



**Australian Government**

**Commonwealth Environmental Water**



## ENVIRONMENTAL WATER DELIVERY

Lachlan River

DECEMBER 2011 V1.0



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The next generation of straw-necked ibis at Booligal breeding colony  
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# Environmental Water Delivery: Lachlan River system

Increased volumes of environmental water are now becoming available in the Murray Darling Basin this will allow a larger and broader program of environmental watering. It is particularly important that managers of environmental water seek regular input and suggestions from the community as to how we can achieve the best possible approach. As part of the consultation process for Commonwealth environmental water we are seeking information on:

- community views on environmental assets and the health of these assets
- views on the prioritisation of environmental water use
- potential partnership arrangements for the management of environmental water
- possible arrangements for the monitoring, evaluation and reporting (MER) of environmental water use.

This document has been prepared to provide information on the environmental assets and potential environmental water use in the Lachlan River catchment. As the first version of the document, it is intended to provide a starting point for discussions on environmental water use. As such, suggestions and feedback on the document are encouraged and will be used to inform planning for environmental water use and future iterations of the document.

The Lachlan supports important ecological values including over 470,000 hectares of wetlands. Potential water use options for the Lachlan include delivering water to Muggabah Creek to improve hydrological connectivity within the Booligal wetland system as well as providing low-level inundation of the lower Lachlan and associated wetlands, including Lake Ita and Lake Waljeers. Environmental water could also be used to support colonial nesting waterbird breeding events, should they occur.

A key aim in undertaking this work was to prepare scalable water-use strategies that maximise the efficiency of water use and anticipate different climatic circumstances. Operational opportunities and constraints have been identified and delivery options prepared. This has been done in a manner that will assist the community and environmental water managers in considering the issues and developing multi-year water-use plans.

The work has been undertaken by consultants on behalf of the Australian Government Department of Sustainability, Environment, Water, Population and Communities. Previously prepared work has been drawn upon and discussions have occurred with organisations such as the New South Wales Office of Environment and Heritage, and the State Water Corporation.

Management of environmental water will be an adaptive process. There will always be areas of potential improvement. Comments and suggestions, including on possible partnership arrangements, are very welcome and can be provided directly to [ewater@environment.gov.au](mailto:ewater@environment.gov.au). Further information about Commonwealth environmental water can be found at [www.environment.gov.au/ewater](http://www.environment.gov.au/ewater).

Commonwealth Environmental Water  
Department of Sustainability, Environment, Water Population and Communities  
GPO Box 787, Canberra ACT 2601  
Tel: +61 2 6275 9245

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# Abbreviations

AEW	Adaptive environmental water
CAMBA	China–Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTF	Commence-to-fill
NSW I&I	NSW Department of Industry and Investment
DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts
DIPNR	NSW Department of Infrastructure Planning and Natural Resources
DLWC	NSW Department of Land and Water Conservation
DPI	NSW Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
DWR	NSW Department of Water Resources
EPBC	Environment Protection and Biodiversity Conservation Act 1999 (Cwlth)
ECA	Environmental contingency allowance
EW	Environmental water
EWAs	Environmental water allowances
EWR	Environmental Water Holder
FNSW	Forests New South Wales
GCS	Great Cumbung Swamp
GS	General security
IQQM	Integrated Quantity and Quality Model
IMEF	Integrated Monitoring of Environmental Flows program
ISRAG	Independent Sustainable Rivers Audit Group
IUCN	International Union for Conservation of Nature
JAMBA	Japan–Australia Migratory Bird Agreement
LCMA	Lachlan Catchment Management Authority
LEWMP	The Lachlan Environmental Water Management Plan

LRWG	Lachlan Riverine Working Group
MCA	Multi-criteria analysis
MEP	Monitoring Evaluation Plan
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MLD EWAG	Murray Lower Darling Environmental Water Advisory Group
MWWG	Murray Wetlands Working Group
NSW	New South Wales
NOW	NSW Office of Water
OEH	NSW Office of Environment and Heritage
RERP	Rivers Environmental Restoration Program
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
SRA	Sustainable Rivers Audit
TLM	The Living Murray program
WMA	Water Management Area
WSP	Water Sharing Plan



## **PART 1:** Management aims



# 1. Overview

## 1.1 Scope and purpose of this document

Information in this document is intended to help establish an operational planning framework that provides scalable strategies for environmental water use based on the demand profiles for selected assets. This document outlines the processes and mechanisms that will enable water-use strategies to be implemented in the context of river operations and delivery arrangements, water trading and governance, constraints and opportunities. It specifically targets water-use options for large volumes of environmental water.

To maximise the systems' benefit, three scales of watering objectives are expressed:

1. water management area (individual wetland features/sites within an asset)
2. asset objectives (related to different water-resource scenarios)
3. broader river-system objectives across and between assets.

As part of this project, assets and potential watering options have been identified for regions across the Murray-Darling Basin. This work has been undertaken in three steps:

1. Existing information for selected environmental assets has been collated to establish asset profiles, which include information on hydrological requirements and the management arrangements necessary to deliver water to meet ecological objectives for individual assets.
2. Water-use options have been developed for each asset to meet watering objectives under a range of volume scenarios. Use of environmental water will aim to maximise environmental outcomes at multiple assets, where possible. Water-use options will provide an 'event ready' basis for the use of environmental water. Options are expected to be integrated into a five-year water delivery program.
3. Processes and mechanisms that are required to operationalise environmental water-use strategies are documented and include such things as:
  - delivery arrangements and operating procedures
  - water-delivery accounting methods that are either currently in operation at each asset or methodologies that could be applied for accurate accounting of inflow, return flows and water 'consumption'
  - decision triggers for selecting any combination of water-use options
  - approvals and legal mechanisms for delivery and indicative costs for implementation.

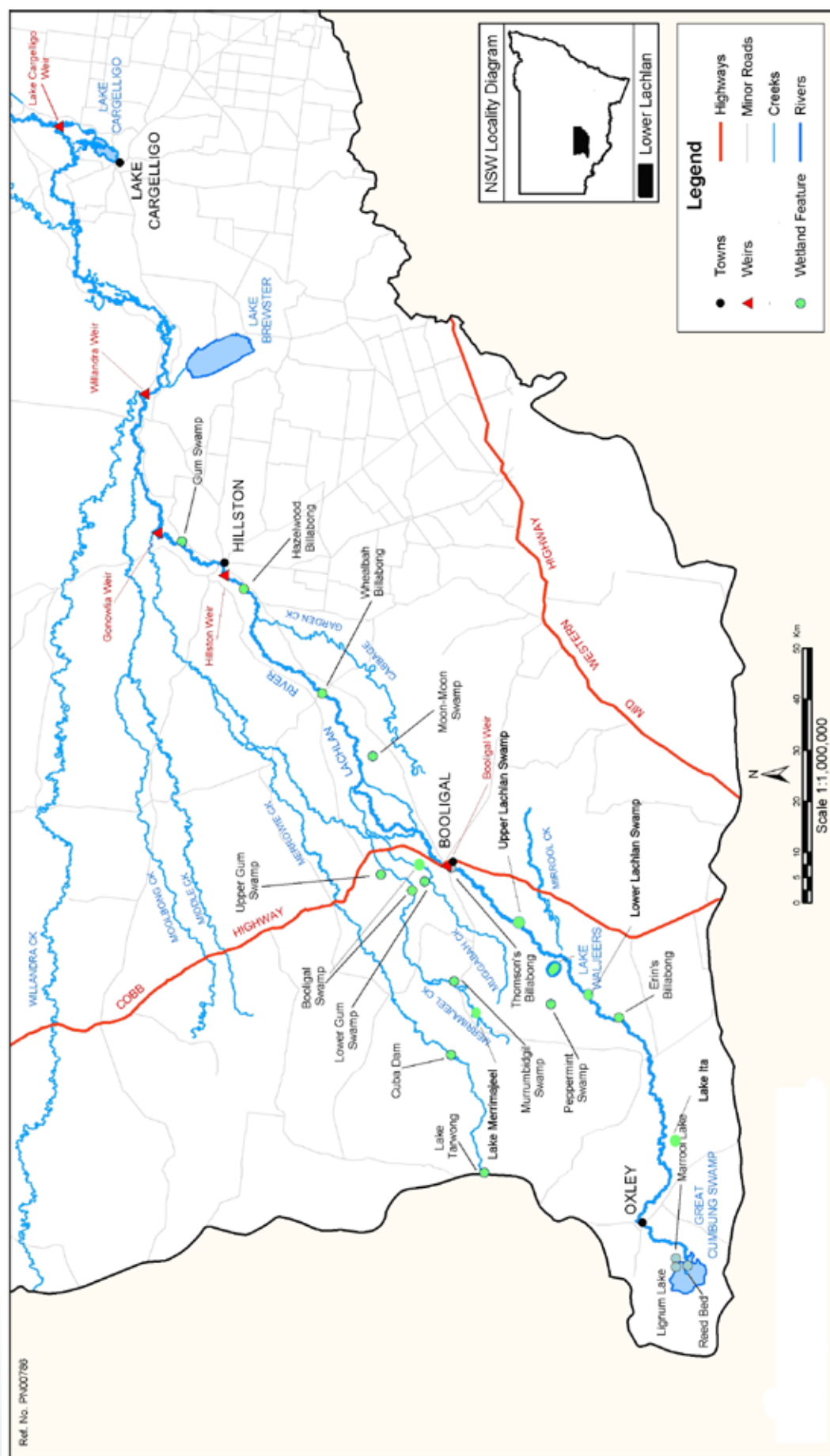
This document focuses on the delivery of water to the Lachlan system to achieve positive environmental outcomes.

## 1.2 Catchment and river system overview

The Lachlan River covers 8 per cent of the Murray-Darling Basin. It is bordered by the Great Dividing Range on the east, the Macquarie River to the north, by the Murrumbidgee River to the south and the Darling catchments in the north-west. The catchment is a virtual-terminal system, with the Lachlan River ending in the extensive wetlands of the Great Cumbung Swamp (Figure 1). A more detailed map of the lower Lachlan wetlands is provided in Figure 2.







The catchment's major water storage is the Wyangala Dam with a storage capacity of 1,218,000 megalitres. There are a series of minor in-stream storages along the Lachlan, including the Carcoar Dam (36,000 megalitres) and Brewster Weir (5,500 megalitres). Major off-stream storages include Lake Cargelligo (36,000 megalitres) and Lake Brewster (145,000 megalitres<sup>1</sup>) near Hillston. Recently, works have been undertaken at Lake Brewster to change its storage characteristics, so the storage capacity is uncertain—see section 6.3.

Floodplain wetlands cover some 400,000 hectares along the river, starting downstream of Forbes with the Lake Cowal system, billabong habitats in the Condobolin anabranch section and large wetland systems downstream of Lake Brewster. The wetlands also cover effluent creeks (Figures 1 and 2).

There are nine nationally important wetlands in the Lachlan catchment:

- Booligal Wetlands
- Murrumbidgee Swamp/Lake Merrimajee (part of the Booligal Wetlands system)
- Cuba Dam
- Merrowie Creek (Cuba Dam to Chilichil Swamp)
- The Great Cumbung Swamp
- Lachlan Swamp (part of mid-Lachlan wetlands)
- Lake Brewster
- Lake Cowal/Wilbertroy Wetlands
- Lower Mirrool Creek Floodplain (Mirrool Creek is a tributary of the Lachlan which joins the river downstream of Booligal and upstream of the Lachlan Swamps; the downstream portion of the creek is an integral part of water management for the Murrumbidgee Irrigation Area, e.g. Barrenbox Swamp).

The Lachlan Environmental Water Management Plan (LEWMP) also identifies nine regionally significant wetlands that represent areas which have been recognised for their contribution to the Lachlan landscape. The regionally important wetlands include:

- Lake Cargelligo
- Lake Ita (as part of the Lachlan Swamp)
- Burrawang West Lagoon
- Willandra Creek
- Moon Moon Swamp
- Yarnel Lagoon
- Baconian Swamp (as part of the Cumbung)
- Upper Merrowie Creek
- Mid-Lachlan Floodplain and Billabongs.

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<sup>1</sup> The Lake Brewster water storage has recently undergone a series of works to reconfigure the storage to try and improve the quality of water releases and its effective storage capacity (see asset profile and information in section 6.3). After many years of being dry, storage of water in the lake has only recently occurred and will also continue with the current flood events. Therefore at this time the actual storage capacity of the lake is unknown and will be established as operational knowledge increases.

## 1.3 Overview of river operating environment

In developing this document, efficient use and delivery of environmental water is a primary consideration. In this context the following background is relevant and is based (but not entirely) on information from BWR (2010), a study which examined the water delivery and ecological conditions for six wetland areas (Moon Moon Swamp, Murrumbidgee Swamp, Lake Merrimajeele, Lower Gum Swamp, Ita Lake and Baconian Swamp) as of winter 2009.

The Lachlan is a very long river with many anabranches and distributary (effluent) creeks both in the section near Condobolin and primarily on the lower river downstream of Lake Brewster. Consequently, the river's channel capacity varies significantly, with it becoming a smaller channel particularly around the Condobolin anabranch area, and progressively downstream of Lake Brewster due to the effects of the distributary channels. (Section 5.1.3 provides details on channel capacities.)

Sources of environmental water in the Lachlan are an important consideration when assessing delivery efficiency. The river regulation storages where this water would reside are Wyangala Dam, Lake Cargelligo, Lake Brewster and Brewster Weir. The storage capacities of the lakes are relatively small compared to Wyangala Dam and historically both reach very low levels each year. The two re-regulating lakes and Brewster Weir are the closest to the target wetlands and are traditionally used to supply stock and domestic water to the downstream river and some creeks, and for some irrigation extraction largely around Hillston. On nearly all occasions in the past, Lake Brewster releases have been used to support colonial waterbird breeding events at Booligal Swamp.

It is important to emphasise that the existence of the two re-regulating storages of Lake Cargelligo and particularly Lake Brewster has major implications for the operation of the Lachlan River. When water is stored in Lake Brewster the river operates as two rivers, that is, Wyangala to Brewster Weir and Brewster Weir to Oxley. When Lake Brewster is empty, the river is operated from Wyangala Dam.

Other sources of water for the Lachlan River come from tributary streams which enter the river below Wyangala Dam, with the main ones being:

- Boorowa River, which enters the river upstream of Cowra
- Belabula River, which is partially regulated by Carcoar Dam, and enters the river downstream of Cowra
- Mandagery Creek which enters the river at Eugowra
- Goobang Creek which enters the river downstream of Forbes
- Mirrool Creek which very rarely provides flows downstream of Booligal.

For the unregulated flows upstream of Lakes Cargelligo and Brewster, it is important to note that these flows provide a highly natural flow regime for the many kilometres of river channel. The filling of these lakes and re-regulation of flows can have a significant influence on the downstream flow regime.

