key wetlands and floodplains in the lower Murray River that are relevant to this Priority in 2013-14 include the wetlands influenced by Lock 8 and Lock 9 weir pools (including Carrs Billabong, Capitts and Bunderoo Creeks in New South Wales), Cliffhouse Wetlands in New South Wales, Overland Corner and Berri and Disher Creek Saline Water Disposal Basins in South Australia (NSW OEH 2013c; Ecological Associates 2013; NSW DECC 2008; SA MDB NRM Board 2013; SA DENR 2012). Berri and Disher Creek Saline Water Disposal Basins provide key refuge habitat for two of the four remaining populations of Murray hardyhead within South Australia (Hammer et al. 2009; SA DENR 2012).

The lower Murray River system includes Chowilla Floodplain, Lindsay-Wallpolla Islands and River Murray Channel icon sites managed under The Living Murray program. At the Chowilla Floodplain and Lindsay-Wallpolla Islands the States, Commonwealth and the Authority have been working together under The Living Murray program to build infrastructure to assist with the delivery of environmental water. Given the current status of the infrastructure and anticipated patterns of environmental water use, the Authority has chosen not to identify any of these sites as Priorities for 2013-14. This does not preclude them from receiving water at the appropriate time with regard to the completed infrastructure.

There are many wetlands connected to the Lower Darling River and on the Darling Anabranch relevant to this Priority (MDBA 2012f; National Murray Cod Recovery Team 2010). For example, Lake Nearie on the Darling Anabranch has important refuge, breeding and foraging habitat for migratory waterbirds listed under the international Japan-Australia Migratory Bird Agreement and China-Australia Migratory Bird Agreement (NSW DECC 2008).

Implementation of the Priority

The prevailing conditions throughout the water year will determine the extent to which this Priority can be achieved and how it is achieved. At the time of preparing the Priority, the Resource Availability Scenarios (RAS) outlook predictions for 2013-14 range from wet to dry.

In wet and very wet scenarios (i.e. high or extremely high inflows) large unregulated natural flows are likely to achieve the Priority by overbank flows across the floodplain or through natural flood runners and tributaries to the wetlands higher in the landscape. In these scenarios held environmental water may not be required during the flood peak but can be used to extend the duration of inundation and manage the flood recession to minimise the mobilisation of saline groundwater, prevent bank slumping and provide flow cues for native fish. In a moderate scenario (or inflows) the flows will inundate low lying wetlands that are influenced by in-stream variability, connected tributaries and flood runners, operation of regulators (where they are already in place) and weir manipulation. In dry and very dry scenarios environmental water holders and managers will only be able to achieve the Priority in isolated areas directly influenced by weirs or regulators by using held environmental water.

Coordination

To achieve this Priority, environmental water holders and managers are encouraged to consider how flows (both natural and managed) can be coordinated between valleys and delivered to increase the connectivity across in-stream, floodplain and wetland environments throughout the lower Murray River system in response to natural cues (see Guiding Philosophy to *deliver water in response to natural cues*).

Flow into the lower Murray River system is determined by inflows and rainfall in the upper reaches of Murray River and then flows subsequently into Coorong, Lower Lakes and Murray Mouth. Therefore implementation of this Priority also needs to consider, build on and complement the implementation of the *Mid-Murray River* and the *Coorong, Lower Lakes and Murray Mouth* Priorities. This coordination will be assisted by the Environmental Water Holders and River Operators Coordination Forum.

Flows from the Barwon-Darling also make a valuable ecological contribution (including the movement of native fish and nutrients) to the lower Murray River and often occur during times of low flows in the Murray River due to different rainfall patterns across the Murray-Darling Basin. Hence, this Priority should be implemented in conjunction and coordination with the *Barwon-Darling River* Priority.

Weir pools

Flow in the lower Murray River is influenced by ten locks and weirs that hold the upstream water at a constant level (which can extend for tens of kilometres upstream), even when the flow rate changes (Walker et al. 1994).

Where possible, the locks and weirs should be operated in a manner which maximises environment outcomes in-channel, in the riparian zone and on the adjacent floodplains and wetlands by creating variable water levels (NSW OEH 2013c) during dry and extremely dry scenarios. They can inundate or expose emergent aquatic vegetation, provide connections between permanent water bodies and temporary wetlands and expose shallow-water habitats or mudflats (Ecological Associates 2013).

Maximising outcomes

Delivery of water, including the rates of rise and fall for peak flow events to the lower Murray River system might be constrained by limitations on channel capacity during summer and autumn due to higher irrigation and consumptive demands, channel capacity below Menindee Lakes in the Lower Darling River, outlet capacity of Lake Victoria and travel times and re-regulation capacity along the Murray River. In 2013 the Authority is preparing a Constraints Management Strategy to identify constraints in the lower Murray River system which restrict the delivery of environmental water (especially higher flows) and make recommendations to mitigate third party impacts.

As part of The Living Murray program, Riverine Recovery program and state construction activities there are works under construction in the lower Murray River system and the delivery of higher flows might exceed the inundation thresholds for these projects.

Priority 7 — Supporting in-stream functions: Barwon-Darling River system

Basin Annual Environmental Watering Priority

Improve habitat and provide opportunities for migration and reproduction of native fish in the Barwon-Darling River system by increasing flow variability and hydrological connectivity

Note: For the purposes of this Basin Annual Environmental Watering Priority (the Priority) the Barwon-Darling River system includes the continuous channel of the Barwon and Darling Rivers from the north to Menindee Lakes in south western New South Wales (NSW).

Expected outcomes of this Priority

It is anticipated that the above Priority will facilitate the following outcomes:

- Provide diversity of in-stream habitat for native fish and other aquatic biota.
- Improve longitudinal hydrological connectivity and biota exchange among the Barwon-Darling and its tributaries.
- Help maintain lateral connectivity between the main river and adjacent wetlands, anabranches and floodplain depressions (through minor breakouts) promoting carbon and nutrient cycling which is important for native fish larvae and juveniles critical habitat.
- Support increased spawning, pre-spawning migrations and recruitment of native fish.
- Maintain the condition, extent and diversity of native aquatic and riparian vegetation communities.
- Maintain water quantity and quality in waterhole refuges important for sustaining fish populations during dry periods.

Why is this a Priority?

The Authority considers this Priority to be of Basin significance because:

- The Barwon-Darling Rive system provides important habitat for approximately 21 of the MDB's native fish species, 3 of which are listed as vulnerable or endangered. Of the six catchments with the best results for fish condition identified in the Sustainable Rivers Audit two are within the Barwon-Darling River system and its tributaries.
- Fish habitat has been declining throughout the Murray-Darling Basin and native fish populations are estimate to be 10% of their pre-European settlement levels.
- Water resource development in the northern basin has reduced the average volume and duration of flooding events by 50% in the Barwon-Darling River system and this has reduced the availability and quality of fish habitat.
- Providing multiple years of migration and recruitment opportunities for native fish will build a more dynamic and resilient community.
- Coordination of environmental water management in the northern basin will be essential to improve ecological outcomes in the Barwon-Darling River system including increasing the availability of fish habitat.

The Barwon-Darling River system

The Macintyre, Barwon and Darling Rivers are the same continuous channel; named the Macintyre River upstream of Mungindi, the Barwon River downstream to the Culgoa confluence, and the Darling for the remainder of its length to Menindee Lakes (Figure 19) (Boys 2007). Major tributaries into this channel include the Culgoa, Macintyre, Gwydir, Namoi, Macquarie, Warrego, and Paroo Rivers (see Figure 19).