## 1.4 Environmental water policy on the Lachlan

Environmental water was first provided on an informal ad hoc basis in 1984 to sustain a waterbird-breeding event at Booligal Swamp. This arrangement continued until 1992 when a water policy for the river was established, with provisions for 100,000 megalitres and later an 80,000-megalitre environmental contingency allowance in Wyangala Dam. This water was available on a reactive basis for waterbird breeding events and water quality reasons.

In 1998, environmental flow rules were adopted as part of NSW water reforms. These flow rules established up to 350,000 megalitres of translucency environmental flows, which were subsequently adopted (with some changes) in the Water Sharing Plan (see section 2.1). The flow rules also established a 10,000 ML/yr environmental contingency allowance with carryover provisions. These rules operated from 1998 to the end of the 2003 water year and were subsequently adopted (with some changes) by the 2004 Water Sharing Plan (see section 2.1).

Translucent flows were released from Wyangala Dam in 1998, however these were subsequently subsumed by large flood events that year. Smaller translucency events occurred in 1999. The full 350,000 megalitres of translucency flow were provided in 2000, followed by another 105,000 megalitres in 2001. The Lachlan then entered a very dry period, with no translucent flows occurring under the Water Sharing Plan which was suspended in 2004 and did not recommence until 1 July 2011, the beginning of the 2011–12 water year.

More information on translucency flows can be found in section 2.1.

## 1.5 Water Sharing Plan provisions for environmental water

The NSW Water Sharing Plan commenced on 1 July 2004, but was soon suspended due to record low inflows to the system. The NSW Office of Water implemented drought contingency rules from 2004 until the end of the 2010–11 water year, due to major inflows into the river. Water Sharing Plan rules for the Lachlan were reinstated on 1 July 2011.

Details of the environmental water provisions are provided in section 8.1.

## 1.6 Flow characteristics

Mean annual flow of the Lachlan River is around 1,325 GL/yr and exhibits extreme variability. Prior to river regulation the Lachlan had long periods of no flow, including sites as far upstream as Cowra, with examples outlined below (DLWC 1998):

- Cowra—no flow for 111 days between March to June 1908
- Forbes—no flow for 224 days between December 1898 to July 1899
- Booligal—no flow for 228 days between December 1919 to July 1920.

No flow periods no longer occur at Cowra and Forbes and are rare at Booligal. The natural flow regime of the river under unregulated conditions was dominated by high flows in winter and spring, with low flows in summer and autumn. River regulation and water use on the Lachlan has affected the flow regime, although it retains elements of the natural regime.

Figure 3 and Table 1 illustrate the change in flows at selected sites.



**Table 1:** Change in flows on the Lachlan River under unregulated and regulated conditions (DLWC 1998).

Location	Unregulated winter daily mean flow (ML/d)	Regulated winter daily mean flow (ML/d)	Unregulated summer daily mean flow (ML/d)	Regulated summer daily mean flow (ML/d)
Forbes	5,220	3,800	1,130	2,170
Condobolin	3,890	2,790	965	1,350
Booligal	1,020	570	542	340
Oxley	565	295	549	340

Note: These modelled data were prior to the summer irrigation, mostly cotton growing, becoming more popular in the Lachlan and likely does not represent current circumstances. Similar model outputs for current conditions would need to be provided by the NSW Office of Water.

## 1.7 Irrigation demand

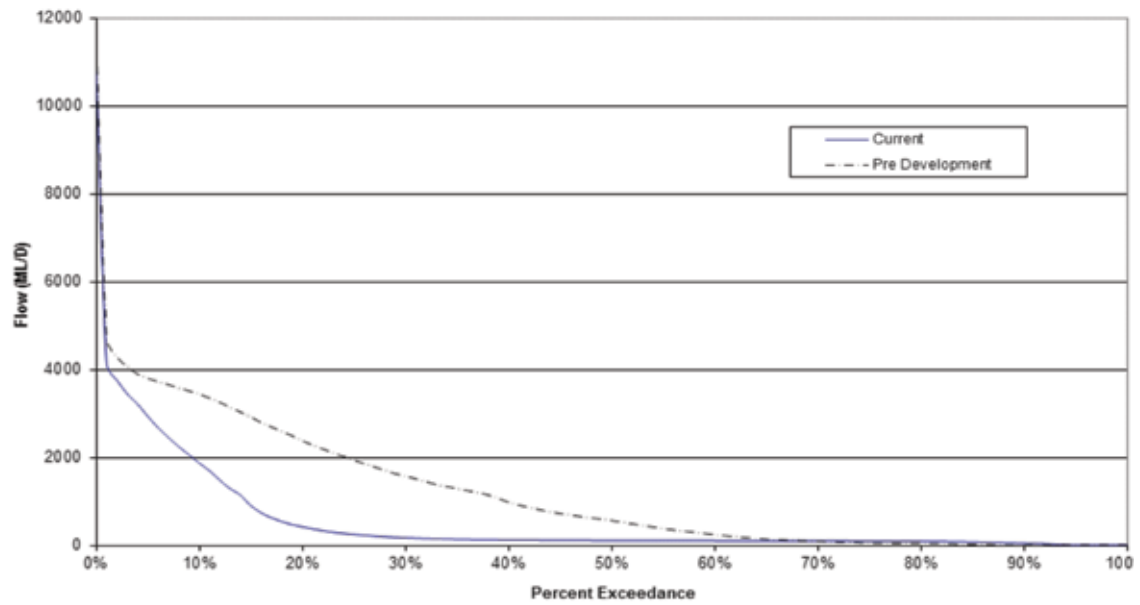
Irrigation demand is spread along the Lachlan River but has two areas of concentration, namely at Jemalong Weir where bulk diversions are made to the Jemalong Irrigation Area, and around Hillston where there has been major growth in irrigation over the past 20 years. The Hillston irrigation is from both river and groundwater sources. There is very little irrigation downstream of the Whealbah area which is located downstream of Hillston.

## 1.8 Flow-monitoring sites

There are a large number of flow-monitoring stations along the regulated Lachlan River and also the effluent creeks. The NSW Office of Water's real-time website provides information on these sites, and also a wide range of flow data and water quality information on the Lachlan catchment. See <http://realtimedata.water.nsw.gov.au/water.stm>.

## 1.9 Hydrology modelling

The NSW Office of Water's Lachlan Integrated Quantity and Quality Model (IQQM) is used to represent flow relationships for the regulated river. The model can be used for a wide range of scenarios for different water sharing and distribution arrangements for the river's main channel. Recently, Barma et al. (2010) developed hydrology models for the NSW Office of Water for 19 wetland systems downstream of Hillston and it is now possible to extend the river water sharing and distribution scenario modelling arrangements to these wetlands. These models could be used to examine different scenarios for environmental water use patterns and outcomes.



**Figure 3:** Change in Lachlan River flow regime at Booligal

## 2. Ecological values, processes and objectives

The Lachlan catchment is a unique region within the Basin. The Lachlan River, under average flow conditions, terminates in wetlands and distributary creeks, with channels extending up to 180 kilometres in length. The Lachlan catchment is the only terminal system in the Basin, and its streams and wetlands support important riverine ecosystems and an array of wildlife (Lachlan Catchment Management Authority (LCMA) 2006).

The Lachlan region supports approximately 470,000 hectares of wetlands, 95 per cent of which occur on the lower Lachlan floodplain (Armstrong, Kingsford & Jenkins 2009). As a result of water regulation and agricultural development, riparian zones and floodplains in the Lachlan have been greatly altered and disconnected. This disconnection has caused a decline in the health of some wetlands, associated riparian zones and habitat. Riparian and wetland condition has also been affected by the introduction of a number of exotic species (e.g. willow trees, lippia and carp). The Lachlan wetlands on the lower river floodplain are of regional and national importance because they support large colonial waterbird breeding events as well as a number of rare, endangered and vulnerable species (CSIRO 2008).

The entire aquatic ecological community of the lower Lachlan River, which is defined as the Lachlan River downstream of Wyangala to the Great Cumbung Swamp, is listed as an endangered ecological community in NSW under the provisions of the *Fisheries Management Act 1994* (NSW). Historically, this area has supported a diverse aquatic community comprising at least 19 native fish species, 10 crustacean species, 8 mollusc species, 2 sponge species and many insects (DPI 2006). River regulation, land management practices (e.g. riparian clearing) and species introductions, however, have resulted in substantial modifications to aquatic habitats in the lower Lachlan and the abundance and distribution of many aquatic species have exhibited considerable reductions. In particular, four native fish species (Macquarie perch, trout cod, southern pygmy perch and purple-spotted gudgeon) and the freshwater river snail are listed in the schedules of the *Threatened Species Conservation Act 1995* (NSW) as either endangered, vulnerable or with endangered populations in the western region.

Under the *Fisheries Management Act 1994* (NSW), the key threatening factors that affect the lower Lachlan aquatic ecological community are in-stream structures and other mechanisms that alter natural flow, exotic species and the degradation of native water-dependent vegetation.

The key values of a catchment are defined as the ecological components, processes and sites of significance known to contribute to the essential character of the catchment. In the Lachlan these have been identified as riparian areas as they filter sediments and pollutants, slow run-off and provide wildlife habitat, and are the last line of defence for aquatic ecosystems from terrestrial inputs. Other values of the catchment include:

- waterbirds, native fish and frogs and their habitats
- semi-permanent wetland vegetation, such as river red gum forest, reed grasslands, black box woodlands
- gilgai depressions
- open-water lagoons
- a chain of ponds or swampy meadows in the upper catchment.

Waterbirds are a valued component of the Lachlan catchment, making up a large proportion of the faunal biomass within the lower catchment. Waterbirds tend to have preferred locations and vegetation for shelter and nest sites. Species that have been recorded using habitats within the lower Lachlan, and that are under international agreements, include the great egret, glossy ibis, bar-tailed godwit, common greenshank, common sandpiper, Latham's snipe, long-toed stint, painted snipe and the white-bellied sea-eagle (see Appendix 1). In 2010–11 there were two substantial colonial nesting waterbird breeding events, predominantly involving straw-necked ibis in the lower Lachlan and a major pelican breeding event in Lake Brewster.

The minimum requirement for successful colonial nesting waterbird breeding is flooding of sufficient volume and duration to inundate colony sites and feeding areas for a minimum of four to five months between August and March. These flows are also critical for maintaining wetland vegetation, and for the completion of life cycles of aquatic invertebrates (Jenkins 2006).

A number of important native fish species are also known to occur in the Lachlan catchment. These include the Macquarie perch, Murray cod, silver perch, olive perchlet and purple-spotted gudgeon (see Appendix 1).

Important fish habitats have been identified in the Lachlan, including the Lachlan River around Warroo Bridge, the Lachlan River and Goobang Creek near Condobolin, the Lachlan River and Mountain Creek near Brewster Weir and the Lachlan River between Gonowlia and Booligal Weirs. Recently a population of 2,000 olive perchlets have been stocked into the river upstream of Lake Cargelligo Weir to try and re-establish this species. These fish were sourced from the Mountain Creek population (DPI 2011).

A number of threatened and/or endangered frog species have been recorded in the Lachlan catchment. These includes the yellow-spotted bell frog (*Litoria castenea*) which was recently discovered in the Southern Tablelands of the upper Lachlan catchment. The yellow-spotted bell frog is listed as critically endangered under the *Threatened Species Conservation Act 1995* (NSW) and as endangered under the *Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth). Another threatened species, the southern bell frog (*Litoria raniformis*), was previously known to occur in the catchment but has not been recorded in the area over recent years (Wassens 2005). This frog species is associated with many wetland types, preferring slow-flowing natural water bodies containing emergent aquatic vegetation. Sloane's froglet (*Crinia sloanei*) is listed as a vulnerable species under the *Threatened Species Conservation Act 1995* (NSW), and was recorded in an area around Merrowie Creek during the 2010 replenishment (see section 2.1 on Water Sharing Plan) and environmental flows (P Packard (OEH) 2011, pers. comm.).

In addition, Yarnel Lagoon and Burrawang West are known to support breeding populations of a number of other frog species including the barking marsh frog (*Limnodynastes fletcheri*), Peron's tree frog (*Litoria peronii*), the inland banjo frog (*Limnodynastes interioris*) and the desert tree frog (*Litoria rubella*) (Wassens & Maher 2010). The delivery of appropriate flows to these wetlands is essential to maintaining these important frog populations.

Extensive river red gum floodplain forests and woodlands form a distinctive and important part of the floodplain character of the Lachlan. The community was assessed by Benson (2006) as "vulnerable" at the landscape level, as approximately only 50 per cent of its extent (prior to European settlement) remains in western NSW. River red gum is important because it provides waterbird nesting sites and habitat for many animals, including woodland birds.

After prolonged drought in the Lachlan, large areas of river red gums became extremely stressed. By 2010 a substantial percentage of the river red gums, previously identified as stressed, had apparently died. A study on the effect of river regulation on river red gums on the Booligal Wetlands indicated that there had also been a significant decline in river red gum populations in that area as a result of river regulation (Armstrong, Kingsford & Jenkins 2009). However, following the flooding in 2010–11 there is anecdotal evidence of a significant recovery in the health of at least some river red gum trees.

The drought has also resulted in the nature of some areas of river red gum woodland and forest changing, with an increase in the area of understorey species suited to drier conditions, such as dryland grasses and chenopods. One indicator of changing flow regime in parts of the lower Lachlan is the colonisation of some areas of river red gum woodland by dryland species, including saltbush.

Extensive stands of common reed (approximately 4,000 hectares) are a distinctive part of the character of the Great Cumbung Swamp, which is listed in the *Directory of Nationally Important Wetlands*. Common reed is known to provide a wide range of habitats and is a major drought refuge. To maintain vigour, it is estimated that flooding is required at least one in every five years (Roberts & Marston 2000).

Another important semi-aquatic vegetation species is water couch, providing habitat and food for a large variety of fauna. It does not tolerate grazing well when water stressed, or when persistently grazed under water. However, recent research suggests that under suitable flow conditions, grazing is a factor in maintaining the dominance of water couch in grassy wetland communities (Wilson et al. 2008).

Black box occurs most commonly in the ephemeral wetland vegetation zone in the Lachlan. Black box woodland is found on flat to slightly undulating landscapes on alluvial soils within rainfall ranges of between 250 millimetres to 450 millimetres a year, and is generally bordered by river red gum or grassland ecosystems. It may also be associated with an understory of saltbushes and short-lived herbs and grasses, with occasional patches of lignum. It provides valuable waterbird breeding habitat, especially for ibis, and has also been assessed by Benson (2006) as being "vulnerable" in NSW.

Less dominant species are also associated with lower Lachlan floodplains, including river cooba, coolibah and myall. Little is known about the ecology of river cooba (*Acacia stenophylla*), which in the Lachlan is mostly found in the lower catchment and is often associated with river red gum or lignum. The species provides valuable nesting habitat, especially for colonial nesting species (Kingsford & Johnson 1998; Kingsford & Auld 2005). Coolibah–black box woodland is listed as an endangered ecological community (EEC) under the *Threatened Species Conservation Act 1995* (NSW), and coolibah open woodland is considered by Benson (2006) to be an "endangered" plant community in NSW. Coolibah occurs in some wetter parts of marsh areas in association with river red gum, although the plant occurs more commonly in less frequently flooded sites, between river red gum and black box woodlands.



Myall or weeping myall woodland is listed as an endangered ecological community under the *Threatened Species Conservation Act 1995* (NSW). Only 14 per cent of the extent (prior to European settlement) of weeping myall woodland remains in NSW and has been assessed by Benson (2006) as an “endangered” plant community. Despite its endangered status, little is known of the ecological requirements of myall. The structure and composition of the community varies, particularly with latitude, as saltbush is more prominent in the western areas of the Lachlan catchment, while other woody species and summer grasses are more common further east. In some areas the shrub stratum may have been reduced or eliminated by clearing or heavy grazing.

Gilgai depressions are small ephemeral pools, usually only a few metres across and less than 30 centimetres deep, and are reasonably common through the mid-and-lower Lachlan. They often support weeping myall, *belah* (*Casuarina cristate*), black box, bimbale box, rosewood (*Alectryon oleifolius*) and river cooba (*Acacia stenophylla*).

Gilgais have been used by graziers to seasonally graze stock in areas that lack permanent water, but are now generally considered a nuisance by many farmers as the movement of soil associated with gilgai formation has been known to damage infrastructure (including building foundations, roads and railway lines, and the undulations produced interfere with crop harvesting). However, gilgais remain of great ecological significance as a source of water for animal and plant life in the Lachlan.

Open water areas exist across the Lachlan floodplain, with notable lagoons including Lake Merrimajeel, and Lignum and Marrool Lakes in the Great Cumbung Swamp. Open water areas provide important habitat for large-bodied fish species and waterbirds and, as they tend to be more permanent water bodies within an ephemeral landscape, can provide drought refuge for a variety of plant and animal species. Open water areas, or pelagic zones, can be divided into the euphotic zone (measured from the surface to where light ceases to penetrate) and the profundal zone (where light does not penetrate). Phytoplankton tend to dominate in the euphotic zone and provide food for zooplankton and fish. The benthic zone, or lake bottom, also provides food and habitat through sediments and accumulated detrital material.

Chains of ponds or swampy meadows were once common in the upper Lachlan catchment. They are generally located in alluvial valley floors not drained by continuous channels, and are characteristically vegetated with dense tussock grass and sedge plants. These permanently or periodically water-saturated environments have been dramatically degraded in the upper Lachlan since European settlement, resulting in these complex systems becoming incised gullies. This has resulted in significant consequences such as loss of sediment through erosion, altered hydrology, loss of biodiversity and a decline in agricultural productivity.

A table of key species found in the Lachlan is presented in Appendix 1.

The Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) has developed objectives for the use of environmental water (DEWHA 2009). These objectives are to guide the use of environmental water under different climatic and flow conditions, often in conjunction with other water to meet ecological objectives related to Lachlan assets. Ecological objectives specifically relating to the delivery of environmental water in the Lachlan at the broad-scale level have been summarised in Table 2. These objectives are incorporated into the delivery scenario objectives presented in section 5.2.

The broad-scale objectives describe the desired outcomes across the many Lachlan assets under different flow scenarios. The ecological objectives were created for individual Lachlan assets in relation to the relevant broad-scale objectives. These objectives guide water-use strategies for the Lachlan.

**Table 2:** Ecological and management objectives for environmental water use under different water resource availability scenarios (DEWHA 2009).

	Extreme dry	Dry	Median	Wet
Ecological watering objectives	Avoid damage to key environmental assets.	Ensure ecological capacity for recovery.	Maintain ecological health and resilience.	Improve and extend healthy and resilient aquatic ecosystems.
Management objectives	<p>Avoid critical loss of threatened species and communities.</p> <p>Maintain key refuges.</p> <p>Avoid irretrievable damage or catastrophic events.</p>	<p>Support the survival and growth of threatened species and communities including limited small-scale recruitment.</p> <p>Maintain diverse habitats.</p> <p>Maintain low-flow river and floodplain functional processes in sites and reaches of priority assets.</p>	<p>Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna.</p> <p>Promote low-lying floodplain-river connectivity.</p> <p>Support medium-flow river and floodplain functional processes.</p>	<p>Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna.</p> <p>Promote higher floodplain-river connectivity.</p> <p>Support high-flow river and floodplain functional processes.</p>
Management actions	<p>Water refugia and sites supporting threatened species and communities.</p> <p>Undertake emergency watering at specific sites of priority assets.</p> <p>Use carryover volumes to maintain critical needs.</p>	<p>Water refugia and sites supporting threatened species and communities.</p> <p>Provide low flow and freshes in sites and reaches of priority assets.</p> <p>Use carryover volumes to maintain follow-up watering.</p>	<p>Prolong inundation/ high-flow duration at key sites and reaches of priority assets.</p> <p>Contribute to the full-range of in-channel flows.</p> <p>Use carryover to provide optimal seasonal flow patterns in subsequent years.</p>	<p>Increase inundation/ high-flow duration and extent across priority assets.</p> <p>Contribute to the full range of flows including over-bank.</p> <p>Use carryover to provide optimal seasonal flow patterns in subsequent years.</p>
	<i>Damage avoidance</i>	<i>Capacity for recovery</i>	<i>Maintained health and resilience</i>	<i>Improved health and resilience</i>

## 2.1 Ecological objectives

A number of broad system-objectives exist for assets within the Lachlan catchment. These range from statutory instruments at the jurisdictional level, to overarching basin and catchment priorities.

### Objectives for the use of Commonwealth environmental water (DEWHA 2009)

The *Water Act 2007* (Cwlth) prescribes that Commonwealth environmental water must be managed for the purpose of protecting or restoring environmental assets, and gives effect to relevant international agreements such as the Ramsar, Bonn, Desertification, Biodiversity and Climate Change conventions, and migratory bird agreements with Japan, China and the Republic of Korea.

The Australian Government's holdings in the Basin must be managed in accordance with the requirements of the Murray-Darling Basin Authority (MDBA) to protect and restore key environmental assets and key ecosystem functions.

These objectives are based on prevailing climatic conditions (Table 2). Climatic conditions will impact upon how much water is available in the system, including how much is available to environmental water managers. As conditions progress from extreme dry through to wet and more environmental water becomes available, the ecological objectives in Table 2 progress from damage avoidance, maintenance of refuges and the capacity for recovery, to maintaining health and resilience, and onto the expansion of a healthy ecosystem.

### Murray-Darling Basin Authority objectives (MDBA 2010)

The MDBA identified the following key assets within the Lachlan catchment (MDBA 2010):

- Great Cumbung Swamp
- Booligal Wetlands
- Lachlan Swamp.

A number of proposed environmental objectives have been determined for these sites using the key environmental asset criteria. Targets to achieve these objectives have been proposed for flood-dependent vegetation communities considered essential to support wetland processes and to provide crucial habitat for identified flora and fauna (MDBA 2010).

Management targets are to:

- Booligal Wetlands:
  - provide conditions conducive to successful breeding of colonial-nesting waterbirds
  - maintain 100 per cent of the permanent and semi-permanent wetland communities in good condition
  - maintain 80 per cent of the current extent of river red gum communities in good condition
  - maintain 80 per cent of the current extent of lignum communities in good condition.
- Lachlan Swamp:
  - provide conditions conducive to successful breeding of colonial-nesting waterbirds
  - maintain 100 per cent of the permanent and semi-permanent wetland communities in good condition
  - maintain 75 per cent of the current extent of river red gum communities in good condition
  - maintain 65 per cent of the current extent of lignum communities in good condition
  - maintain 40 per cent of the current extent of black box communities in good condition.

- Great Cumbung Swamp:
  - provide conditions conducive to successful breeding of colonial-nesting waterbirds
  - maintain 95 per cent of the area of permanent and semi-permanent wetland communities in good condition
  - maintain 60 per cent of the current extent of river red gum communities in good condition
  - maintain 20 per cent of the current extent of floodplain wetland communities in good condition.

## The Lachlan Catchment Action Plan (LCMA 2006)

The Catchment Action Plan, developed by the Lachlan Catchment Management Authority in 2006, addresses resource conditions of the Lachlan catchment through a number of management targets. The targets most relevant to environmental water delivery include:

- Management Target 15—By 2016, deliver 10,000 megalitres of water more efficiently for the benefit of riverine ecosystems and for identified Aboriginal cultural practices
- Management Target 20—By 2016, manage eight nationally significant wetlands and five regionally significant wetlands for improved biodiversity conservation
- Management Target 21—By 2016, implement activities identified within existing and future floodplain management plans which are identified as providing environmental benefits
- Management Target 22—By 2016, improve in-stream habitat at 80 sites.

The Lachlan Catchment Action Plan and its implementation will be reviewed during 2011. Targets relating to water management may change as they are revised as part of the development of the latest catchment action plans.

## Water Sharing Plan for the Lachlan Regulated Water Source (DIPNR 2004a)

The Water Sharing Plan (WSP) has a number of objectives to ensure water management meets a variety of economic, socio-cultural and environmental needs. It can be accessed online at: [http://www.austlii.edu.au/au/legis/nsw/consol\\_reg/wspftlrws2003568/](http://www.austlii.edu.au/au/legis/nsw/consol_reg/wspftlrws2003568/)

The environmental objectives are to maintain or restore the key environmental features of the Lachlan River system by a river-flow regime that, as much as possible, mimics natural conditions to provide the following outcomes:

- a diversity of natural in-stream and riparian habitat and biota
- the restoration, by naturally triggered flooding, of the riverine floodplain to its previous rich mosaic of ecosystems
- the improved health and function of wetlands as the frequency and duration of inundation is restored
- an abundance and diversity of native aquatic species
- an abundance and diversity of native water birds
- the restoration of water quality that supports aquatic ecosystems
- the recovery of threatened species, communities and populations.

The WSP outlines rules for planned environmental water, including the management of 'translucent releases'. A translucent release, as defined in the WSP, is "the release from a water storage of some portion of inflow to the water storage coincident with the occurrence of that inflow" (DIPNR 2004a). Translucency flows are intended to mimic natural flows in the system and restore some natural flow characteristics (such as winter-spring flow variability), and also improve lower-system flows.

The WSP also provides for the supply of water to towns, riparian landholders, irrigation and other industry for the benefit of rural communities in the Lachlan River system. In order to meet these objectives, 'replenishment flows' are managed by State Water according to the rules outlined in the plan.

Replenishment flows, as defined in the WSP, are "flows provided to refill pools and water holes in effluent river systems downstream of the water source and provide water for household and town use and stock" (DIPNR 2004a). While this water is not strictly identified as 'environmental water' (planned environmental water or held environmental water), benefits to environmental values may accrue and improved delivery efficiency can be achieved when operational flows and environmental flows are managed in concert with each other (in this context see sections 3.1 and 5.1.6 and Tables 5 and 8).

## The Draft Lachlan Environmental Water Management Plan

The Water Sharing Plan for the Lachlan Regulated River sets out rules for the allocation and release of planned environmental water. However, the Water Sharing Plan does not provide direction for the management of licences committed as adaptive environmental water or other environmental water entitlements, or the desired ecological outcomes and overall environmental objectives associated with the use of this water. The draft Lachlan Environmental Water Management Plan (LEWMP) is being developed by the Lachlan Riverine Working Group (LRWG) to address the effective use of licenced environmental water. It details:

- the wetlands of the Lachlan River and their watering needs
- the environmental watering decision-making process, e.g. wetland selection, timing, volumes and frequency
- the ecological objectives of environmental watering
- the role of the LRWG in delivering the plan
- the various rules, legislation and other institutional arrangements that must be considered.

According to its terms of reference, the role of the LRWG is to:

- identify issues relating to the allocation, accounting and management of the environmental water provisions in the Lachlan Water Sharing Plan or other allocated environmental water
- provide input to water-delivery strategies that will integrate the management of environmental flows and river operations
- review river operations and policies in relation to the management of the environmental water allowance(s)
- identify critical issues which affect the management and effectiveness of the environmental water provisions
- provide advice on other matters relevant to the sustainable management of high-value wetlands and other riverine environments that are dependent on the water sources in the Lachlan catchment
- communicate with the public and stakeholder groups through the media or other means on issues relating to environmental flows.

The draft LEWMP is a web-based tool which is constantly updated to reflect increased knowledge through monitoring and evaluation carried out by agencies including the NSW Office of Water (NOW) and the NSW Office of Environment and Heritage. Asset objectives provided by the draft LEWMP have been incorporated as relevant in the operational objectives in this document.

## The Lachlan RiverBank Water Use Plan No. 1 (NSW Office of Environment and Heritage)

The Water Use Plan authorises the use of water for environmental purposes that:

- enhance opportunities for the recruitment of threatened (and other) native fish and waterbirds in the Lachlan Regulated River Water Source
- enhance river and wetland habitat for water-dependent biota in the Lachlan Regulated River Water Source
- maintain the ecological character of Murrumbidgee Swamp on Merrimajeel Creek
- restore a near-natural wetting pattern to Ita Lake
- provide for ecologically beneficial flooding of the Merrowie, Torriganny, Muggabah and Merrimajeel effluent creek systems by enhancing annual replenishment flows
- provide for ecologically beneficial flows in the Lachlan River channel below Booligal Weir; and/or contribute to maintaining the ecological character of the Great Cumbung Swamp.



## 3. Watering objectives for water-dependent assets

### 3.1 Ecological and watering objectives for asset and water management areas

There are several key considerations involved in developing asset watering requirements. Consideration has been given to each of the climate sequence scenarios in the development of environmental watering objectives for each asset or water management area (WMA). Under each climate scenario, it is likely that there will be different volumes of environmental water available, and therefore environmental watering outcomes will vary accordingly.

In reality, the climate scenarios are part of a constant continuum and only the current circumstances can be assessed in relation to the past few years to determine which scenario applies. Forecasting the future climate scenario is difficult, although short-term probabilities are provided by the Bureau of Meteorology.

Details of the water availability probabilities under each scenario, and some examples, are provided in Table 3. Under an extremely dry or dry climate, the watering of Lachlan assets using stored environmental water has limited feasibility, with only 0–47 per cent of General Security (GS) water entitlements based on modelled October allocations and 0–8 per cent of GS water entitlements based on modelled April allocations. Based on Commonwealth environmental water holdings at October 2010, there would be a maximum of 47,971 megalitres of GS water available for use under a dry climate scenario, based on modelled April allocations. This amount would be sufficient to water a limited number of assets on its own, with more watering options dependent on piggybacking opportunities.