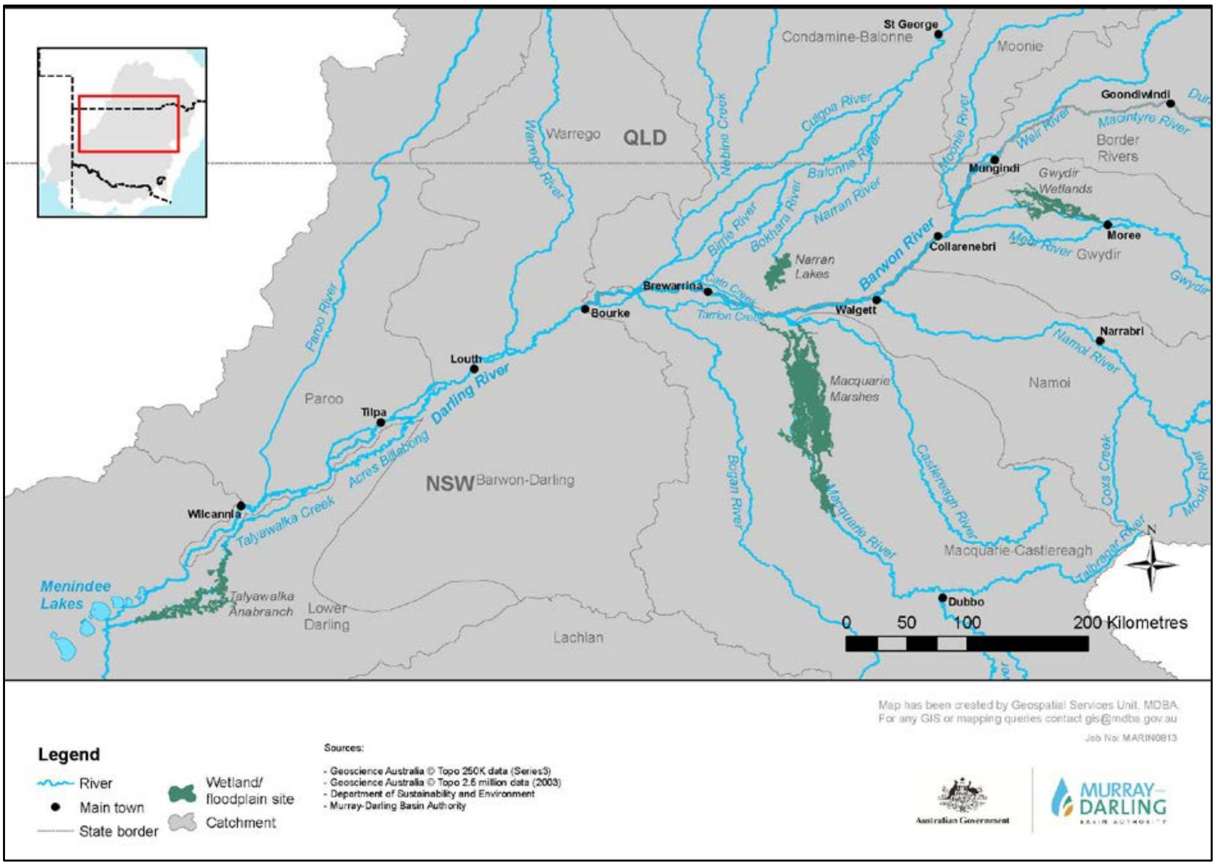

Figure 39: Map of the Barwon-Darling River system and its tributaries

Significance of site

The Barwon-Darling River system has a complex morphology and hydrology which provides a multitude of habitats that play a critical role in the life cycles of a wide range of species (NSW DPI 2007). The main stem of the Barwon-Darling River system and the lowland reaches of its NSW tributaries are listed as an endangered ecological community under the *NSW Fisheries Management Act 1994*.

The Barwon-Darling River system supports a diverse range of floodplain wetlands from Mungindi to Menindee with extensive flood runners, anabranches and billabongs (MDBA 2012h). The Barwon-Darling River system also provides flows to the Talyawalka Anabranch and associated lakes. This wetland system includes numerous lakes and supports large areas of black box (*Eucalyptus largiflorens*) and river red gum (*Eucalyptus camaldulensis*) (Jenkins and Briggs 1997). Floodplain wetlands are major sites for the cycling of carbon and nitrogen which is essential for the primary productivity of river-floodplain ecosystems (Robertson et al. 1999).

The Barwon-Darling River system is recognised for its ability to support populations of native fish. Fish are excellent indicators of the condition of rivers and their catchments. The Sustainable Rivers Audit has demonstrated a widespread decline in native fish populations throughout the Murray-Darling Basin, raising the importance of maintaining native fish populations in the Barwon–Darling River (Davies et al. 2008). A total of 21 species of fish have been recorded within the lower reaches of the Barwon-Darling River system and its tributaries (Boys 2007). The Barwon-Darling River system supports three species of fish that are listed as vulnerable or endangered under State or Commonwealth threatened species legislation (SKM 2009). Silver perch (*Bidyanus bidyanus*) is listed as vulnerable and freshwater catfish (*Tandanus tandanus*) is listed as endangered under the NSW Threatened Species Conservation Act 1994, while the Murray cod (*Maccullochella peelii*) is listed as vulnerable under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.

Condition of environmental asset and functions

Water resource development has resulted in up to 50% reduction in the frequency and duration of the range of flood events along the Barwon-Darling River system (Brennan et al. 2002). Changes to the natural flow regime and habitat degradation have been recognised as a major cause of the declining condition of freshwater fish populations throughout the world (Boys et al. 2005). In addition to the effects of water resource development, the northern rivers predominately received low inflows due to the long drought between 2000 and 2010 (the millennium drought) which had a substantial effect on the environmental condition of the region. The Sustainable Rivers Audit 2 found that at the end of the millennium drought the majority of the rivers in the northern basin had poor to very poor river ecosystem health with the exception of the Warrego and the Paroo (Davies et al. 2012).

Between 2010 and 2012 the Barwon-Darling tributary catchments have experienced wet to very wet conditions providing large flows to river channel assets, distributary systems and floodplain wetlands across the region, including the Barwon-Darling River. These beneficial flooding flows contributed to the recovery of assets affected by drought conditions in the previous decade.

Native fish populations in the Barwon-Darling are expected to have benefitted from the wet years following the end of the millennium drought, as a result of breeding opportunities provided by increased connectivity and variability. However, further breeding opportunities are required in successive years to build resilient populations, particularly for long lived species such as golden perch and Murray cod. Individuals of these species often take a number of years to reach maturity so continued favourable conditions are important to support development of juveniles through to maturity. Promoting sequential spawning events builds a more dynamic community composition which includes fish of various age classes and more potential for mates once cohorts reach breeding age (K. Cheshire pers. comm. 2013).

Matters of interest

Hydrology

The flow regime of the Barwon-Darling River system is highly variable, dominated by low-flows interspersed with episodic flooding events that inundate the extensive areas of semi-arid floodplain (Boys 2007). The Barwon-Darling River System is an unregulated river, although many of the tributaries are regulated systems with public and private storages. 99 % of surface water availability in is generated in regions upstream of the Barwon-Darling River system, including 23 % from the Namoi, 22 % from the Macquarie-Castlereagh, 15 % from the Condamine-Balonne via the Culgoa and Bokhara Rivers and 20 % from the Border Rivers (CSIRO 2007b). The variable nature of flows in the Barwon-Darling River system has been exhibited in the past decade where flows have ranged from very low to the highest on record. Figure 20 illustrates this variability at Bourke on the Darling River.

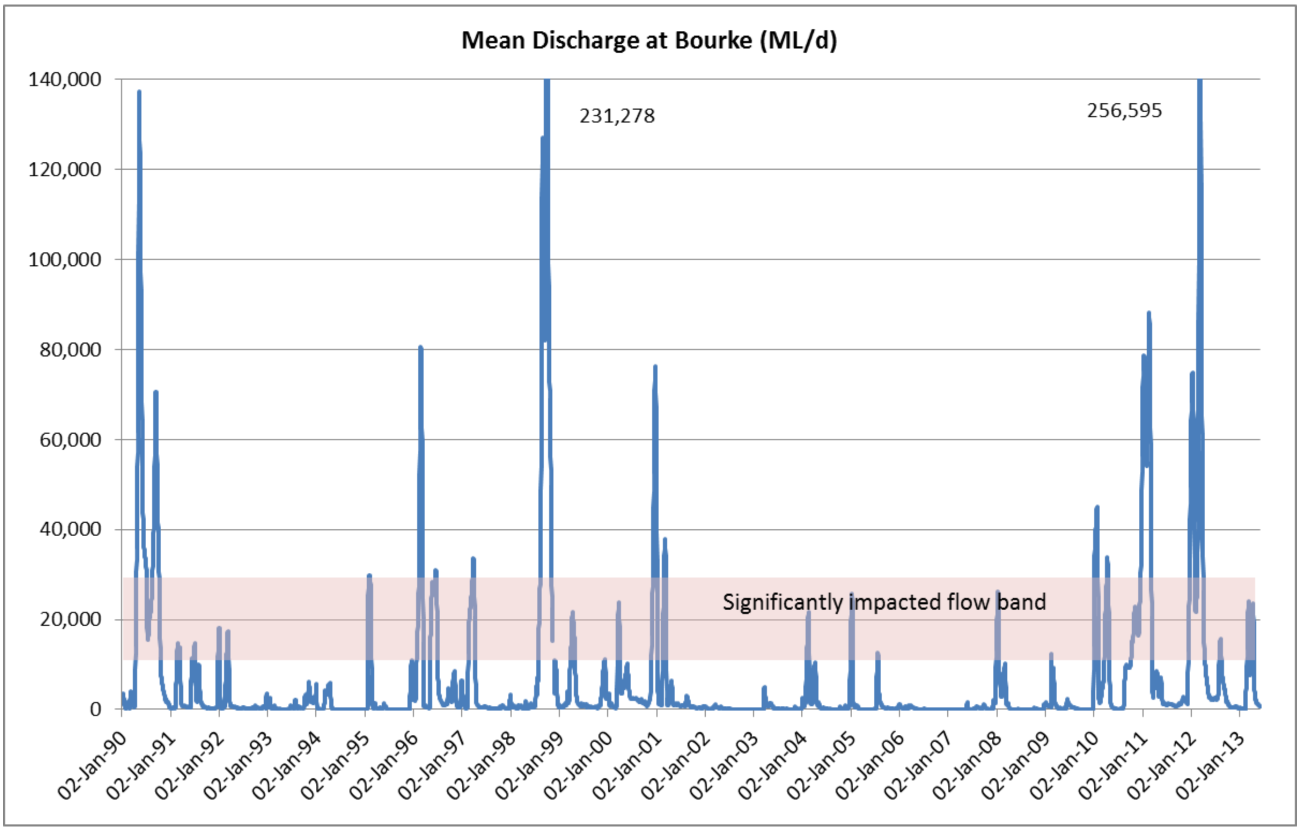

Figure 40: Average daily flow of Darling River at Bourke

Run-off generated in the Barwon-Darling River is low. However, the river plays an important role in connecting major river systems of the northern Basin to its southern reaches. It periodically delivers large volumes of water from the upstream catchments down into the lower Darling River (downstream of Menindee Lakes Storage Scheme) and the Murray River. These flows make an extremely valuable contribution to river health in the lower Murray River, particularly when they correspond with periods of low flows in the southern systems.

The variation in timing of seasonal inflows from the tributary catchments is critical to adding variability and pulses to the system. For example, in recent years discharges from the Condamine-Balonne and Border River catchments have dominated inflows, and historically the Macquarie contributes spring freshes at Bourke.

The variable hydrology of the Barwon-Darling River system has resulted in complex channel cross-sections featuring in-channel benches that occur at multiple levels (Southwell 2008). Variable flow patterns also facilitate ecosystem processes including nutrient cycling and exchange as previously dry benches and floodplains are alternately inundated and dried. Southwell (2008) found that in-channel benches between Walgett and Bourke acted as sediment and nutrient sinks and were an important source of dissolved nutrients.