Under a median or wet climate, the watering of a larger number of Lachlan assets would be feasible as water availability is expected to increase. The forecasted availability of Commonwealth GS water entitlements is illustrated in Table 3. Forecasts indicate that 87–100 per cent of GS allocation would be available under median-to-wet conditions under October and April allocations (Table 3). This means that between 71,957 megalitres and 82,709 megalitres of Commonwealth GS water would be available for use based on current entitlements. Probabilities of unregulated flows for various percentiles at Booligal and Willandra have also been determined. These are present for each month for extreme dry to extreme wet scenarios (Appendix 3).

From the ecological objectives for each asset/WMA, environmental watering objectives have been developed for each asset/WMA under different climate scenarios. Appendix 2 provides a description of each of these sites and relevant hydrological information in relation to the ecological values and objectives.

Flow types and how they relate to the ecological objectives are outlined in Table 4. The environmental watering objectives for each climate scenario and antecedent condition are presented in Table 5, but can be summarised as:

- avoiding damage by protecting the asset from over-grazing and weeds and reduce the duration of time between flow events
- providing for a natural drying cycle
- providing drought refuge for native fish species and waterbirds
- supporting wetland vegetation and waterbird breeding
- improving hydrologic connectivity between channel and floodplain
- increasing hydrological variability through increased flow volumes in floods and freshes.

The volume-to-fill estimates in Table 5 for wetland sites are based on the area of the site and an upper limit watering requirement of 12 megalitres per hectare (see also section 5.1.6), or according to other advice as outlined in Table 5. The environmental watering objectives (Table 5) are subsequently used to develop the corresponding environmental water order in Table 8.

It is important to note that in some cases the environmental watering objective may be met by baseflows or replenishment flows (e.g. see Table 4), but these flows are not intended to be met by held environmental water releases. However if the base or replenishment flow is not provided, additional water may need to be provided from held environmental water to meet the watering objective and order (see also section 5.1.6 and Table 8).

**Table 3:** Likely modelled volume available to the environment from Commonwealth environmental water holdings (as at October 2010) and NSW Riverbank entitlements.

Holder	Licence volume	Entitlement category	October allocation				April allocation			
			Extreme dry	Dry	Median	Wet	Extreme dry	Dry	Median	Wet
General-security access licence allocation (%)			0	47	87	100	0	58	100	100
High-security access licence allocation (%)			100	100	100	100	100	100	100	100
Commonwealth environmental water (ML)	733	High	733	733	733	733	733	733	733	733
NSW Riverbank (ML)	1,000	High	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Commonwealth environmental water (ML)	82,709	General	0	38,873	71,957	82,709	0	47,971	82,709	82,709
NSW Riverbank (ML)	24,575	General	0	11,550	21,380	24,575	0	14,254	24,575	24,575
Commonwealth environmental water (Lake Brewster Water Savings) (ML)	12,000	General	0	5,640	10,440	12,000	0	6,960	12,000	12,000

(Note: does not include environmental water under the Water Sharing Plan).

**Table 4:** Flow types and relationship to asset ecological objectives

Flow type	Water management area	Asset ecological objectives
<b>Baseflow</b> —to provide sufficient baseflow to maintain suitable water quality in the regulated river channel during drought years.  Provide a drought refuge for native fish species; avoid the build-up of organic matter and maintain riparian and in-stream vegetation health.	Permanent regulated river section.	Maintain water quality within channels and pools. Prevent stratification in deep pools.
		Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna.
		Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.
		Maintain inundation of weir pools in the river to prevent exposure of acid sulphate soils. e.g. Booligal Weir pool.
<b>Minor Inflows</b> —Increase hydrological variability through increased flow volumes in floods and freshes. Flood smaller wetlands with low commence-to-fill (CTF).	Small-to-medium-sized wetlands with low CTF or structures for water delivery, e.g. Burrawang West Lagoon, Yarnel Lagoon, Lake Brewster Inflow Wetland.	Protect wetland habitat for native fish (including olive perchlet and purple spotted gudgeon), frogs and waterbirds (including brolgas).
		Establish and maintain native water plants for improved water quality and wetland habitat outcomes.
		Promote diversity outcomes through flooding lagoons and associated riverine areas.
<b>Medium Inflows</b> —Increase extent and duration of inundation and connectivity; support colonial waterbirds and fish.	End-of-system flows; distributary systems and associated wetlands, e.g. Willandra Creek, upper Merrowie Creek, Muggabah and Merrimajeele Creeks.	Provide adequate flooding regime to support river red gum, black box and lignum communities associated with distributary systems.
		Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets, herons.
		Provide adequate water depth and flood frequency to support Cumbung reed bed.
		Increase connectivity between floodplain and distributary creeks to increase productivity.
<b>High Inflows</b> —Increase extent and duration of inundation and connectivity; support colonial waterbirds and fish; increase open water areas.	Inundate wetlands requiring greater volumes and high CTF, Cumbung Swamp red gum forest, Tarwong Lake, Lake Merrimajeele and Lake Ita.	Provide adequate flooding regime to support river red gum, black box and lignum communities associated with distributary systems.
		Maintain open water areas by providing adequate flooding flows to lakes.
		Increase duration of connectivity between floodplain and distributary creeks to increase productivity.
		Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets, herons.

**Table 5:** Environmental watering objectives to meet ecological objectives under different climate scenarios.

Asset	WMA	Climate scenario	Asset ecological objectives <sup>1</sup>	Asset environmental watering objectives <sup>2,3</sup>
Lachlan River channel	Lachlan River reach- Wyangala-Jemalong	Extreme dry	Provide drought refuge for native fish species in pools.	Baseflow to prevent cease-to-flow.
		Dry	Provide drought refuge for native fish species in pools.	Baseflow to prevent cease-to-flow.
		Median	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Cottons Weir (Forbes) for 1 week.
		Wet	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Cottons Weir (Forbes) for 2 weeks.
	Lachlan River reach- Jemalong- Lake Cargelligo	Extreme dry	Provide drought refuge for olive perchlet and other native fish species in pools.	Baseflow to prevent cease-to-flow.
		Dry	Provide drought refuge for olive perchlet and other native fish species in pools.	Baseflow to prevent cease-to-flow.
		Median	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Condobolin and West Condobolin Weirs for 1 week.
		Wet	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Condobolin and West Condobolin Weirs for 2 weeks.
	Lachlan River reach-Lake Cargelligo-Lake Brewster	Extreme dry	Brewster weir pool—provide drought refuge for olive perchlet and other native fish species.	Baseflow to prevent cease-to-flow.
		Dry	Brewster weir pool—provide drought refuge for olive perchlet and other native fish species.	Baseflow to prevent cease-to-flow.
		Median	Brewster weir pool—improve habitat for olive perchlet and other native fish species.	Maintain inundation of Brewster Weir pool.
		Wet	Brewster weir pool—improve habitat for olive perchlet and other native fish species.	Maintain inundation of Brewster Weir pool.
	Lachlan River reach-Lake Brewster-Great Cumbung Swamp	Extreme dry	Provide drought refuge for native fish species in pools.	Baseflow to prevent cease-to-flow.
		Dry	Provide drought refuge for native fish species in pools.	Baseflow to prevent cease-to-flow.
		Median	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Willandra (8,500 ML/d) and Hillston (4,750 ML/d) Weirs for 1 week.
		Wet	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Willandra (8,500 ML/d) and Hillston (4,750 ML/d) Weirs for 2 weeks.

<sup>1</sup> Ecological objectives may change as water is accrued for each climate scenario as per Table 3

<sup>2</sup> The baseflows and water for consumptive use (e.g. replenishment flows) are not to be substituted by held environmental water. In instances when these flows are not provided, additional water may need to be provided from held environmental water to meet the watering objectives. In some systems this may not be feasible given the volume that would be required.

<sup>3</sup> Appendix 2 provides the necessary narrative for the development of these objectives.

Asset	WMA	Climate scenario	Asset ecological objectives <sup>1</sup>	Asset environmental watering objectives <sup>2,3</sup>
Burrawang West Lagoon	Burrawang West Lagoon	Extreme dry	Protect relocated purple-spotted gudgeons (if viable population still exists), other native fish and brolga habitat.	Deliver up to 50 ML (volume-to-fill) to Burrawang West Lagoon.
		Dry	Protect relocated purple-spotted gudgeons (if viable population still exists), other native fish and brolga habitat.	Deliver up to 50 ML (volume-to-fill) to Burrawang West Lagoon.
		Median	Support breeding opportunities for relocated purple-spotted gudgeons (if viable population still exists), other native fish and frogs and protect brolga habitat.	Deliver up to 50 ML (volume-to-fill) to Burrawang West Lagoon.
		Wet	Support breeding opportunities for relocated purple-spotted gudgeons (if viable population still exists), other native fish and frogs and protect brolga habitat. Water riparian vegetation and provide connectivity to floodplain.	Deliver >50 ML (volume-to-fill) to Burrawang West Lagoon.
Yarnel Lagoon	Yarnel Lagoon	Extreme dry	Protect frog and brolga habitat.	Deliver up to 360 ML (volume-to-fill) to Yarnel Lagoon
		Dry	Protect frog and brolga habitat.	Deliver up to 360 ML (volume-to-fill) to Yarnel Lagoon
		Median	Water riparian vegetation, support frog and brolga breeding.	Deliver up to 360 ML (volume-to-fill) to Yarnel Lagoon
		Wet	Support riparian vegetation, frog and brolga breeding. Provide connectivity to floodplain.	Deliver >360 ML (volume-to-fill) to Yarnel Lagoon
Booberoi Creek	Booberoi Creek	Extreme dry	Provide native fish and water plant refuge.	Baseflow to maintain pools.
		Dry	Provide native fish and water plant refuge.	Baseflow to maintain pools.
		Median	Support native fish passage and recruitment.	Deliver flushing flows to Booberoi Creek up to 3,000 ML.
		Wet	Support native fish passage and recruitment.	Deliver flushing flows to Booberoi Creek up to 3,000 ML.



Asset	WMA	Climate scenario	Asset ecological objectives <sup>1</sup>	Asset environmental watering objectives <sup>2,3</sup>
Lake Brewster	Lake Brewster Inflow Wetland	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Support wetland plant growth and pelican breeding, provide improved habitat for olive perchlet and other wetland species.	Deliver up to 1,500 ML (volume-to-fill) to Brewster Inflow Wetland. (Note: this estimate provided by State Water.)
		Median	Support wetland plant growth and pelican breeding, provide improved habitat for olive perchlet and other wetland species.	Deliver up to 1,500 ML (volume-to-fill) to Brewster Inflow Wetland. (Note: this estimate provided by State Water.)
		Wet	Support wetland plant growth and pelican breeding, provide improved habitat for olive perchlet and other wetland species.	Deliver up to 1,500 ML (volume-to-fill) to Brewster Inflow Wetland. (Note: this estimate provided by State Water.)
	Lake Brewster Outflow Wetland	Extreme dry	No water delivered under extremely dry conditions.	No water delivered under extremely dry conditions.
		Dry	Establish/maintain wetland vegetation for improved water quality in cells 1, 2 and 3.	Deliver up to 5,000 ML (volume-to-fill) to Brewster Outflow Wetland. (Note: this estimate provided by State Water.)
		Median	Establish/maintain wetland vegetation for improved water quality in cells 1, 2 and 3.	Deliver up to 5,000 ML (volume-to-fill) to Brewster Outflow Wetland. (Note: this estimate provided by State Water.)
		Wet	Establish/maintain wetland vegetation for improved water quality in cells 1, 2 and 3 plus the additional northern wetland cell.	Deliver >5,000 ML to Brewster Outflow Wetland. Volume-to-fill of the northern cell not known.

Asset	WMA	Climate scenario	Asset ecological objectives <sup>1</sup>	Asset environmental watering objectives <sup>23</sup>
Willandra Creek	Willandra Creek- upstream reach (Willandra Regulator to Willandra Homestead Weir)	Extreme dry	Provide drought refuge for native fish and waterbirds, particularly with regard to Willandra National Park riparian areas and Homestead Weir pool.	Base flows to wet channel and fill pools.
		Dry	Provide drought refuge for native fish and waterbirds, particularly with regard to Willandra National Park riparian areas and Homestead Weir pool.	Base flows to wet channel and fill pools.
		Median	Support waterbird breeding, particularly within Willandra National Park riparian areas and Homestead Weir pool. Increase connectivity through weir drownouts.	Volume of environmental water required to achieve the asset ecological objective is currently unknown.
		Wet	As above.	Volume of environmental water required to achieve the asset ecological objective is currently unknown.
	Willandra Creek- downstream reach (Homestead Weir to Ivanhoe/Balranald Road)	Extreme dry	Provide drought refuge for native fish and waterbirds.	Baseflows to wet channel and fill pools.
		Dry	Provide drought refuge for native fish and waterbirds.	Baseflows to wet channel and fill pools.
		Median	Maintain wetland habitats for native fish and waterbirds. Increase connectivity through weir drownouts.	Volume of environmental water required to achieve the asset ecological objective is currently unknown.
		Wet	Maintain wetland habitats for native fish and waterbirds. Increase connectivity through weir drownouts.	Volume of environmental water required to achieve the asset ecological objective is currently unknown.
	Morrison's Lake	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle.	No water delivered under dry conditions.
		Median	Support wetland habitat and waterbirds.	Deliver up to 4,000 ML (volume-to-fill) to Morrison's Lake. (Note: this estimate provided by State Water.)
		Wet	Support wetland habitat and waterbirds.	Deliver up to 4,000 ML (volume-to-fill) to Morrison's Lake. (Note: this estimate provided by State Water.)