Native Fish

Many of the water dependent ecosystems occurring along the Barwon-Darling River system upstream of Menindee Lakes are reliant on the variable mix of high and low flows that characterise this system. Research in the Barwon-Darling and Paroo Rivers showed that flow variability in these rivers promotes the availability of structural habitat over time, and that water resource development in the Barwon-Darling, by limiting the magnitude and frequency of flow events, has reduced the availability of in-stream habitats (Boys et al. 2005).

Many native fish species rely on seasonal flow patterns to support successful spawning and recruitment. Increased flows during spring and summer can enhance the recruitment in some species in two ways;

1. Increased flows trigger spawning of adult fish and /or
2. Higher flows indirectly benefit the survival of larvae and juvenile fish by providing greater access to habitat and food.

Other species however, will successfully spawn and recruit under low flow conditions (NSW DPI 2011; Humphries et al. 1999). Evidence also suggests that the provision of flows that connect the river channel to the floodplain as well as in-channel flow variability, are critical to sustaining native fish populations (Beesley et al. 2011).

Another important component of successful reproduction in several species of native fish is access to woody debris habitat (NSW Department of Primary Industries 2011). Murray cod and various species of gudgeons spawn adhesive eggs onto and in submerged logs (NSW DPI 2011). Boys (2007) found a strong association between the occurrence of Murray cod and golden perch and large wood debris.

As noted above there has been a significant change to the hydrology of the Barwon Darling, with the reduced number and size of flow events impacting on opportunities for native fish migration and recruitment. Analysis by the MDBA (2012h) found that compared to without development conditions, the frequency of flows that provide periodic access to large woody debris and improve in-channel nutrient cycling (e.g. events between 5,000–20,000 ML/day at Louth) had been reduced by 45% Similarly the frequency of flows in the range of 10,000 to 30,000 ML/d at Bourke, which promote in-stream bench inundation and nutrient cycling, have been reduced by 47%. Based on the known reproductive requirements of the Murray cod (Lintermans 2007; Humphries et al. 1999; NSW DPI 2011) the Authority set a 10 day flow duration for events to support the inundation of key habitat (MDBA 2012h).

Implementation

Achieving the outcomes identified in this Priority is dependent upon:

- Resource availability in terms of adequate rainfall and inflows/events at the appropriate time.
- Protection of important flow pulses from diversion or consumption.
- Co-ordination of inflow from tributaries.

Resource availability

The Barwon-Darling River is largely unregulated which limits the ability to actively manage water, with environmental water use dependent on natural inflow events. In a moderate to wet Resource Availability Scenario (RAS) there is likely to be a series of pulse events entering the system contributing to flow variability and connectivity. Such events will also provide opportunities for the coordination of managed flows (discussed below). In an extremely dry or dry scenario there will be fewer opportunities to achieve this Priority, however events may still occur which contribute to achieving this Priority.

Protection of flows

Currently flows in the Barwon Darling are protected through two measures, the purchase or recovery of entitlements and, rules within Water Resource Plans. Ongoing in-stream use of entitlements recovered by the Commonwealth in unregulated streams in the Northern Basin (Lower Balonne, Nebine Creek, Moonie River, Border rivers, Warrego and the Barwon-Darling River system itself) will result in a greater proportion of certain flow events remaining in the river for environmental benefit. Removal of these entitlements from the consumptive pool will contribute to achieving this Priority by increasing inflows to the Barwon-Darling River, improving flow variability and enhancing longitudinal and lateral connectivity in 2013-14. However, the contribution to in-stream flow from (current) held environmental water entitlements (relative to unregulated flows/planned environmental water) will be modest under most flow conditions.

There are also opportunities to protect flows through the temporary purchase of extraction rights in relevant flow windows in the Barwon-Darling and/or tributary streams that are hydrologically connected at the time. This may also complement and facilitate the coordination of flows (as discussed below). It should be noted that currently the Commonwealth is only purchasing permanent entitlements. The trading of Commonwealth entitlements is being investigated; however temporary water recovery may not be feasible for 2013-14.

Activation of existing rules in water sharing plans for the Barwon-Darling and key northern NSW tributaries designed to protect flows in certain windows, may also contribute to achieving this

Priority. These rules allow for restrictions to be placed on extraction of unregulated flows (Barwon-Darling) or supplementary water (in the Border Rivers, Gwydir and Namoi Water Resource Plan areas) to meet flow targets for fish migration, algal suppression or to maintain stock and town water supplies ('riparian' flows) in the Barwon-Darling River. In relation to fish migration, extraction can be suspended through Barwon-Darling Unregulated and Alluvial Water Sources 2012 to achieve a flow of at least 10,000 ML/day at Bourke for 5 days in between September and February (unless two such flows have already occurred within that period).

Co-ordination of flows

In the regulated tributaries, sequencing of environmental flows based on managed releases to improve ecological outcomes in the Barwon-Darling River system may be possible. For example, the delivery of a large volume of environmental water to the Macquarie Marshes (to achieve a Macquarie objective) could contribute to a flow in the Barwon-Darling River system. If this managed event was delivered in conjunction with a natural trigger such as an unregulated event (see Guiding Philosophy -*Deliver water in response to natural cues*) this would build on the event increasing connectivity and variability to the Barwon-Darling River system. It is recognised that it is challenging to coordinate the delivery of held or managed environmental water with unregulated events, and it would be limited by the need to meet in-catchment environmental needs. In addition the protection of coordinated environmental water as it moves through unregulated stretches will be required.

Future strategies

As outlined above there are limitations in managing water for environmental outcomes in the Barwon-Darling River. In order to fully implement this priority and the objectives of the Basin Plan investigation is required into the full range of water management strategies including:

- Strategic water recovery, including trading extraction rights on an event basis.
- Options to improve environmental provision rules in water resource plans.
- Options to coordinate tributaries.
- The protection of environmental water as it travels through unregulated systems.

As part of the implementation of the Basin Plan, the MDBA has established a Northern Basin Work Program, and commissioned a review of the scientific basis for the environmental water requirements in the Condamine-Balonne and Barwon Darling. The implementation of the work program over the next few years will improve understanding of the environmental water requirements needed to support the desired outcomes in other years.

Flows from the Darling River have been identified as an important contributor to environmental outcomes in the lower reaches of the Murray River (see *lower Murray River system* and *Coorong Lower Lakes and Murray Mouth* Priorities), and as such outcomes within the Barwon-Darling River system should also be considered in conjunction with other priorities and potential outcomes in the southern-connected Basin.

Priority 8 — Supporting in-stream function: Lower Goulburn River

Basin Annual Environmental Watering Priority

Improve habitat and provide opportunities for migration and reproduction of native fish in the lower Goulburn River through re-instating a variable flow regime which includes a large 'in-channel' spring/summer fresh.

Note: For the purposes of this Basin Annual Environmental Watering Priority (the Priority) the spring/summer period can be considered as October to December.

Expected outcomes of this Priority

It is anticipated that the above Priority will facilitate the following outcomes:

- Support the habitat requirements of aquatic species, including native fish, turtles, frogs and macroinvertebrates.
- Support movement, breeding and recruitment of native fish.
- Promote maintenance and increased extent and diversity of aquatic and native riparian vegetation communities.
- Promote exchange of biota between the Goulburn and Murray Rivers.
- Contribute to flows with sufficient shear stress to mobilise and move fine sediments, and scour sediments from pools.
- Provide variable flows to support bank stability.

Why is this a Priority?

The Authority considers this Priority to be of Basin significance because:

- The lower Goulburn River is of high conservation significance for its diverse native fish assemblage.
- A major objective of environmental water freshes in the lower Goulburn River is to stimulate spawning amongst golden perch (Macquaria ambigua). Monitoring of freshes in recent years has only identified a limited spawning response from this species, and research has suggested that a higher fresh may illicit a stronger spawning response.
- Significant freshes in the lower Goulburn provide a valuable contribution to flows in the Murray River system, thereby contributing to multiple benefits throughout the southern-connected Basin.

Significance of site

The Goulburn River system is located in north-central Victoria, rising in the Great Dividing Range and flowing into the River Murray upstream of Echuca (Figure 21). It is a major tributary of the Murray system second only to the Murrumbidgee in terms of surface water availability.

The lower section of the Goulburn River downstream of Goulburn Weir is of high conservation significance for its diverse native fish assemblage. The high degree of connectivity between the lower Goulburn and mid-Murray rivers have resulted in the lower Goulburn becoming an important spawning ground for several native fish species, including golden perch (Koster et al. 2012). Seven fish species which have conservation status under state or federal legislation have been recorded in this reach, including trout cod (*Maccullochella macquariensis*), Murray cod (*Maccullochella peelii*) and freshwater catfish (*Tandanus tandanus*).

Another valuable asset in this part of the Basin is the Lower Goulburn Floodplain, which covers some 13,000 ha alongside the river channel from the Goulburn Weir to the Murray River junction. The floodplain forms an important breeding area for waterbirds (including species listed under international migratory bird agreements) and contains excellent examples of river red gum open forests and woodland communities (DSEWPaC 2013c). The Lower Goulburn Floodplain also has high cultural value for its Aboriginal heritage. Sites include scarred trees, oven mounds and artefact scatters (DSEWPaC 2013c).

Condition of environmental assets and functions

The lower Goulburn River and floodplain experienced a period of severe drought over the period 1997 to 2009 followed by widespread flooding from natural flows in 2010-11. A smaller flood then followed in 2011-12. The impacts of the drought followed by the floods have left native fish, aquatic vegetation, riparian vegetation and macroinvertebrate communities within the lower Goulburn River in reduced condition (GB CMA 2013). Floodplain vegetation is generally in good condition (GB CMA 2013).

In the past two years, environmental water freshes have been released in the lower Goulburn River for a range of objectives including to promote spawning in golden perch, encourage the germination of riparian vegetation and increase available macroinvertebrate habitat (GB CMA 2012; CEWO 2012b). Monitoring of the 2011-12 fresh demonstrated that golden perch spawning did occur coinciding with the environmental water release, although only low levels of spawning were detected (Koster et al. 2012). Preliminary monitoring results from the 2012-13 freshes also found minor evidence of golden perch spawning (ARI 2013).

Following the freshes of 2012-13 it was recognised that maintenance of the river at a stable level during the higher flow rate may be contributing to some bank notching along the lower Goulburn River channel (GB CMA 2013). Environmental water releases provided at a variable flow rate should help to mitigate this issue in the future. It may also be beneficial to time environmental water releases to occur when they would have occurred naturally.

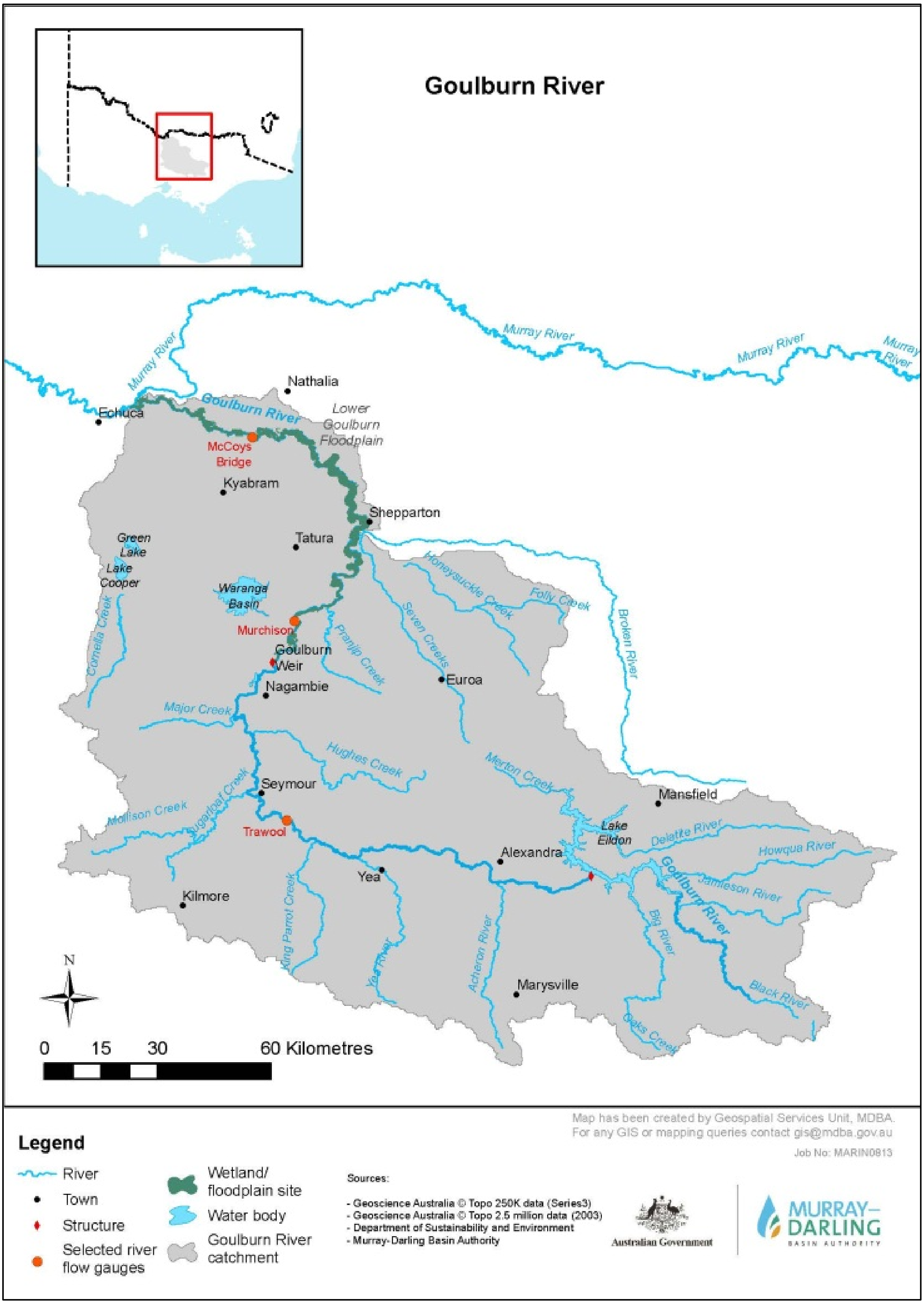

Figure 21: Map of the Goulburn River catchment

Matters of Interest

Golden perch spawning

While some native fish species spawn regardless of river discharge, others such as golden perch have demonstrated a preference for spawning under flood and high flow conditions (Cheshire et al. 2012; King et al. 2009; Ye et al. 2008). For the lower Goulburn River, previous recommendations for flow freshes have proposed flows of up to 6,600 ML/d for a minimum of two weeks (Cottingham et al. 2010). However, new information on spawning ecology of golden perch in the lower Goulburn suggests that higher freshes (greater than 10,000 ML/d) may stimulate increased spawning activity (Koster et al. 2012).

Higher freshes also have a number of other additional benefits over moderate to low in-channel freshes. By inundating a greater proportion of the channel, higher freshes can serve to germinate riparian vegetation on the lower slopes of the bank and provide increased habitat for macro-invertebrates via greater inundation of snags (Cottingham et al. 2010). Flows up to bankfull have also been identified in the Goulburn system as an important flow component for maintaining channel shape and preventing in-filling of pools (VEWH 2012). Higher flows in the lower Goulburn River are also likely to contribute to overbank flows along the central Murray River.

In regards to timing of higher freshes, spawning amongst golden perch is thought to be triggered once water temperatures exceed 17^{o}C, which is generally around late spring in the lower Goulburn (Koster et al. 2012). Also, if mature golden perch migrate between the lower Goulburn and Murray River during spawning periods, then timing of a higher fresh would best be tailored to coincide with high natural and/or environmental flows in the River Murray (Koster et al. 2012).

Flow variability

Building in flow variability is an important aim for environmental water delivery in the lower Goulburn. This has been recognised in previous environmental flow recommendations relating to the delivery of baseflows, freshes and overbank events in this system (Cottingham et al. 2010; Vic. DSE 2011).

The ecological benefits of providing flow variability relate to the encouragement of fish passage between the Goulburn River and River Murray, and the promotion of increased plant biodiversity on the banks of the lower Goulburn channel (Koster et al. 2012; Cottingham et al. 2007). In addition, flow variability can support bank stability by mitigating negative geomorphic processes, such as bank notching, that are associated with flow events maintained at stable river heights.

Inundation of the Lower Goulburn Floodplain

The Lower Goulburn Floodplain requires regular inundation in order to maintain the health of floodplain vegetation and to support key ecosystem functions and habitat requirements of native fauna (MDBA 2012i). This view is reiterated in specific overbank flow recommendations developed by Victoria DSE (2011) which advise that an annual floodplain inundation event should be re-instated for the Lower Goulburn Floodplain in the majority of years.

From an ecological perspective, an overbank event in the lower Goulburn River would be a priority environmental watering action for the coming year if suitable conditions arose. However, in the short-term there are a variety of constraints which currently prevent environmental water from being actively delivered onto the floodplain. Hence the Lower Goulburn Floodplain is not explicitly identified in this Priority.

It is important that the constraints limiting the delivery of environmental water onto the Lower Goulburn Floodplain be addressed. As required by the Basin Plan, the Authority is currently developing a Constraints Management Strategy in consultation with Basin states and the public. The strategy to be completed in 2013, will identify constraints in the system, including within the Goulburn catchment, which restrict the delivery of environmental water. The strategy will make recommendations for the remediation of key constraints, including the identification of mechanisms to mitigate any third party impacts.

If constraints restricting overbank flows in the Lower Goulburn Floodplain can be overcome, river operators and environmental water holders/managers will have greater flexibility in how environmental water is delivered in the Goulburn River. This will enable environmental water holders/managers increased opportunities to target multiple objectives throughout the Goulburn and Murray systems.

Implementation of the Priority

A large spring/summer fresh in the lower Goulburn River can be achieved through a combination of held environmental water delivered in conjunction with unregulated tributary inflows. The CEWO, VEWH and The Living Murray (TLM) together hold over 260 GL of high reliability environmental water entitlements within the Goulburn catchment. These held entitlements will have a significant influence on the achievement of the lower Goulburn River Priority.

Bankfull events in the lower Goulburn River correspond to a flow of approximately 19,000 ML/d. (Peter Cottingham & Associates and SKM 2011). At flows of about 14,000 ML/d, water starts leaving the main channel and flowing into the Wakiti Creek anabranch system before returning to the Goulburn River once river levels fall (G. Earl pers. comm. 30 April 2013). Depending on inflows, delivery of bankfull events in the lower Goulburn River may be unachievable due to the risk of flooding private land (Water Technology 2010).

As of 5 June 2013, Lake Eildon is at 69% capacity, which is above the long term average for storage volume at this time of year (G-MW 2013a). The current forecast for high-reliability water shares in the Goulburn is that 100% of entitlements will be allocated by mid-August 2013 under average inflow conditions (G-MW 2013b). As this is the main entitlement type of environmental water in this catchment, it is anticipated that environmental water holders will have significant water allocations available for use early in the 2013-14 water year.