Asset	WMA	Climate scenario	Asset ecological objectives <sup>1</sup>	Asset environmental watering objectives <sup>23</sup>
Merrowie Creek	Upper Merrowie Creek (offtake to Toms Lake)	Extreme dry	Provide drought refuge for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
		Dry	Support creek channel vegetation (red gum, black box, lignum) for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
		Median	Support creek channel vegetation (red gum, black box, lignum) for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
		Wet	Support creek channel vegetation (red gum, black box, lignum) for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
	Merrowie Creek- Toms Lake	Extreme dry	Provide drought refuge for native fish and waterbirds and provide connectivity.	Baseflows to wet channel and fill pools.
		Dry	Support wetland habitats (red gum, black box, lignum) for native fish and waterbirds and provide connectivity.	Deliver 3,000–3,600 ML.
		Median	Support wetland habitats (red gum, black box, lignum) for native fish and waterbirds and provide connectivity.	Deliver 3,000–5,000 ML.
		Wet	Support wetland habitats for native fish and colonial bird breeding.	Deliver 5,000–7,200 ML.
	Merrowie Creek- Mutherumbung Weir pool	Extreme dry	Provide drought refuge for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
		Dry	Support wetland habitats (red gum, black box, lignum) for native fish and waterbirds, and provide connectivity.	Deliver 3,500–5,000 ML to Mutherumbung Weir.
		Median	Support red gums, black box, lignum and bird breeding in the lake and swamps.	Deliver 3,500–5,000 ML to Mutherumbung Weir.
		Wet	Support wetland habitats for native fish and colonial bird breeding.	Deliver 5,000–7,200 ML to Mutherumbung Weir.
	Merrowie Creek- Cuba Dam	Extreme dry	Provide drought refuge for native fish and waterbirds and provide connectivity.	Baseflows to wet channel and fill pools.
		Dry	Support wetland habitats (red gum, black box, lignum) for native fish and waterbirds and provide connectivity.	Deliver up to 5,000 ML to Cuba Dam.
		Median	Improve the condition of river red gum, black box and lignum communities and support bird breeding in the lake and swamps.	Deliver up to 5,000 ML to Cuba Dam.
		Wet	Support wetland habitats for native fish and colonial bird breeding.	Deliver up to 7,200 ML to Cuba Dam.
	Merrowie Creek- Lake Tarwong and Tarwong Swamps	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle.	No water delivered under dry conditions.
		Median	Improve the condition of river red gum communities and support bird breeding in the lake.	Deliver up to 2,000 ML to Lake Tarwong.
		Wet	Improve the condition of river red gum, black box and lignum conditions and support waterbird breeding in the lake and swamps.	Deliver up to 9,000 ML to Lake Tarwong and the south and north swamps.

Asset	WMA	Climate scenario	Asset ecological objectives <sup>1</sup>	Asset environmental watering objectives <sup>23</sup>
Moon Moon Swamp	Moon Moon Swamp	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle.	No water delivered under dry conditions.
		Median	Provide water to river red gums and drought refuge for waterbirds.	Deliver up to 2,500 ML to Moon Moon Swamp (this is a nominal requirement as the volume of water required for breeding is unknown).
		Wet	Extend duration of river red gum watering and support waterbird breeding. Floodplain inundation downstream of Moon Moon Swamp which is an area of 20,000–30,000 ha.	Deliver up to 2,500 ML to Moon Moon Swamp (as above) and downstream environment.
Booligal Wetland	Booligal Swamp	Extreme dry	Provide natural drying cycle. (Replenishment flow will water habitat along Merrimajeel Creek.)	Baseflows to wet channel and fill pools.
		Dry	Provide natural drying cycle. (Replenishment flow will water habitat along Merrimajeel Creek.)	Baseflows to wet channel and fill pools.
		Median	Improve lignum condition and support waterbird breeding events.	Deliver up to 5,000 ML to Booligal Swamp.
		Wet	Support lignum condition and support waterbird-breeding events.	Deliver up to 5,000 ML to Booligal Swamp.
	Murrumbidgee Swamp	Extreme dry	Provide natural drying cycle. Replenishment flow will water habitat along Merrimajeel Creek.	No water delivered under extremely dry conditions.
		Dry	Provide water to river red gums.	Deliver 1,400 ML (volume-to-fill) to Murrumbidgee Swamp.
		Median	Provide water to river red gums and support bird breeding.	Deliver >1,400 ML (volume-to-fill) to Murrumbidgee Swamp. The volume required to support bird breeding is unknown.
		Wet	Provide water to river red gums and bird breeding.	Deliver >1,400 ML (volume-to-fill) to Murrumbidgee Swamp. The volume required to support bird breeding is unknown.
	Lake Merrimajeel	Extreme dry	Provide natural drying cycle. (Replenishment flow will water habitat along Merrimajeel Creek.)	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle. (Replenishment flow will water habitat along Merrimajeel Creek.)	No water delivered under dry conditions.
		Median	Provide water for wetland habitat.	Deliver 1,200 ML (volume-to-fill) to Lake Merrimajeel.
		Wet	Providing water for wetland habitat and support waterbird breeding.	Deliver >1,200 ML (volume-to-fill) to Lake Merrimajeel. The volume required to support bird breeding is unknown.
	Lower Gum Swamp	Extreme dry	Provide natural drying cycle. Replenishment flow will water habitat along Merrimajeel Creek.	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle. Replenishment flow will water habitat along Merrimajeel Creek.	No water delivered under dry conditions.
		Median	Improve the condition of river red gum communities.	Deliver up to 3,400 ML (volume-to-fill) to Lower Gum Swamp.
		Wet	Improve the condition of river red gum communities and support water bird breeding.	Deliver up to 2,500 ML to Lower Gum Swamp. This volume based on Booligal swamp experience.

Asset	WMA	Climate scenario	Asset ecological objectives <sup>1</sup>	Asset environmental watering objectives <sup>2,3</sup>
Lachlan Swamps	Lake Waljeers	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide water to river red gum communities.	Deliver up to 2,600 ML (volume-to-fill) to Lake Waljeers.
		Median	Provide water to river red gum communities.	Deliver up to 6,240 ML to Lake Waljeers.
		Wet	Provide water to river red gum communities.	Deliver up to 6,240 ML to Lake Waljeers.
	Peppermint Swamp	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide water to river red gum communities.	Deliver up to 1,440 ML to Peppermint Swamp
		Median	Provide water to river red gum communities and support bird breeding.	Deliver >1,440 ML to Peppermint Swamp. The volume of water to support waterbird breeding is not known.
		Wet	Provide water to river red gum communities and support waterbird breeding.	Deliver >1,440 ML to Peppermint Swamp. The volume of water to support waterbird breeding is not known.
Ita Lake	Ita Lake	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Support waterbird and native fish habitat within the Kalyarr Conservation Area.	Deliver up to 14,400 ML to Ita Lake.
		Median	Provide waterbird and native fish habitat within the Kalyarr Conservation Area.	Deliver up to 14,400 ML to Ita Lake.
		Wet	Provide water to river red gum and black box communities within the Kalyarr Conservation Area.	Deliver >14,400 ML to Ita Lake.
Baconian Swamp	Baconian Swamp	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide water to river red gum communities.	Deliver 9,600 ML to Baconian Swamp
		Median	Improve the condition of river red gum and black box communities and support waterbird and frog breeding.	Deliver >9,600 ML to Baconian Swamp. Volumes required for waterbird and frog breeding unknown.
		Wet	Improve the condition of river red gum and black box communities and support bird and frog breeding.	Deliver >9,600 ML to Baconian Swamp. Volumes required for waterbird and frog breeding unknown.

Asset	WMA	Climate scenario	Asset ecological objectives <sup>1</sup>	Asset environmental watering objectives <sup>23</sup>
Great Cumbung Swamp (GCS)	Reed bed	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Maintain reed bed condition.	Deliver up to 4,900 ML to reed bed.
		Median	Maintain reed bed condition.	Deliver up to 4,900 ML to reed bed.
		Wet	Maintain and improve reed bed condition.	Deliver up to 4,900 ML to reed bed.
	GCS WMA	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions
		Dry	Provide natural drying cycle.	No water delivered under dry conditions.
		Median	Improve the condition of river red gum communities.	Deliver up to 30,000 ML to GCS.
		Wet	Improve the condition of river red gum and black box communities and support bird breeding.	Deliver up to 45,000 ML to GCS.







## **PART 2:** Water use strategy



## 4. Environmental water requirements

### 4.1 Watering requirements

Asset environmental watering objectives were presented in the previous section. The associated watering requirements and delivery regimes for these objectives are presented in this section. Watering requirements for wetland-dependent vegetation and ecological components have been documented in a number of reports including Roberts and Marston (2000), Davis et al. (2001), and Rogers and Ralph (2010). The survival and maintenance watering requirements of the major ecological components found in many lower-Lachlan wetlands are outlined in Table 6, based on information provided by Rogers and Ralph (2010). Fish-specific requirements have been extracted from Lintermans (2007). While the list in Table 6 is not exhaustive, it provides detailed watering information on a number of important features associated with Lachlan assets.

These watering requirements have been used to determine appropriate watering regimes for Lachlan assets (section 5 and Table 8). The dominant vegetation or ecological component within each wetland has been used as the basis of watering requirements for each wetland. Table 5 (in section 3) summarises the ecological objectives for watering purposes of each wetland.

**Table 6:** Watering requirements for selected water-dependent species of the Lachlan River (modified from Rogers & Ralph 2010; Lintermans 2007)

Water-dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Plants survival and maintenance									
River red gum	1–3 yrs	2–8 mths	24 mths	Winter–spring	Winter–early summer	–	–	5–15 mths	36–48 mths
Black box	1 in 2–5 yrs	2–4 mths	5 mths	Any	Any	–	–	Variable	Unknown
Lignum	3–10 yrs	1–6 mths	12 mths	Spring–early summer	–	0–60 cm	–	1–10 yrs	Unknown
Common reed	1–2 yrs	~6 mths	12 mths or permanent	Spring	Any	20–50 cm	2 m	Few mths	12 mths
Waterbird breeding									
Great and intermediate egret	Not known	12 mths	–	Nov–May	Sept–May	Deep–slow fall	–	Not listed	Not listed
		3–4 mths breeding							
Little egret	Not known	6 mths	–	Oct–March	–	Deep–mod fall	–	Not listed	Not listed
		3–4 mths breeding							
Straw-necked ibis	Not known	9–12 mths	–	Sept–Feb	Anytime	0.5–1 m slow fall	–	Not listed	Not listed
		3–mths breeding							
Glossy ibis	Not known	2–mths breeding	–	Oct–Feb		Deep–slow fall	–	Not listed	Not listed
Grey teal	Not known	4–5 mths	–	June–Feb	Anytime	Unknown–mod fall	–	Not listed	Not listed
		3–4 mths breeding							
Freckled duck	Not known	5 mths	–	June–Dec	Anytime	Unknown mod–slow fall	–	Not listed	Not listed
		3–mths breeding							
Brolga	Not known	3–4 mths		July–Nov	May–March	0.24–0.72 m	–	Not listed	Not listed

Water-dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Native fish									
Olive perchlet	Not listed	Not listed	Not listed	Oct–Dec	Not listed	Not listed	Not listed	Not listed	Not listed
Purple spotted gudgeon	Not listed	Not listed	Not listed	Oct–April	Not listed	Not listed	Not listed	Not listed	Not listed
Murray cod	Not listed	Not listed	Not listed	Sept–Dec	Not listed	Not listed	Not listed	Not listed	Not listed
Macquarie perch	Not listed	Not listed	Not listed	Oct–Dec	Not listed	Not listed	Not listed	Not listed	Not listed
Golden perch	Not listed	Not listed	Not listed	Oct–Dec	Not listed	Not listed	Not listed	Not listed	Not listed
Silver perch	Not listed	Not listed	Not listed	Sept–Mar	Not listed	Not listed	Not listed	Not listed	Not listed
Freshwater catfish	Not listed	Not listed	Not listed	Oct–Jan	Not listed	Not listed	Not listed	Not listed	Not listed
Southern pygmy perch	Not listed	Not listed	Not listed	Sept–Jan	Not listed	Not listed	Not listed	Not listed	Not listed
Unspecked hardyhead	Not listed	Not listed	Not listed	Oct–Feb	Not listed	Not listed	Not listed	Not listed	Not listed
Northern river blackfish	Not listed	Not listed	Not listed	Oct–Jan	Not listed	Not listed	Not listed	Not listed	Not listed
Frogs									

Water-dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Eastern froglet	<3 mths—permanent	Not listed	2–4 mths	Summer–autumn	Not listed	Not listed	Not listed	Not listed	Not listed
Perons tree frog	<3 mths—permanent	Not listed	3–4 mths	Summer	Not listed	Not listed	Not listed	Not listed	Not listed
Southern bell frog	3 mths—permanent	Not listed	3–5 mths	Summer	Not listed	Not listed	Not listed	Not listed	Not listed

Note: Rogers and Ralph (2010) also provides additional information on other outcomes such as reproduction and regeneration requirements and a functional classification for floodplain plants.



## 5. Operating regimes and environmental water-delivery strategies

To meet environmental watering objectives for an asset requires the delivery of flows at an appropriate volume and duration that meets the needs of the ecological objective. For the successful implementation of a delivery strategy, there are many matters that need to be considered for environmental water delivery in terms of determining the requirements of the 'water order'. The combination of these factors forms the operational delivery regime. The main considerations for water orders for assets on the Lachlan are provided below.

As identified in section 1.3, the existence of the two re-regulating storages of Lake Cargelligo and Lake Brewster has major implications for the operation of the Lachlan River. When water is stored in Lake Brewster the river operates as two rivers, Wyangala to Brewster Weir and then Brewster Weir to Oxley. When Lake Brewster is empty, the river is operated from Wyangala Dam.

As the river operator, State Water addresses these considerations and determines the delivery requirements to meet environmental water orders required by environmental water managers. Section 5.2 and Table 8 provide the water orders for each asset/WMA.

### 5.1 Delivery considerations

#### 5.1.1 Travel time for delivery of environmental water

The length of time it takes for environmental water to reach a targeted asset from the water storage is an important consideration, particularly in the Lachlan, given the multiple storages and the length of the river and distributary creek channels. The following are approximate travel times:

- Wyangala to Lake Cargelligo—15 days
- Lake Cargelligo to Lake Brewster—three to five days
- Lake Brewster to Moon Moon Swamp—17 days
- Lake Brewster to Booligal Weir—20 days
- Booligal Weir to Corrong—18 days
- Corrong to Oxley—7 to 14 days depending on flow level.

The total travel time from Wyangala to Oxley is approximately 90 days.

Additional travel times are required along the distributary/effluent creek systems (see asset profiles for more details):

- Willandra Creek—approximately 90 days to Morrison’s Lake and 100 days to Balranald/Ivanhoe Road
- Merrowie Creek—approximately 50–60 days to Cuba Dam
- Merrimajeel Creek—approximately 70 days to Murrumbidgeil Swamp.

Stock and domestic replenishment flows are frequently delivered to the lower Lachlan, including to its distributaries, and delivered annually if water is available. As much as possible these replenishment flows are provided by unregulated tributary flows, but if these flows do not occur, replenishment flows can be provided from the river regulation storages. In the latter circumstances and for the lower river areas, it is preferable to provide these flows from Lake Cargelligo and/or Lake Brewster. Section 10.2 provides more details on these replenishment flows as there is potential to use this water in conjunction with environmental water releases.