The prevailing conditions early on in the new water year will be the determining factor on the extent to which this Priority can be achieved. Dry to moderate scenarios are likely to provide the greatest opportunity for a bankfull event, as environmental water may be added to tributary inflows to fill the channel in the lower Goulburn River. A wet scenario will provide greater tributary inflows but may also require river operators to lower environmental water releases to allow sufficient spare channel capacity to manage flooding risks. This may restrict the peak volume of the spring/summer fresh. For a very wet scenario it is unlikely that environmental water will be actively managed to achieve this Priority as it is anticipated that unregulated natural flows would provide an event close to bankfull (or above) in which case the Priority would have been met.

For a very dry scenario, there may not be sufficient flows in the Goulburn catchment for environmental water to build upon to achieve a bankfull event. In these scenarios, environmental water holders and managers can follow natural cues to deliver a spring/summer fresh of as great a volume as is practicable.

Flows from the Goulburn River provide an important contribution to environmental outcomes in the central and lower Murray. As such this Priority should be considered in conjunction with other Priorities in the southern-connected Basin, particularly the *mid-Murray River Priority* and the *lower Murray River system* Priority.

Managers of Gunbower Forest, which is located downstream of the confluence of the Goulburn and Murray Rivers, have indicated a preference for a drying phase throughout 2013-14 (Vic. NCCMA 2013a). Flows begin to enter the Gunbower Forest wetlands from the Murray River via a number of effluent streams at approximately 15,000 ML/d to 25,000 ML/d at Torrumbarry Weir (MDBA 2012j). This could potentially limit the magnitude of flows coming down the lower Goulburn River.

However, if Gunbower Forest is naturally flooded, then there would unlikely be any limitations on the flow passing down the Goulburn River. Early analysis by the MDBA indicates that the probability of Gunbower Forest incurring a natural flood event by spring (i.e. greater than 20,000ML/d at Torrumbarry) is somewhere in the order of 75% (J. Smart pers. comm. 10 April 2013).

Priority 9 — Supporting in-stream function: Mid-Murray River

Basin Annual Environmental Watering Priority

Improve habitat and provide opportunities for migration and reproduction of native fish in the mid-Murray River, including the Edward-Wakool and other smaller anabranches, distributary creeks and low-lying wetlands throughout the region.

Note: For the purposes of this Basin Annual Environmental Watering Priority (the Priority) the mid-Murray River region extends from Hume Dam to the junction of the Murray and Darling Rivers at Wentworth, including the Edward-Wakool River System.

Expected outcomes of this Priority

It is anticipated that the above Priority will facilitate the following outcomes directly related to sections 8.05, 8.06 and 8.07 of the Basin Plan:

- Support the movement, breeding and recruitment of native fish.
- Support the habitat requirements of native fish and other native species including frogs, turtles and invertebrates.
- Provide connectivity between habitats along the Murray River and its anabranches.
- Improve habitat quality in ephemeral watercourses.
- Support mobilisation, transport and dispersal of biotic and abiotic material (e.g. sediment, nutrients and organic matter).
- Support inundation of low-lying wetlands/floodplains along the Murray River channel and its anabranches.
- Maintain health of riparian, floodplain and wetland native vegetation communities.
- Reinstate a more natural wetting-drying cycle for ephemeral wetlands and watercourses.

Why is this a Priority?

The Authority considers this Priority to be of Basin significance because:

- The mid-Murray River contains an abundance of distributary creeks, anabranches and off-channel wetlands and floodplain complexes. These features play an important role in the ecosystem functioning of the overall Murray system.
- The largest anabranch in the region, the Edward-Wakool, is considered to be a highly significant breeding and recruitment ground for many native aquatic species including Murray cod (*Maccullochella peelii*) and silver perch (*Bidyanus bidyanus*). Therefore it has the potential to play a significant role in the post-drought recovery of aquatic species through the Murray River ecosystem.
- For 2013-14, inundation of certain wetlands along the mid-Murray would be desirable to continue the positive environmental outcomes of recent wet years and to build resilience amongst flora and fauna communities along the Murray River.
- Longitudinal connectivity will contribute to the overall ecosystem health of the lower Murray through to the Lower Lakes, Coorong and Murray Mouth.

Significance of region

The mid-Murray River has a number of anabranches and distributary creeks of significant ecological value (Figure 22). Of these, the largest and most well-known is the Edward-Wakool River system, which is a complex region covering more than 1,000 square kilometres of inter-connecting rivers, creeks, floodrunners and wetlands. The Edward-Wakool system supports large areas of flood dependent vegetation communities and is considered to be a significant breeding and recruitment ground for many aquatic species in the broader Murray River. In particular, it supports large populations of Murray cod and silver perch (MDBA 2012k).

There are many other smaller anabranches and creeks of note throughout the mid-Murray region. These systems have the potential to carry a diverse assemblage of aquatic species and can provide a valuable alternative habitat to the main Murray River channel. Some of these creeks can be classified as ephemeral streams, which are watercourses that do not have surface water flow for the entire year. The transfer of sediment, nutrient, salt and organic matter through these small creeks into larger river systems such as the Murray River is important for overall ecosystem function (LWA 2008).

The mid-Murray region also contains an abundance of wetlands adjacent to the main river channel (Figure 22). This includes large icon sites recognised through The Living Murray program as well as hundreds of other smaller off-channel wetlands and billabongs. These wetlands are of ecological value as they retain remnants of the natural character and attributes of the ancient Murray River floodplain, including the capacity to support a number of threatened species under state and federal legislation (Vic. Mallee CMA 2013). Whilst some of the larger wetland complexes throughout the mid-Murray are on public land, many others are located on private property.

In recognition of its high environmental value, the entire 'aquatic ecological community in the natural drainage system of the lower Murray River catchment' is listed as an 'Endangered Ecological Community' under the *NSW Fisheries Management Act 1994*. This listing includes all natural creeks, rivers and associated lagoons, billabongs and lakes of the Murray River downstream of Hume along with the Edward-Wakool (FSC 2001).

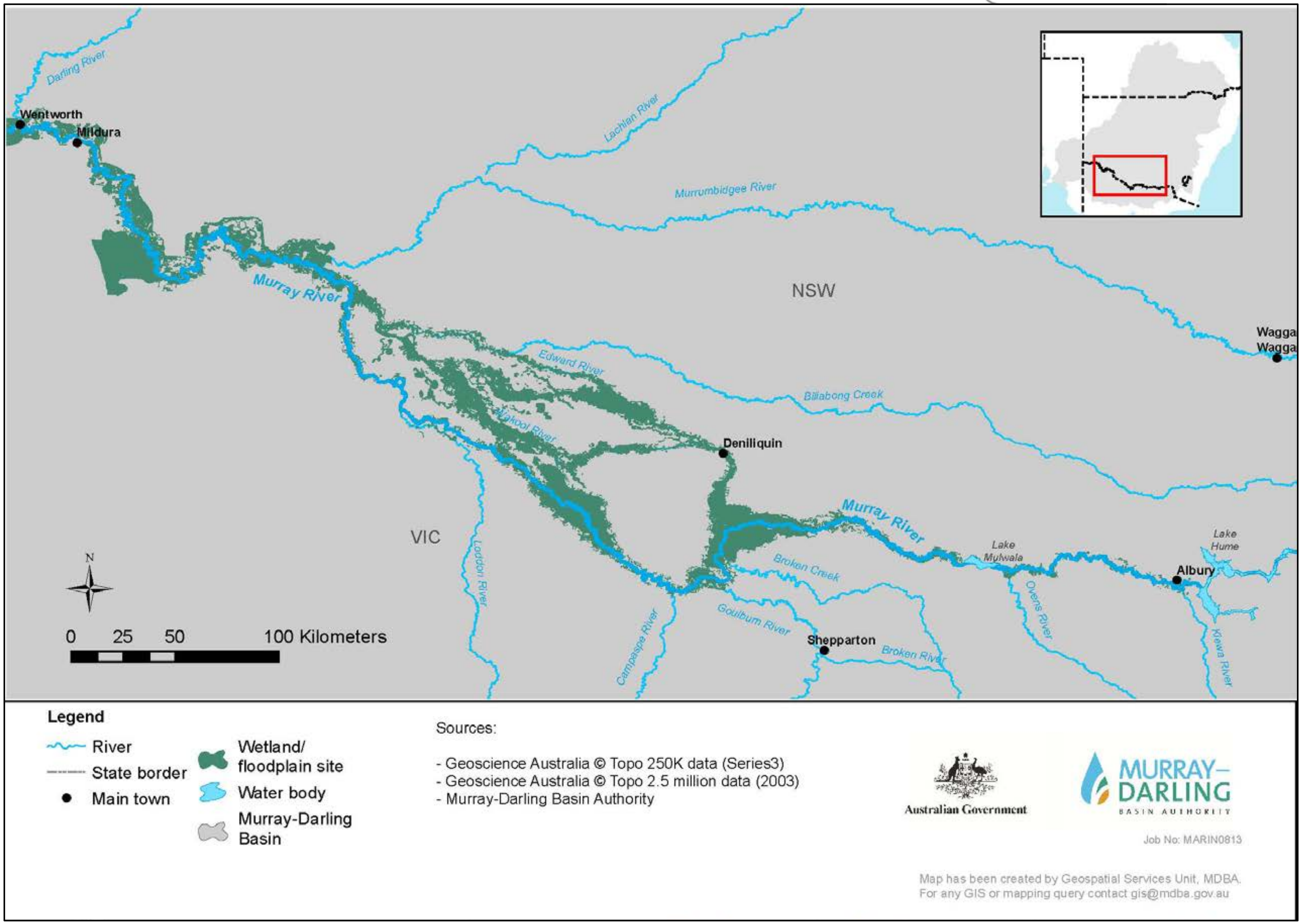

Figure 22: Map of the mid-Murray region

Condition of environmental assets and functions

The mid-Murray region received limited rainfall and inflows during 2001-2011 (Figure 23). Low flow conditions during this drought resulted in widespread ecological decline, including limited spawning and recruitment by large-bodied native fish and a reduction in vital processes such as nutrient exchange and temporary wetland inundation (MDBA 2013a).

Extensive rainfall and high inflows throughout 2010-11 and 2011-12 relieved the drought and initiated a recovery process throughout much of the mid-Murray region. Catchments were still wet leading into the commencement of 2012-13, but since September there has been limited rainfall and as a result inflows into the Murray River system have largely remained below long term averages (MDBA 2013b). For 2013-14, inundation of certain wetlands along the mid-Murray would be desirable to continue the positive environmental outcomes of recent wet years and to build resilience amongst flora and fauna communities along the Murray River (Vic. Mallee CMA 2013; NSW OEH 2013c).

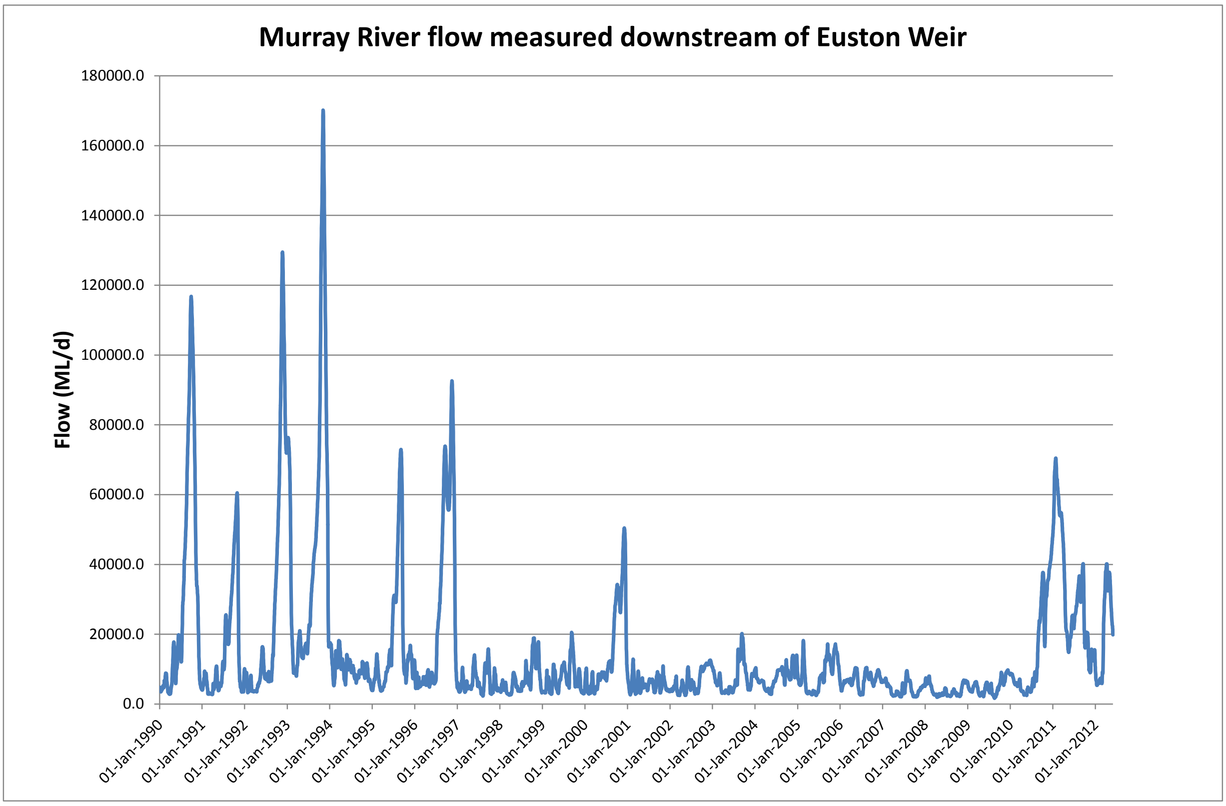

Figure 23: Flow rate of the Murray River measured at downstream of Euston Weir from 1990 to May 2013. This location was used as an indicator of total flows coming through the mid-Murray system.

In the Edward-Wakool system, the arrival of the floods of 2010-11 relieved the drought and opened up new habitat throughout the system. However, floodwaters also brought about many fish deaths due to hypoxic blackwater events. The impact of this blackwater was worsened due to the length of time between floods (which meant there were large amounts of organic matter built up on the floodplain) coupled with the higher water temperatures associated with the summer timing of the floods. In-channel environmental water pulses delivered in 2011-12 and 2012-13 aimed to promote survival and recovery of native fish from the blackwater events in this system.

Matters of Interest

Longitudinal connectivity and ecosystem function along the Murray River

The protection and restoration of connectivity within and between water-dependent ecosystems is a key objective of the Basin Plan's Environmental Watering Plan. Through this Priority, the Authority seeks to emphasise the important role of the many distributary creeks, anabranches and wetlands along the mid-Murray River. Whilst many of these assets are relatively small at the Basin-scale (with the exception of the Edward-Wakool system), their collective input into the Murray River has a significant role in the overall ecosystem function of this system.

It is important to support the recovery of the full suite of ecological assets along the mid-Murray system. In some cases this may mean providing environmental water, whilst for others a drying phase will be preferred. This is because a balance between wet and dry regimes is required for many wetlands along the mid-Murray in order to maintain their ecological integrity and promote biodiversity within the system (Vic. Mallee CMA 2012).

The ideal timing of delivery of environmental water to assets along the mid-Murray is spring. This is to reflect natural flooding times and to optimise ecological responses from native fish. Many native fish species do not spawn until water temperatures reach 18^{0}C or higher (Baumgartner et al. 2013).

Edward-Wakool

Since 2010-11 the Murray Catchment Management Authority (CMA) and partners[4] have been facilitating research into ecosystem responses to environmental flows in the Edward-Wakool (the Fish Response Project). The focus of this research has been native and alien fish habitat requirements, recruitment and movement patterns. The watering program has sought to put in place a process of adaptive management incorporating scientific research and community input to improve understanding of native fish in this system (see Baumgartner et al. 2013).

In addition to the Fish Response Project, Murray CMA, NSW Office of Environment and Heritage (OEH), the Commonwealth Environmental Water Office (CEWO) and other agencies have been actively engaging local landholders to manage environmental water in the Edward-Wakool. In the past three years these partnerships have resulted in the delivery of environmental water to many creeks and wetlands throughout the Edward-Wakool.

The Authority recognises that targeted environmental watering in the Edward-Wakool has the potential for a variety of ecosystem benefits. The reason this Priority has primarily focused on native fish is because this system provides important spawning grounds and fish habitat, particularly in times of drought, not only at a local scale but also at the broader Basin scale (MDBA 2012k).

[4] Charles Sturt University, Monash University, the Commonwealth Environmental Water Office (CEWO), NSW Department of Primary Industries (DPI) Fisheries, and NSW Office of Environment and Heritage (OEH).

Creeks, anabranches and wetlands of the mid-Murray

The mid-Murray region includes four high-value icon sites identified by The Living Murray program: the River Murray channel, Barmah-Millewa Forest, Gunbower-Koondrook-Perricoota Forest and Hattah Lakes. The focus of this Priority is the anabranches, creeks and smaller off-channel wetlands of the Murray River, which could potentially be considered as part of the River Murray channel icon site. For the other icon sites, the States, Commonwealth and the Authority have been working together under The Living Murray program to build infrastructure to assist with the active delivery of environmental water to many of these sites. Given the current status of the infrastructure and anticipated patterns of environmental water use, the Authority has chosen not to identify any of these sites as Priorities for 2013-14. This does not preclude them from watering at appropriate times with regard to completed works.

There is a vast array of ecological assets along the mid-Murray River that could be considered for environmental watering under this Priority. Examples of some of the creek and anabranch systems (outside of the Edward-Wakool region) include Speewa, Sandilong, Bengallow, Butlers, Fletchers and Washpen Creeks. Examples of wetlands include Boomanoomana Swamp, Margooya Lagoon, Heywoods Lake, Thegoa Lagoon and Round, Cardross and Koorlong Lakes; the latter three of which are known to support remnant populations of the endangered Murray Hardyhead (*Craterocephalus fluviatilis*) (NSW OEH 2013c; Vic. Mallee CMA 2013; Vic. NCCMA 2013b). Some of these sites have high commence-to-flow levels and meeting their watering requirements may be dependent on high river flows (see Implementation section).

The sites noted above are not an exhaustive list and there are likely to be other watering actions that would also be consistent with this Priority. The Authority understands that there are some knowledge gaps regarding the hydrologic connection and ecological values of many of the creeks, wetlands and anabranches along the mid-Murray system. Nonetheless environmental water holders and managers can look for opportunities to provide water to these assets in particular through coordination of flows from multiple tributaries.

Implementation of the Priority

Coordination of flows

Many ecologically significant sites of the mid-Murray region are discrete and can be managed independently of each other. However, it is the intention of this Priority that the watering of multiple sites could be coordinated so as to maximise connectivity outcomes throughout the system.

In implementing this Priority, environmental water holders and managers are encouraged to consider how tributary inputs (both natural and managed) may complement flows in the mid-Murray to increase the connectivity of waterbodies throughout the length of the system. This will require forward planning to draw linkages between the mid-Murray water requirements together with flows provided from other valleys, particularly the freshes discussed in the *lower Goulburn River* and *mid-Murrumbidgee wetlands* Priorities. Outcomes further downstream as described in the *lower Murray River system* and *Coorong, Lower Lakes and Murray Mouth* Priorities will also need to be considered. This task will be assisted by the Environmental Water Holders and River Operators Coordination Forum, which is a new group proposed to be established in 2013-14.