## 5.1.2 Storage release capacities

The following storage release capacities apply to each storage at maximum storage levels (DLWC 2002). The release capacity will decrease as the storage level drops. Any order for environmental water needs to consider other water orders and therefore possible valve and channel (see section 5.3) capacity sharing:

- The outlet valves at Wyangala Dam have a maximum capacity of 7,400 ML/d at maximum storage level.
- When the Wyangala storage exceeds 55 per cent it is possible to release water via the spillway gates as per the following (the operation of these gates is more complex and there will be less precision with the release volumes than via the dam outlet valves):
  - at 57 per cent storage, releases of up to 10,000 ML/d
  - at 58 per cent storage, releases up to 20,000 ML/d<sup>2</sup>
  - at 62 per cent storage, releases up to 70,000 ML/d.
- Lake Cargelligo has an outlet capacity of 1,000 ML/d when full.
- Lake Brewster, in conjunction with the conduit for Brewster Weir, previously had a release capacity of 3,500 ML/d. The current arrangements for releases are 1,200–3,000 ML/d as per the following:
  - 1,200 ML/d via Brewster Weir conduit
  - 600–1,800 ML/d via the lake depending on storage capacity.

## 5.1.3 Channel capacities

The main parts of the Lachlan River which have channel capacity limitations for regulated water-delivery purposes are:

- Forbes—channel capacity is about 32,500 ML/d. This is not a barrier to regulated releases, though some minor inundation is experienced at 15,000 ML/d in this area.
- Condobolin—channel capacity is about 6,000 ML/d.
- Condobolin anabranches—flows are generally delivered at around 1,000 ML/d at Condobolin. When discharge exceeds approximately 4,000 ML/d in Island Creek upstream of Condobolin, water may start to spill out of the anabranch system, and onto the floodplain and other creeks. Other Condobolin anabranches have much lower channel constraints with the Goobang/Bumbuggan system limited to 2,000 ML/d, Wallamundry system less than 390 ML/d and Booberoi Creek less than 175 ML/d (S. Sritharan, State Water, pers. comm.). This area would be particularly sensitive to overbank flows since there is considerable cropping undertaken adjacent to these Creeks.

2 Flows above about 15,000 ML/d at Forbes start to break out of the river channel and flood private lands. Releases from Wyangala above this rate are only undertaken for flood-mitigation purposes. Therefore total Wyangala releases above 15,000 ML/d are avoided under the current translucent environmental releases under the Water Sharing Plan.

- Willandra Creek—regulator is overtopped by flows of 2,400 ML/d, with substantial flows passing down Willandra Creek as this threshold is further exceeded (Note: the natural commence-to-flow for Willandra Creek was around 8,000 ML/d—see Willandra asset profile.)
- Middle Creek—commence-to-flow is 2,000 ML/d at Hillston Weir.
- Merrowie Creek—commence-to-flow (assuming no boards and the Gonowlia Weir Regulator is open) is 1,500 ML/d at Hillston Weir.
- Lake Waljeers area—overbank flows into this system commence at around 800–1,200 ML/d at Booligal Weir. Lake Ita, which is located in this area, appears to have a commence-to-flow of around 600 ML/d at Corrong following the removal of a regulator from its inlet channel. This figure is yet to be confirmed.

Channel capacity has to be shared with other water uses and users and exceeding channel capacity may result in flooding of cultivated land (mainly in the Condobolin area) or other non-target areas. Channel constraints, where known, have generally been taken into account in the delivery of environmental water. But these conditions, particularly for lower capacity channels, may change with obstructions which may appear in these channels, for example due to vegetation growth from plants like Cumbungi.

Consequently, third party impacts from environmental water delivery must be considered when water orders are placed to reduce the risk to property and infrastructure.

## 5.1.4 Availability of conveyance water

Conveyance water is that which is provided to 'run the river' and provide for the natural water forfeit which occurs along the river and creek channels due to "water evaporation and seepage from surface water sources and man-made water transportation features, such as irrigation channels" (National Water Commission 2011). On most parts of regulated rivers, water orders for extractive or environmental use (orders) are provided 'on top of' the conveyance water. In NSW, volume requirements to provide for conveyance water are shared amongst all users and accounted for when the annual and progressive water resource assessment is undertaken by the NSW Office of Water in conjunction with State Water. This volumetric requirement is set aside in the relevant water storages prior to any other water allocations (both high and general security) being determined. In 2003 the annual conveyance reserve volume in the Lachlan was about 200,000 megalitres in Wyangala Dam (LRMC 2003). However this reserve may have altered, and possibly reduced, in recent years with the experience gained in running the river more efficiently during the recent drought (see also section 8.2).

Locations along the river and creeks to which conveyance water is provided is an important consideration for an environmental water manager. If an environmental water order is placed within the conveyance system limits, the order only needs to consider the asset watering needs. However, if the asset is outside of the conveyance system limits, the environmental water order will need to provide for any conveyance water losses. The current NSW RiverBank Water Use Plan No. 1 specifies these locations (see also section 6.2) according to the following arrangements:

### *"Part 3 Plan area*

*This plan authorises the use of water within:*

- (1) those sections of the Lachlan Regulated River Water Source that are downstream of Wyangala Dam;*
- (2) the Merrowie Creek Trust District;*
- (3) the Toriganny, Muggabah and Merrimajeel Creeks Trust District;*

*(4) the following specific areas prioritised by RiverBank for water application, being:*

- (a) the lagoon on the property "Burrawang West" formed behind a structure on Goobang Creek (Grid Reference 542100 east, 6331700 north, Condobolin Map 1:50,000, Sheet 8331);*
- (b) the lagoon on the property "Yarnel" formed behind a structure on Wallaroi Creek (Grid Reference 505500 east, 6327500 north, Condobolin Map 1:50,000, Sheet 8331);*
- (c) Murrumbidgee Swamp (Grid Reference 281000 east, 6249000 north, Tarwong Map 1:50,000, Sheet 7730) on Merrimajeel Creek;*
- (d) Lake Ita (Grid Reference 252000 east, 6203000 north, Maude Map 1:50,000, Sheet 7729) on Kalyarr State Conservation Area;*
- (e) The Lachlan River channel and associated riparian lands below Booligal Weir; and*
- (f) The Great Cumbung Swamp (Grid Reference 230000 east, 6206000 north, Maude Map 1:50,000, Sheet 7729).*

## **Part 5 Conditions on water use**

*4) For the purpose of measurement of water delivered, the access licences that nominate the plan shall also nominate the works owned by State Water in order to use water allocations and for water accounting.*

*1. Access licences that order water for use:*

- a. Under Part 3 (1) shall nominate Brewster Weir;*
- b. Under Part 3 (2) shall nominate Merrowie Offtake Regulator;*
- c. Under Part 3 (3) and (4)(c) shall nominate Torriganny Weir;*
- d. Under Part 3 (3) and (4)(c) shall nominate Merrimajeel Offtake Regulator (to be constructed);*
- e. Under Part 3 (3) and (4)(c) shall nominate Muggabah Offtake Regulator (to be constructed); and*
- f. Under Part 3 (4)(e) and (f) shall nominate Booligal Weir."*

Generally, conveyance water is available for the watering of some river-based environmental assets upstream of Booligal Weir, but not downstream. This consideration is further addressed in section 5.2 below.

Given some environmental water orders will likely result in the need for more conveyance water (e.g. Moon Moon Lake—see below), this could result in more water needing to be set aside in the resource assessment process. If this occurs, it will reduce the volumes and reliability of general-security allocations.

### 5.1.5 Base conveyance flows in the regulated river channel

The baseflow provided to the river channel varies with the time of the year and in consideration of groundwater accessions and losses in the relevant river section. For the river upstream of Lake Cargelligo the seasonal baseflow requirement is lower in the winter period (as low as 100 ML/d; see Appendix 6) and much higher during the summer (up to 400–500 ML/d; see Appendix 6) with greater evapotranspiration. Baseflow requirements for the river downstream of Lake Cargelligo are also provided in Appendix 6. Because of this variability, the baseflows for the river sections in Table 7 are only for the minimum requirement.

In severe drought periods, the commitment is to provide town water supply flows only as far as Condobolin. Consequently, under extreme circumstances, some sections of the river downstream of this point may not receive regulated baseflow releases.

### 5.1.6 Piggybacking opportunities

The existence of conveyance water in parts of the Lachlan provides for piggybacking opportunities to assist efficient delivery of environmental water orders. Other water in the river also provides opportunities for piggybacking, including stock and domestic replenishments, other water orders and unregulated flow events. Table 8 outlines the water orders required for several circumstances with and without stock and domestic replenishments on Willandra Creek, Merrowie Creek and the Muggabah–Merrimajeele Creek systems.

Unregulated flows and translucent environmental flow events are important piggybacking opportunities. As an indication of what would be required to deliver environmental water to Moon Moon Swamp, the following information is provided on the February–March 2010 unregulated flow event. This event reached the commence-to-fill for Moon Moon and some water filled the lower parts of the swamp (P Packard (OEH) 2011, pers. comm.) but the extent of flooding has not been determined:

- The combined flow at Willandra Weir and Regulator was some 26,100 megalitres between February 21 and March 12 (includes flows above 200 ML/d). The maximum discharge reached 2,869 ML/d at the weir with a maximum of some 100 ML/d down Willandra Creek.
- The flow at Hillston Weir reached 2,170 ML/d and therefore some water may have passed into Middle Creek.
- Over the 30 days associated with the event, some 25,000 megalitres passed Whealbah gauge with a maximum of 2,200–2,300 ML/d for five days.

Table 7 provides information on the flow regime and total volumes of water that could be used to piggyback an environmental water order for assets/WMAs as relevant.

### 5.1.7 Asset/WMA antecedent moisture conditions

The moisture condition of the environmental asset/WMA is an important consideration in determining the water order. If the soil moisture profile of an asset/WMA is already wet, far less water will be required for the order than if the soil profile is dry. This situation is best illustrated by the water order which is required to reach sites in Murrumbidgee Swamp where much more water is needed in the absence of piggybacking environmental water on the stock and domestic replenishment, as outlined in Table 5. Equally, the volume of water required to inundate Murrumbidgee Swamp will be greater if the site is dry, than if the soil profile is already wet (Table 7).

**Table 7:** Wet and dry water orders for Murrumbidgee Swamp<sup>1</sup> (source – Water Management Area Profile)

	Wet order	Dry order
Murrumbidgee Creek supply channel	Nil if already channel wetted and in winter months.	4,000 ML in winter (based on stock and domestic replenishment share of 7,000 ML for Murrumbidgee Creek).
Murrumbidgee Swamp (100 -ha area)	600 ML if swamp is wet.	1,400 ML if swamp is dry.
<b>Total order</b>	<b>600 ML</b>	<b>5,400 ML</b>

<sup>1</sup> Note that the following 'rule of thumb' method has been used to calculate estimates: 6 ML/ha (wet) and 12 ML/ha (dry) for wetland areas in the profiles. Additional to soil moisture, many other factors will have a significant influence on the actual watering requirement of the wetland such as soil type, depth and overall bathymetry of the sites, time of the year, etc. More accurate watering requirements can be obtained from the development and ongoing calibration of hydrodynamic and hydrology models for individual wetlands. The Barma et al. (2010) study has developed hydrology models for many of the subject Lachlan wetlands and provides the first calibration of these models.

Determination of wet-versus-dry condition soil-moisture profile of an asset/WMA is influenced primarily by flows from the Lachlan River and local rainfall. Objective measures of the soil-moisture profile, in relation to ecological water requirements for the site, can be obtained using instruments such as neutron probes.

In the absence of objective measures, 'time since last watering' can be estimated based on the relationship between river flow events and response thresholds (i.e. commence-to-fill) of the asset/WMA. The closest meteorological station can also provide information on the severity of rainfall events. This information can be provided by local landholders, and probably more accurately for the actual site conditions.

At the time of writing, no objective relationship has been established between watering events (either river flows or rainfall) and the soil-moisture profile conditions for the Lachlan assets (these may have differing soil types and consequently differing relationships). Therefore the assumption used in this document is that an asset/WMA is considered to be dry if it has not been wetted within a two-year period, and consequently will require a dry water order.

## 5.1.8 Efficient release below Lake Brewster

The maximum release for irrigation peak demand to the Hillston area, and for avoiding losses to Willandra and Middle Creeks, occurred in 2000. The amount released was 2,000 ML/d from Lake Brewster and Brewster Weir pool (some releases from Wyangala Dam were also involved to fill the weir pool). Flows in this vicinity to downstream wetlands are likely to be the most efficient in terms of the risk of losing water to the Willandra and Middle Creek systems.

Lake Brewster is especially important for the provision of environmental water, due to its storage and release capacity and its location in the catchment. In this context some important issues need to be considered about this storage:

- Lake Brewster is often dry or non-operational toward the end of each water year or during extended drought periods. For example, until the 2010–11 water year, Lake Brewster had not held water for stock and domestic releases or water allocations since 2001. The lake can also be empty or with low water levels in periods with high water allocations. Even with 100 per cent allocations it is common for the lake to be low or empty in year two of these circumstances due to the high downstream water demands in year one. Therefore there may be circumstances when the lake is dry or has limited water when environmental releases are wanted (also see bulk water transfers below).

- The lake frequently develops serious, toxic blue-green algal blooms (and other poor water-quality characteristics) and therefore releases have seeded the river downstream and resulted in algal warnings being issued. Under these circumstances releases from the lake have either been terminated or reduced, with 'make-up' water having to be released from Wyangala Dam. The Water Sharing Plan has provisions for these circumstances and there are operating protocols which restrict releases from the lake.
- Under the recently implemented Lake Brewster Water Efficiency Project, actions have been taken at the lake to reduce potential for poor water quality through the construction of inflow and outflow wetlands. At this stage it is not known how effective these wetlands will be, and particularly at low lake levels when water quality is at its worst.
- Given the significant growth in available environmental water on the Lachlan, and the pivotal importance of the lake in providing this water to the lower river, there is likely to be a growing need to ensure this water resides in the lake as much as possible. Provision of this water will likely be of a substantially different demand pattern (i.e. winter–spring, large volume and high-loss water orders—see Table 7) versus that which has traditionally been the case (i.e. summer, lower volume and low-loss water orders). As such, this need may require bulk environmental water transfers to be made from Wyangala Dam, which has not occurred previously in the Lachlan. This action could have major consequences such as impacts on the upstream river ecosystem, water loss through evaporation in the lake, and third-party impacts on other water users. There has been no investigation of bulk water transfers in the Lachlan as previously there has been no need for these.

## 5.2 Water orders for Lachlan environmental assets

The determination of delivery requirements, watering frequencies and duration for the water-dependent assets of the Lachlan River will be subject to the conditions existing at the desired time for watering and many dynamic considerations (some of these were outlined above). The actual water delivery specifications will be determined by State Water, to reflect delivery constraints and the environmental water order placed by environmental water managers.

The information in Table 8 is provided based on the water order which would be placed by environmental water managers to meet the ecological and environmental watering objectives for each asset/WMA presented in Table 5, and has drawn on the information of Table 6 to determine the timing and duration of watering. The water order in Table 8 considers the essential parameters that environmental water managers would provide to State Water as per their Water Order Application Form (see Appendix 4). The extraction details for bulk orders required under the order form are:

- start date
- number of days pumping (or duration of flow in the environmental assets)
- volume per day in megalitres.