In meeting this Priority, environmental water holders and managers are also advised to consider natural cues as triggers for environmental water releases. This may mean delivering environmental water in response to a rainfall event or a spawning event of a particular native fish species. Further information relating to environmental watering based on natural cues is contained in the *Guiding Philosophy* that complements the Priorities for 2013-14.

Pumping and use of irrigation infrastructure

Delivery of environmental water to certain sites along the mid-Murray may require the use of irrigation infrastructure or pumps to extract water from the main Murray channel. Irrigation networks can provide an efficient means to transport environmental water by allowing targeted delivery to specific creeks and watercourses. However, depending on the timing of environmental flows, channel capacity may not be available within irrigation infrastructure to carry the additional water. The use of pumps and irrigation infrastructure also incurs additional financial costs, which can limit the ability to undertake environmental watering in this way.

Resource Availability Scenario (RAS)

In the Edward-Wakool, an event favourable for breeding of certain native fish groups (guilds) is likely to be possible under the full range of climate scenarios. Depending on rainfall and inflows, environmental water may be used to contribute to a range of flow components including base flows, freshes and the recession of bankfull and overbank flows.

Elsewhere in the mid-Murray, the ability to provide environmental water to specific sites will be heavily influenced by flows along the Murray River and its tributaries. Where possible environmental water should be used to complement and augment existing flows. This may involve releases from multiple tributaries. Coordinating flows in this manner could facilitate inundation and/or flushing many of the smaller creeks, anabranches and wetlands of the mid-Murray that may otherwise have not received inflows.

For those disconnected wetlands that cannot be watered from high in-channel flows, a wetter scenario may provide the benefit of cost efficiencies in pumping. In drier scenarios, there may be limited natural flows passing down the Murray, Goulburn and Murrumbidgee Rivers and therefore delivering water to those assets with higher commence-to-flow thresholds may not be feasible.

Priority 10 — Supporting in-stream functions: Coorong, Lower Lakes and Murray Mouth

Basin Annual Environmental Watering Priority

Facilitate Ruppia recovery by ensuring appropriate flows into the Coorong; and maintain the connection between the Lower Lakes to improve the water quality in Lake Albert.

Expected outcomes of this Priority

It is anticipated that the above Basin Annual Environmental Watering Priority (the Priority) will facilitate the following outcomes:

- Support recovery of *Ruppia tuberose* and *Ruppia megacarpa* through managing appropriate salinity and seasonal water levels in the Coorong as *Ruppia* sp. are key indicator species of the overall health of the Coorong.
- Provide suitable water levels in the Coorong for waterbirds.
- Provide suitable conditions to support spawning, pre-spawning migrations and recruitment of native fish (such as Congolli).
- Facilitate salt and nutrient export from the Murray River out of the Murray Mouth.
- Ensure hydrological connectivity between the Lower Lakes and the Coorong via the barrages and between the Coorong and Southern Ocean through an open Murray Mouth.
- Continue to improve the water quality in Lake Albert (specifically salinity levels).
- Ensure variability in the water levels of Lake Alexandrina and Lake Albert for fringing vegetation, submerged and emergent aquatic plants.

Why is this a Priority?

The Authority considers this Priority to be of Basin significance because:

- The Coorong, Lower Lakes and Murray Mouth were in a critical condition during the drought. There was reduced exchange and nutrient transport between the Lower Lakes and Coorong, an acidification threat in the Lower Lakes and high salinity levels in both the Lower Lakes and the Coorong.
- During the millennium drought, the lack of inflows resulted in high salinity spike within the Lower Lakes rendering the water quality unusable for consumptive and irrigation use and too high for many native plants and animals. This is still the case for Lake Albert.
- *Ruppia tuberosa* and *Ruppia megacarpa* are key indicator species of the overall health of the Coorong. They play a pivotal role in the Coorong's ecology and important primary producers of the system, providing a valuable food source for migratory waterbirds.
- The Coorong, Lower Lakes and Murray Mouth support a number of fish species during critical stages of their life cycles, including the nationally vulnerable Murray hardyhead (*Craterocephalus fluviatilis*) and Yarra pygmy perch (*Nannoperca obscura*).

Significance of site

Approximately 140,000 ha (of the total 142,500 ha) of the Coorong and Lakes Alexandrina and Albert (Lower Lakes) were listed under the Convention of Wetlands on International Importance (the Ramsar Convention) in 1985 (see Figure 24). This site meets eight of the nine nominating criteria for Ramsar listing (Phillips and Muller 2006) and contains 23 Ramsar wetland types. The Coorong, Lower Lakes and Murray Mouth is one of the six icon sites under The Living Murray program.

The site supports numerous water birds that rely on the wetlands for migration stop-overs, breeding habitat or as refuge during droughts. Forty-nine species of birds have been recorded, including 25 species listed under international migratory bird agreements (including Japan-Australia Migratory Bird Agreement, China-Australia Migratory Bird Agreement Republic and Republic of Korea-Australia Migratory Bird Agreement).

The Coorong and Murray Mouth is the only estuarine system in the Murray-Darling Basin and plays a significant role in the life cycle of migratory fish as it allows for movement between marine, estuarine and freshwater environments. Water flow out of the Murray Mouth is both important to export salt from the Murray-Darling Basin and to ensure tidal exchange to maintain the Coorong ecosystem (MDBA 2012l).

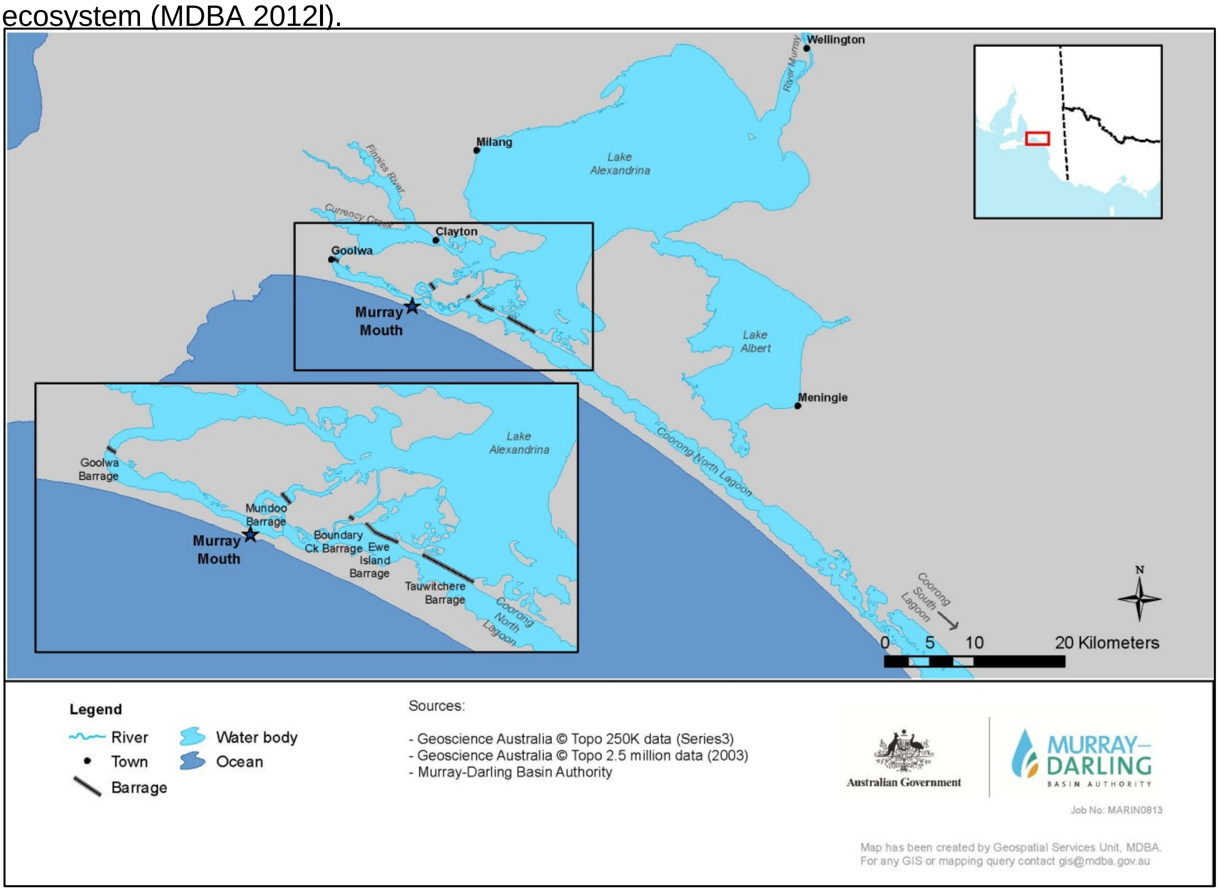

Figure 24. Coorong, Lower Lakes and Murray Mouth

Condition of environmental asset and functions

South-eastern Australia experienced a severe drought from 2000 to 2010, the millennium drought. As water levels lowered and salinity increased there was the threat of acidification in the Lower Lakes, the severe reduction in out flows from the lakes to the Coorong limited nutrient and salt discharge from the Murray-Darling Basin. There was reduced tidal exchange between the Coorong and Southern Ocean and salinity levels dramatically increased in the Coorong. These changes have been linked to a decline in abundance of *Ruppia* species, fish and waterbird species recorded in the Coorong (Brookes et al. 2009).

In an attempt to maintain the water levels in the Lower Lakes above critical acidification levels the barrages were closed from 2007 to 2010. Even with this action, acidification occurred in some of the exposed fringing habitats of the Lower Lakes as the water level dropped well below 0.0m (Australian Height Datum) AHD and much of the lake bed was exposed. As a consequence, there were no or minimal flow out of the barrages, resulting in the need for prolonged dredging of the Murray Mouth between 2002 and 2010.

Since spring 2010 there have been large inflows into the Lower Lakes, Coorong and through an open Murray Mouth from both natural high inflows and managed environmental water releases. These flows have returned the Lower Lakes to above their Full Supply Level of 0.75m AHD, facilitated critical fish movement, reconnected Lake Albert, and the Goolwa Channel to Lake Alexandrina and released large volumes of water through the barrages into the Coorong and opened the Murray Mouth without the assistance of dredging (South Australian Government 2012). The ecological monitoring results indicate the fish, mudflat invertebrates and waterbird communities are showing signs of improvement since spring 2010.

During 2012-2013 the Commonwealth Environmental Water Holder has delivered 780 GL and The Living Murray program has delivered 289 GL to the Coorong, Lower Lakes and Murray Mouth. This water assisted in reducing the high salinity levels in Lake Albert, maintaining the water levels in the Lower Lakes within the normal lake operating range and delivering flows from the Lower Lakes via the barrages into the Coorong.

Matters of Interest

Lower Lakes: Water levels and water quality

Water levels in the Lower Lakes are influenced by Murray River inflows, other smaller tributary inflows from the Eastern Mount Lofty Ranges, local evaporation and barrage operations. Water levels in the Lower Lakes fluctuate seasonally as they are generally higher in winter and lower in summer due to inflows, wind, tidal movement and evaporation (Phillips and Muller 2006).

The water level height and variability in Lakes Alexandrina and Albert influence the extent and condition of fringing vegetation, submerged and emergent aquatic plants (Phillips and Muller 2006). Current management of Lake Alexandrina and Albert ensures there is appropriate variation in water levels.

Lake Albert is a terminal lake with a narrow connection to Lake Alexandrina, hence flow into and out of Lake Albert is controlled by the water level in Lake Alexandrina, which in turn is affected by inflows, wind and evaporation (Heneker 2009). During the millennium drought, the lack of inflows resulted in high salinity within the Lower Lakes rendering the water quality unusable for consumptive and irrigation use as well as being too high for many species of flora and fauna species. While Lake Alexandrina's water quality has improved, Lake Albert still has a high salinity with a reading of 3110 EC at Menindee as of 29 May 2013 (MDBA 2013c). Lake Albert's salinity levels are currently being managed by oscillating the water levels of the two lakes to cycle freshwater in and saline water out of Lake Albert (Heneker 2009; South Australian Government 2012).

There is a significant risk of acidification in the Lower Lakes should water levels fall too low, with an estimated 85% of the sediments potentially becoming acid when exposed to air (SA DEH 2010). This acidification process can create very low pH levels, contaminate soils and lead to the deoxygenation and contamination of the Lower Lakes. This can potentially damage the significant ecology, create a risk to the quality of stock and domestic water and create a public health hazard.

To avoid broad scale acidification of the Lower Lakes, water levels must be managed above the acidification trigger levels, -0.75m AHD in Lake Albert and -1.75m AHD in Lake Alexandrina (SA DEH 2010). Whilst these acidification trigger levels provide an absolute minimum operating level for the Lower Lakes, in practice the lakes need to be managed at a higher level in order to avoid acidification issues and bank collapse (including in the Lower Lakes up to Lock 1). The Basin Plan contains an objective that water levels within the Lower Lakes are to be maintained above 0.4m AHD for 95% of the time, as far as practicable.

Ruppia recovery

Ruppia tuberosa and *Ruppia megacarpa* are the dominant benthic macrophytes in the Coorong (Nicol 2005). They have been identified as key indicators of the overall health of the Coorong (MDBA 2012l), play a pivotal role in the Coorong's ecology (Brookes et al 2009), are considered to be important primary producers of the Coorong and provide a valuable food source for local and migratory waterbirds (Nicol 2005). *Ruppia* species provide habitat and food resources for a range of species, including waterbirds. Therefore, providing appropriate conditions for these *Ruppia* species will provide appropriate conditions for the broader Coorong ecosystem (MDBA 2012l).

The distribution of the two species differs in response to the salinity levels, water depth and turbidity in the Coorong (Carruthers et al. 1999). *Ruppia turberosa* is more prevalent in the higher saline waters of the Coorong's South Lagoon (Overton et al. 2009; MDBA 2012l) and *Ruppia megacarpa* is common in the less saline waters of the Coorong's North Lagoon and in the Lower Lakes (Carruthers et al. 1999; MDBA 2012l). Salinity levels in the Coorong are influenced by two mechanisms, the water released by the barrages and through tidal exchange with the Southern Ocean. There is also some limited flow into the South Lagoon of the Coorong via the Upper South East Drainage Scheme which is important for reducing salinity in the South Lagoon.

Native fish

The Coorong, Lower Lakes and Murray Mouth support a large number of fish during critical stages of their life cycles. Of the 49 species of native fish recorded, 20 species utilise the site at critical stages of their life cycle (MDBA 2012l). This includes the nationally vulnerable Murray hardyhead and Yarra pygmy perch (*Environment Protection and Biodiversity Conservation Act 1999*).

Murray hardyhead is an omnivorous small-bodied native freshwater species that is nationally critically-endangered. Even though they are freshwater species, they are also found in habitats with high salinity levels (Wedderburn et al. 2008 cited in South Australian Government 2011). The Murray hardyhead's distribution is patchy within the Murray-Darling Basin (Treadwell and Hardwick 2003 cited in South Australian Government 2011). Prior to the reduction of water levels in the Lower Lakes during the drought they were found in wetland and irrigation channels on Hindmarsh

Island and sheltered lake-edge habitats of Goolwa Channel, Clayton, Milang Bay and Lake Albert (Wedderburn and Hammer 2003 cited in South Australian Government 2011).

Yarra pygmy perch is a small-bodied native freshwater fish restricted in distribution to wetlands and irrigation channels on Hindmarsh Island, lower Finniss River and the edge of Goolwa Channel (Higham et al. 2005a, Bice and Ye 2007, Hammer 2007 cited in South Australian Government 2011). This species is found in habitats with submerged and in-stream aquatic vegetation (Allen et al. 2002, Woodward and Malone 2002, Wedderburn and Hammer 2003 cited in South Australian Government 2011). During the drought some of these areas were disconnected from their water source (Hammer unpub. data), which caused a decline in the species.

Congolli (*Pseudaphritis urvillii*) are diadromous fish (i.e. fish that undertake obligate migrations between marine and freshwater environments) endemic to the coastal rivers of South-Eastern Australia (David et al. 2010; Zampatti et al. 2011). Adult Congolli spawn in estuarine or marine environments (following the female's downstream migration from freshwater) and juveniles migrate back upstream. Connectivity between the Lower Lakes and Coorong is essential during the peak downstream migration period for female Congolli (June to August) to allow for breeding and recruitment of the species. It is recommended that barrage gates and fishways are open and operational to allow for fish passage between the Lower Lakes and Coorong and to preserve Congolli populations in the Murray-Darling Basin. In addition to the movement between the Lower Lakes and Coorong, it is important to facilitate the upstream movement of juvenile fish during late spring and summer (Zampatti et al. 2011).

Implementation of the Priority

The prevailing conditions early in the water year will determine the extent to which this Priority can be achieved. At the time of preparing the Priority, the Resource Availability Scenarios (RAS) outlook predictions for 2013-14 range from wet to dry. It is anticipated that the Priority will be met across the full range of RAS, however, the scale of a watering event will vary with the RAS. During dry scenarios not all planned activities will be possible.

In very wet and wet scenarios (i.e. extremely high or high inflows) it is expected that sustained unregulated (natural) flows could achieve a significant proportion of the Priority. In these scenarios held environmental water may not be required during the flood peak but may be used to extend the duration of the peak.

In a moderate scenario (or inflows) it is unlikely that unregulated flows will achieve a significant proportion of the Priority and the use of held environmental water will be required to meet the Priority.

In a very dry scenario environmental water holders and managers may focus on maintaining the water levels in the Lower Lakes rather than releasing water through the barrages. However this will be dependent on the water availability outlook and risk of dry conditions continuing.

Maximising outcomes

Delivery of water to the Lower Lakes can be constrained by limitations on channel capacity in the Murray River during summer and autumn, channel capacity below Menindee Lakes in the Lower Darling, outlet capacity of Lake Victoria and travel times and re-regulation capacity along the Murray River. In addition, as part of The Living Murray program, the Riverine Recovery program and state construction activities there are works under construction along the Murray River and the delivery of larger flows might exceed the inundation thresholds for these projects.

To meet this Priority environmental water holders and managers are encouraged to consider how flows (both natural and managed) can be coordinated between valleys, which can include using managed releases from Hume Reservoir, Lake Victoria and Menindee Lakes, natural Murray River inflows and return flows from tributaries such as the Goulburn and Lower Darling Rivers. Implementation of this Priority also needs to consider, build on and compliment the *Barwon-Darling River*, *mid-Murray River* and the *lower Murray River system* Priority.

Timing of environmental water delivery

To allow for water movement between Lake Alexandria, Coorong and the Southern Ocean, assist in maintaining an open Murray Mouth and to reduce salinity in the South Lagoon it is recommended that low level barrage releases occur year-round (MDBA 2012m). Ideally, environmental water will be delivered in response to natural cues (see Guiding Philosophy to *deliver water in response to natural cues*) and barrage releases will start to increase from spring (i.e. October 2013), peak during mid-summer and then reduce over late summer (i.e. February 2014). This summer peak will mitigate falling water levels in the Lower Lakes and Coorong, provide cues for Congolli recruitment, inundate the Coorong’s mudflats to allow the reproduction of *Ruppia tuberosa* (MDBA 2012m). The gradual reduction of barrage releases over late summer will expose feeding habitat for migratory wading birds on mudflats at the edge of the Coorong and Lower Lakes (MDBA 2012m).

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