There is also another State Water form for the use of multiple licences for the water order.

In addition, the water order in Table 8 considers the antecedent condition of the asset based on considerations outlined in section 5.1.6 above. Descriptions of each of the WMA and assets for which delivery regimes have been determined are provided in Appendix 2.

Because of the complexity and length of Table 8, Table 9 provides a summary of Table 8 water orders.



**Table 8:** Water orders to meet environmental watering objectives for Lachlan assets and water management areas.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Lachlan River channel	Lachlan River reach–Wyangala–Jemalong	Extreme dry	Baseflow to prevent cease-to-flow.	Wet	No watering action required, subject to 120 ML/d of conveyance and town water supply releases at Forbes delivered from Wyangala or unregulated flows. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	As above. Because this part of the river channel remains continuously wet, there is no additional dry requirement.
		Dry	As above.	Wet	No watering action required, subject to 120 ML/d of conveyance and town water supply releases at Forbes delivered from Wyangala or unregulated flows. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	As above.
		Median	Drownout Cottons Weir (Forbes) for 1 week.	Wet	Drownout threshold is 9,250 ML/d or a total volume of 64,750 ML delivered over seven days is required to achieve this order. Can be achieved through Wyangala Dam release (see section 5.1.2) or piggybacking.
				Dry	As above.
	Lachlan River reach–Jemalong–Lake Cargelligo	Wet	Drownout Cottons Weir (Forbes) for 2 weeks.	Wet	Drownout threshold is 9,250 ML/d, or a total volume of 129,500 ML delivered over 14 days is required to achieve this order. Can be achieved through Wyangala Dam release (see section 5.1.2) or piggybacking.
				Dry	As above.
		Extreme dry	Baseflow to prevent cease-to-flow.	Wet	No watering action required, subject to conveyance and town water supply releases of 150 ML/d at Jemalong and 30 ML/d at Lake Cargelligo Weir. (Note: See section 5.1.5 and this volume will vary seasonally. Also, regulated flows may be stopped at Condo in these climate years.)
				Dry	As above. In the recent drought, regulated flows were maintained to Lake Cargelligo and the river channel remains wet.
		Dry	As above.	Wet	No watering action required, subject to conveyance and town water supply releases of 150 ML/d at Jemalong and 30 ML/d at Lake Cargelligo Weir. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	As above.
Lachlan River channel	Median	Median	Drownout Condobolin and West Condobolin Weirs for 1 week.	Wet	Condo Weir threshold is 4,100 ML/d and a total order of 28,700 ML over 7 days is required. West Condo Weir threshold is 3,800 ML/d, requiring a total order of 26,600 ML over 7 days provided concurrently with the Condo Weir order. Can be achieved through Wyangala Dam release (see section 5.1.2) or piggybacking.
				Dry	As above.
	Wet	Wet	Drownout Condobolin and West Condobolin Weirs for 2 weeks.	Wet	Condo Weir threshold is 4,100 ML/d and a total volume of 57,400 ML over 14 days is required. West Condo Weir threshold is 3,800 ML/d, requiring a total order of 53,200 ML over 14 days provided concurrently with the Condo Weir order. Can be achieved through Wyangala Dam release (see section 5.1.2) or piggybacking.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Lachlan River channel	Lachlan River reach-Lake Cargelligo-Lake Brewster	Extreme dry	Baseflow to prevent cease-to-flow.	Wet	80 ML/d at Lake Cargelligo Weir. (Note: See section 5.1.5 and this volume will vary seasonally. Also regulated flows may be stopped at Condo in these climate years.)
				Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
	Lachlan River reach-Lake Brewster-Great Cumbung Swamp	Median	Maintain inundation of Brewster Weir pool.	Wet	The full storage volume of Brewster Weir pool is 5,500 ML; olive perchlet refuges do not require full storage, appropriate storage volume to protect olive perchlet habitat is not known.
				Dry	As above.
		Wet	As above.	Wet	The full storage volume of Brewster Weir pool is 5,500 ML; olive perchlet refuges do not require full storage, appropriate storage volume to protect olive perchlet habitat is not known.
				Dry	As above.
		Extreme dry	Baseflow to prevent cease-to-flow.	Wet	50 ML/d required at Booligal to maintain visible flow. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	In the recent drought, particularly in this reach, regulated releases for stock and domestic flows were restricted and substantial parts of the channel which are normally wet became dry. It is not known how much additional water is required to re-wet the dry channel portion.
		Dry	As above.	Wet	50 ML/d at Booligal to maintain visible flow. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	As above.
	Median		Drownout Willandra and Hillston Weirs for 1 week.	Wet	Willandra Weir threshold is 8,500 ML/d or a total volume of 59,600 ML delivered over 7 days. Hillston Weir threshold is 4,750 ML/d or 33,250 ML over 7 days. The maximum possible Brewster Weir and Brewster Lake release is 3,000 ML/d or 21,000 ML per week. Order for both sites only to be achieved with piggybacking.
				Dry	As above.
	Wet		Drownout Willandra and Hillston Weirs for 2 weeks.	Wet	Willandra Weir threshold is 8,500 ML/d or a total volume of 119,000 ML delivered over 14 days. Hillston Weir threshold is 4,750 ML/d or 66,500 ML over 14 days. The maximum possible Brewster Weir and Brewster Lake release is 3,000 ML/d or 42,000 ML for two weeks. Order for both sites only to be achieved with piggybacking.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Burrawang West Lagoon	Burrawang West Lagoon	Extreme dry	Deliver up to 50 ML (volume-to-fill) to Burrawang West Lagoon.	Wet	Requires flows to Bumbuggan Weir via Bumbuggan Creek, or unregulated. Flows via Goobang and Yarrabandai Creek (total volume required to deliver 50 ML volume-to-fill is 420 ML; 30–50 ML/d over 8–14 days).
				Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
		Median	As above.	Wet	As above.
	Burrawang West Lagoon	Wet	Deliver >50 ML (volume-to-fill) to Burrawang West Lagoon.	Dry	As above.
				Wet	Requires flows to Bumbuggan Weir via Bumbuggan Creek or unregulated. Flows via Goobang and Yarrabandai Creek (total volume required to deliver >50ML volume-to-fill is >420 ML; 30–50 ML/d over 8–14 days).
		Dry		Dry	As above.
Yarnel Lagoon	Yarnel Lagoon	Extreme dry	Deliver up to 360 ML (volume-to-fill) to Yarnel Lagoon.	Wet	Requires 9,360 ML to deliver 360 ML (volume-to-fill), subject to 9,000 ML replenishment flow delivered at 150 ML/d for 60 days at Wallaroi Creek gauge between October and April (threshold gauge height at Wallaroi Creek is 1.027 m).
				Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
		Median	As above.	Wet	As above.
	Yarnel Lagoon	Wet	Deliver >360 ML (volume-to-fill) to Yarnel Lagoon.	Dry	As above.
				Wet	Requires 9,360 ML to deliver 360 ML (volume-to-fill), subject to 9,000 ML replenishment flow delivered at 150 ML/d for 60 days at Wallaroi Creek gauge between October and April (threshold gauge height at Wallaroi Creek is 1.027 m).
		Dry		Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Booberoi Creek	Booberoi Creek	Extreme dry	Baseflow to maintain pools.	Wet	No watering action required, subject to 12,500 ML replenishment flow at 30–50 ML/d for 12 months from Booberoi Weir. The replenishment may not be available from regulated releases in extreme dry conditions. State Water advise 4,000 ML will reach the end of the Booberoi system.
				Dry	As above.
		Dry	As above	Wet	As above.
				Dry	As above.
		Median	Deliver flushing flows to Booberoi Creek up to 3,000 ML (additional to the replenishment flow).	Wet	Up to 3,000 ML in addition to 12,500 ML replenishment; to pulse 200 ML/d for 20 days between June to Sept from Booberoi Weir. The volume of water delivered is for dry antecedent conditions and less will be required under wet antecedent conditions. Currently it is not possible to deliver these higher flows into the creek due to major siltation in the creek near the regulator.
				Dry	As above.
Lake Brewster		Wet	Deliver flushing flows to Booberoi Creek up to 3,000 ML (additional to the replenishment flow).	Wet	As above.
				Dry	As above.
	Lake Brewster inflow wetland	Extreme dry	No water delivered under extremely dry conditions.	NA	The wetland is part of the Lake Brewster operational storage. 1,500 ML (volume-to-fill) is the filling requirement estimated by State Water. For the wetland to optimise its water-quality improvement function, inflows of less than 500 ML/d have been estimated.
		Dry	Deliver at least 1,500 ML (volume-to-fill) to Brewster inflow wetland	NA	The Lake Brewster Water Use Plan outlines objectives for the water savings including assisting in the establishment and maintenance of constructed inlet and outlet wetlands. These water savings belong to the Australian Government but are administered by the NSW Office of Environment and Heritage.
		Median	As above.	NA	While the inflow wetland volume-to-fill has been estimated at 1,500 ML, required volumes based on the area of wetland (300 ha) are:
		Wet	As above.	NA	<ul style="list-style-type: none"> <li>1,800 ML for wet antecedent conditions order based on 6 ML/ha</li> <li>3,600 ML for dry antecedent condition order based on 12 ML/ha.</li> </ul>
	Lake Brewster outflow wetland	Extreme dry	No water delivered under extremely dry conditions.	NA	

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Lake Brewster		Dry	Deliver up to 5,000 ML to Brewster outflow wetland.	Wet	The wetland is part of the Lake Brewster operational storage and would be filled from the main lake or via channel sources. The total area of the 3 cells is 745 ha.  While the outflow wetland volume-to-fill has been estimated at 5,000 ML, required volumes based on the area of wetland (745 ha) are:  4,470 ML for wet antecedent condition order based on 6 ML/ha  8,940 ML for dry antecedent condition order based on 12 ML/ha.
				Dry	No water delivered under dry antecedent conditions.
		Median	As above.	NA	The wetland is part of the Lake Brewster operational storage and would be filled from the main lake or via channel sources. The total area of the 3 cells is 745 ha.
		Wet	Deliver >5,000 ML to Brewster outflow wetland.	NA	While the outflow wetland volume-to-fill has been estimated at 5,000 ML, required volumes based on the area of wetland ( 745 ha) are:  4,470 ML for wet antecedent condition order based on 6 ML/ha  8,940 ML for dry antecedent condition order based on 12 ML/ha.
				Wet	No watering action required, subject to 12,000 ML replenishment flow provided at 150 ML/d to Homestead Weir. The volume of water delivered is for dry antecedent conditions and less will be required under wet antecedent conditions.
				Dry	As above.
				Wet	As above.
Willandra Creek	Willandra Creek-upstream reach (Willandra Regulator to Willandra Homestead Weir)	Extreme dry	Baseflows to wet channel and fill pools.	Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
		Median	Deliver water (volume to be determined).	Wet	Deliver water (volume to be determined), piggybacked on replenishment flow.
				Dry	As above.
				Wet	As above.
		Wet	As above.	Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Willandra Creek	Willandra Creek— downstream reach (Homestead Weir to Balranald/ Ivanhoe Rd)	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to 12,000 ML replenishment flow provided at 150 ML/d to Homestead Weir. The volume of water delivered is for dry antecedent conditions and less will be required under wet antecedent conditions.
				Dry	As above.
				Wet	As above.
		Median	Deliver water (volume to be determined).	Dry	As above.
				Wet	Deliver water (volume to be determined) piggybacked on the replenishment flow.
				Dry	As above.
	Morrison's Lake	Wet	As above.	Wet	As above.
				Dry	As above.
				NA	As above.
		Extreme dry	No water delivered under extremely dry conditions.	NA	None
				NA	None
				Wet	Wet antecedent condition order based on 6 ML/ha = 1,560 ML which requires 10 days at 150 ML/d at Willandra Homestead Weir.
Willandra Creek	Morrison's Lake	Median	Up to 4,000 ML (volume-to-fill) delivered to Morrison's Lake (estimate provided by State Water).	Dry	Dry antecedent condition order based on 12 ML/ha = 3,744 ML or 25 days at 150 ML/d at Homestead Weir.  (Note: State Water advise that the lake can be filled from the stock and domestic replenishment but only after the replenishment has reach Ivanhoe Road. This may satisfy the environmental watering objective, but if not, an environmental water order will be required.)
				Wet	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Merrowie Creek	Upper Merrowie Creek (offtake to Toms Lake)	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Dry	As above.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Median	As above.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Median	As above.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Wet	As above.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.



Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Merrowie Creek	Merrowie Creek– Toms Lake	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowilla Weir. Wet conditions likely to require <9,000 megalitres.
		Dry	Deliver 3,000 to 3,600 ML.	Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowilla Weir.
		Median	As above.	Dry	3,000–3,600 ML provided at 150 ML/d for about 20 days, piggybacked on replenishment flow between Jun and Sept.
			Deliver 3,000 to 5,000 ML.	Wet	3,000–5,000 ML provided at 150 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Dec. Wet conditions likely to require <9,000 megalitres.
	Merrowie Creek– Mutherumbung Weir pool	Wet	Deliver 5,000 to 7,200 ML.	Dry	3,000–5,000 ML provided at 150 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Dec.
				Wet	5,000–7,200 ML provided at 150–300 ML/d for about 45 days, piggybacked on replenishment flow between Jun and Dec. Wet conditions likely to require <9,000 megalitres.
		Extreme dry	Baseflows to wet channel and fill pools.	Dry	5,000–7,200 ML provided at 150–300 ML/d for about 45 days, piggybacked on replenishment flow between Jun and Dec.
				Wet	No watering action required, subject to replenishment flow of up to 9,000 ML at 150 ML/d for about 6–8 weeks between June to Sept from Gonowilla Weir. Wet conditions likely to require <9,000 ML.
		Dry	Deliver 3,500 to 5,000 ML to Mutherumbung Weir.	Dry	No watering action required, subject to replenishment flow of 9,000 ML provided at 150 ML/d for about 6–8 weeks from Gonowilla Weir.
				Wet	3,500–5,000 ML provided at 150 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Sep.
		Median	As above.	Dry	No watering action required, subject to replenishment flow of up to 9,000 ML at 150 ML/d for about 6–8 weeks between June to Sept from Gonowilla Weir.
				Wet	3,500–5,000 ML provided at 150–300 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Dec.
		Wet	Deliver 5,000– 7,200 ML to Mutherumbung Weir.	Dry	As above.
				Wet	5,000–7,200 ML provided at 150–300 ML/d for up to 45 days, piggybacked on replenishment flow between Jun and Dec.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Merrowie Creek	Merrowie Creek– Cuba Dam	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to 9,000 ML replenishment flow provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowila Weir. Wet conditions likely to require <9,000 ML.
				Dry	No watering action required, subject to 9,000 ML of replenishment flow provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowila Weir.
		Dry	Deliver up to 5,000 ML to Cuba Dam.	Wet	5,000 ML provided at 150–300 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Sep.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks from Gonowila Weir between Jun and Sep.
	Merrowie Creek– Lake Tarwong and Tarwong Swamps	Median	As above.	Wet	5,000 ML provided at 150–300 ML/d for up to 30 days, piggybacked on the replenishment flow between Jun and Dec.
				Dry	As above.
		Wet	Deliver up to 7,200 ML to Cuba Dam.	Wet	5,000–7,200 ML provided at 150–300 ML/d for up to 45 days, piggybacked on the replenishment flow between Jun and Dec.
				Dry	As above.
		Extreme dry	No water delivered under extremely dry conditions.	NA	
				NA	
		Dry	No water delivered under dry conditions.		
		Median	Deliver up to 2,000 ML to Tarwong Lake.	Wet	Up to 2,000 ML provided at 150–300 ML/d for up to 13 days, piggybacked on replenishment flow between Jun and Dec.
				Dry	As above.
		Wet	Deliver up to 9,000 ML to Lake Tarwong and the south and north swamps.	Wet	Up to 9,000 ML provided at 150–300 ML/d for up to 60 days, in addition to the replenishment flow between Jun and Dec.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Moon Moon Swamp	Moon Moon Swamp	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	No water delivered under dry conditions.	NA	
		Median	Deliver up to 2,500 ML (volume-to-fill) to Moon Moon Swamp.	Wet	The inflow channel capacities (i.e. filling rate) from the Lachlan River into the swamp are not known but 100 ML/d has been assumed.
		Wet	Deliver up to 2,500 ML to Moon Moon Swamp (as above) and downstream environment.	Dry	The following is known: <ul style="list-style-type: none"> <li>The CTF for these channels is about 2,000 ML/d at Whealbah. This flow rate for 30 days is known to result in the inundation of the swamp. In 2010 a total flow about 25,000 ML achieved flooding of Moon Moon. Timing is from June to December.</li> <li>Wet: 1,050 ML at 100 ML/d for 10.5 days.</li> <li>Dry: 2,500 ML at 100 ML/d for 25 days.</li> </ul>
	Booligal Swamp	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to replenishment flows of up to 9,000 ML provided at 100 ML/d for 90 days in winter. Less water required under wet antecedent conditions.
				Dry	No watering action required, subject to replenishment flows of up to 9,000 ML provided at 100 ML/d for 90 days in winter.
Booligal Wetland		Dry	As above.	Wet	No watering action required, subject to replenishment flows of up to 9,000 ML provided at 100 ML/d for 90 days in winter. Less water required under wet antecedent conditions.
				Dry	No watering action required, subject to replenishment flows of up to 9,000 ML provided at 100 ML/d for 90 days in winter.
		Median	Deliver up to 5,000 ML to Booligal Swamp.	Wet	Deliver up to 5,000 ML via diversion from Torriganney Weir into Merimajee Creek. Flows provided at 50 ML/d for up to 100 days. In addition to the replenishment flow between May and August.
				Dry	No watering action required as waterbird breeding unlikely in absence of prior wetting.
		Wet	As above.	Wet	Deliver up to 5,000 ML via diversion from Torriganney Weir into Merimajee Creek. Flows provided at 50 ML/d for up to 100 days. In addition to the replenishment flow between May and August.
				Dry	No watering action required as waterbird breeding unlikely in absence of prior wetting.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Boolligal Wetland	Murrumbidgee Swamp	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver 1,400 ML (volume-to-fill) to Murrumbidgee Swamp.	Wet	Deliver 1,400 ML at 40 ML/d for 35 days from Torrigan Weir, piggybacked on replenishment flow.
		Median	Deliver >1,400 ML (volume-to-fill) to Murrumbidgee Swamp.	Dry	As above.
		Wet	As above.	Wet	Deliver 1,400 ML + 4,000 ML = 5,400 ML (in the absence of replenishment flow) via Merrimajee Creek at 100 ML/d for 54 days from Torrigan Weir from May to August.
				Dry	As above.
	Lake Merrimajee	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	No water delivered under dry conditions.	NA	
		Median	Deliver 1,200 ML (volume-to-fill) to Lake Merrimajee.	Wet	See Murrumbidgee Swamp order (1,400 ML + 4,000 ML in the absence of replenishment flow). An additional 600 ML to be added and for an additional 30 days from Torrigan Weir.
				Dry	See Murrumbidgee Swamp order. An additional 1,200 ML to be added and for an additional 30 days from Torrigan Weir.
		Wet	Deliver >1,200 ML to Lake Merrimajee.	Wet	See Murrumbidgee Swamp order. An additional volume >1,200 ML to be added and for at least an additional 30 days from Torrigan Weir.
				Dry	See Murrumbidgee Swamp order. An additional volume >1,200 ML to be added and for at least an additional 30 days from Torrigan Weir.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Boolligal Wetland	Lower Gum Swamp	Extreme dry	No water delivered under extremely dry conditions	NA	
		Dry	No water delivered under dry conditions	NA	
		Median	Deliver up to 3,400 ML (volume-to-fill) to Lower Gum Swamp	Wet	Deliver 400 ML at 40 ML/d for 10 days from Torrigan Weir, piggybacked on replenishment flow.
	Lake Waljeers			Dry	Deliver 400 ML+ 3,000 ML= 3,400 ML (in absence of replenishment piggyback) via Merimajee Creek at 40 ML/d for 85 days from Torrigan Weir in May to August.
		Wet	Deliver up to 2,500 ML to Lower Gum Swamp	Wet	Deliver 2,500 ML at 40 ML/d for 62 days from Torrigan Weir, piggybacked on replenishment flow.
Lachlan swamps	Lake Waljeers	Extreme dry	No water delivered under extremely dry conditions.	Dry	No watering action required as waterbird breeding unlikely in absence of prior wetting.
				NA	
		Dry	Deliver up to 2,600 ML (volume-to-fill) to Lake Waljeers.	Wet	2,600 ML required. CTF is 800–1,200 ML/d at Booligal Weir. Lake inflows occur at about 100 ML/d therefore it takes 26 days to fill (or 20,800–31,200 ML at Booligal Weir). Delivered Jun–Dec.
	Lower Gum Swamp			Dry	No water delivered under dry antecedent conditions.
		Median	Deliver up to 6,240 ML to Lake Waljeers.	Wet	6,240 ML required. CTF is 800–1,200 ML/d at Booligal Weir. Lake inflows occur at about 100 ML/d therefore it takes 62 days to fill (or 49,600–74,400 ML at Booligal Weir). Delivered Jun–Dec.
Lachlan swamps	Lake Waljeers			Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Lachlan swamps	Peppermint Swamp	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 1,440 ML (volume-to-fill) to Peppermint Swamp.	Wet	600 ML at 50–100 ML/d or 6–12 days. Delivered June–Dec.
				Dry	1,440 ML at 50–100 ML/d or 14–29 days. Delivered June–Dec.
					The orders are additional to those for Lake Waljeers and similarly the requirement for additional flows at Booligal Weir.
		Median	Deliver >1,440 ML (volume-to-fill) to Peppermint Swamp.	Wet	>1,440 ML at 50–100 ML/d or >20 days. Delivered June–Dec.
					The orders are additional to those for Lake Waljeers and similarly the requirement for additional flows at Booligal Weir.
Ita Lake				Dry	As above.
		Wet	Deliver >1,440 ML (volume-to-fill) to Peppermint Swamp.	As above.	As above.
	Ita Lake	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 14,400 ML to Ita Lake.	Wet	Deliver 7,200 megalitres. The CTF for the lake is about 800 ML at Corrong based on recent changes to the regulator on the inflow channel. The relationship between Corrong flows and inflows volumes to the lake is not known. If it assumed 100 ML/d flows into the lake at a Corrong flow of 2,000 ML/d, it will take 72 days to provide the 7,200 ML (or about 140 GL at Corrong). To be delivered in June to Dec.
				Dry	14,400 megalitres. As above but for 144 days at 2,000 ML/d at Corrong required or 288,000 megalitres. To be delivered in June to Dec.
		Median	As above.	Wet	As above.
Ita Lake				Dry	As above.
		Wet	Deliver >14,400 ML to Ita Lake.	Wet	Deliver >14,400 megalitres. As above but for >144 days at 2,000 ML/d at Corrong required or >288,000 megalitres. To be delivered in June to Dec.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Baconian Swamp	Baconian Swamp	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 9,600 ML to Baconian Swamp.	Wet	Deliver 4,800 ML. The CTF for Baconian swamp is 350 ML/d at Corrong. The relationship between Corrong flows and inflow volumes to the swamp are not known. If 100 ML/d flows into the lake are assumed—at a Corrong flow of 1,500 ML/d, it would take 48 days to provide this requirement or a total Corrong flow of 72,000 ML. To be delivered in June to Dec.
				Dry	Delivery of 9,600 ML will follow the scenario above but will take 96 days of 1,500 ML/d at Corrong of 144,000 ML.
		Median	Deliver >9,600 ML to Baconian Swamp.	Wet	>9,600 ML. As above but will take >96 days of 1,500 ML/d at Corrong of >144,000 ML.
				Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.
Great Cumbung Swamp	Reed bed	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 4,900 ML to reed bed.	Wet	Deliver 2,450 ML, provided at 700 ML/d at Booligal Weir for 3.5 days. Deliver in June to Dec.
				Dry	Deliver 4,900 ML, provided at 700 ML/d at Booligal Weir for 7 days. Deliver in June to Dec.
		Median	As above.	Wet	As above.
				Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.



Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective <sup>1</sup>	Antecedent condition or time since last watering <sup>2</sup>	Water order <sup>3,4</sup>
Great Cumbung Swamp	GCS WMA	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	No water delivered under dry conditions.	NA	
		Median	Deliver up to 30,000 ML to GCS.	Wet	Deliver 15,000 ML, provided at 700 ML/d at Booligal for about 21 days. Deliver in June to Dec.
				Dry	Deliver 30,000 ML, provided at 700 ML/d at Booligal for about 43 days. Deliver in June to Dec.
		Wet	Deliver up to 45,000 ML to GCS.	Wet	Deliver 22,500 ML, provided at 700 ML/d at Booligal for about 32 days. Deliver in June to Dec.
				Dry	Deliver 45,000 ML, provided at 700 ML/d at Booligal for about 64 days. Deliver in June to Dec.

1 Table 5 provides the corresponding ecological objective.

2 For wetlands, 6 megalitres per hectare is used for wet and 12 megalitres per hectare used for dry conditions.

3 Water order does not include conveyance or piggybacking water requirements, although some indication of these requirements are given where known. The baseflows and water for consumptive use (e.g. replenishment flows) are not to be substituted by held environmental water. In instances when these flows are not provided, additional water may need to be provided from held environmental water to meet the watering objectives. In some systems this may not be feasible given the volume that would be required. Regardless of this, the water order parameters for the baseflows or water for consumptive use are provided.

4 Where possible, delivery constraints have been considered in the water orders provided above. However, delivery constraints (outlined in sections 5.1 and 10.1) must be reviewed prior to the implementation of watering actions.

**Table 9:** Summary of proposed environmental water-order volumes and delivery strategies

Asset	Volume Range for water order (site watering only)	Volume of replenishment flows	Additional water required, e.g. piggybacking	Other assets incidentally watered (Note: depends on water storage source)
Lachlan River channel	<p>Current operational flows between 50–150 ML/d provides for some ecological objectives to be met at sites to Booligal.</p> <p>Weir drownouts:</p> <ul style="list-style-type: none"> <li>Cottons: 64,750–129,500 ML</li> <li>Condo: 28,700–57,400 ML</li> <li>Willandra: 59,600–119,000 ML.</li> </ul>	Operational flows and unregulated tributary flows undetermined.	Yes	None. Low-mid elevation wetlands and floodplain.
Burrawang West Lagoon	Up to 420 ML.	NA	NA	None
Yarnell Lagoon	Up to 360 ML (9,360 ML if not piggybacked).	9,000 ML	Yes	Wallaroi Creek riparian areas.
Booberoi Creek	Up to 3,000 ML (15,500 ML if not piggybacked).	12,500 ML	Yes	Return flows from Booberoi Creek to the Lachlan River downstream of Lake Cargelligo.
Lake Brewster	1,500 ML to >5,000 ML	Part of Lake Brewster water quality improvement.	NA	May be used to re-regulate environmental water.
Willandra Creek	4,000 ML up to volume to be determined (at least 16,000 ML if not piggybacked).	12,000 ML	Yes	Morrison's Lake
Marrowie Creek	3,000–9,000 ML (18,000 ML if not piggybacked).	9,000 ML	Yes	Lake Tarwong
Moon Moon Swamp	1,050–2,500 ML		Yes, 25,000 ML at Whealbah.	Willandra Creek and Marrowie Creek by 'additional water' to reach CTF.
Booligal Wetlands	400 ML to >6,600 ML (>15,600 ML if not piggybacked).	9,000 ML	Yes. Up to 20,000–50,000 ML from Torrigan required to stimulate for waterbird breeding.	Willandra, Marrowie, Moon Moon by 'additional water' to reach CTF.

Asset	Volume Range for water order (site watering only)	Volume of replenishment flows	Additional water required, e.g. piggybacking	Other assets incidentally watered (Note: depends on water storage source)
Lachlan Swamp	2,600–7,680 ML	NA	Yes. Up to 74,400 ML required at Booligal Weir to meet this order.	Willandra, Merrowie, Moon Moon and Booligal system by 'additional water' to reach CTF.
Lake Ita	7,200 ML to >14,400 ML	NA	Yes. Up to 288,000 ML at Corrong.	Willandra, Merrowie, Moon Moon, Booligal system and Lachlan Swamps by 'additional water' to reach CTF.
Baconian Swamp	4,800 ML to >9,600 ML	NA	Yes. Up to 144,000 ML at Corrong.	Willandra, Merrowie, Moon Moon, Booligal system, Lachlan Swamps and Lake Ita by 'additional water' to reach CTF.
Great Cumbung Swamp	2,450–45,000 ML	End of system flows.	Yes. 700 ML/d or greater at Booligal will result in additional GCS flooding.	700 ML/d (the delivery rate) will result in some flooding of Baconian. Higher flows will increasingly flood other areas.

## 6. Governance and planning arrangements

### 6.1 Delivery partners, roles and responsibilities

The partners involved in the provision of water to water-dependent assets in the Lachlan system include:

- NSW Office of Water—as the administrator of the Lachlan Water Sharing Plan and its environmental water provisions. There is an informal inter-agency agreement that has resulted in NSW Office of Water being responsible for rules-based environmental water (i.e. translucent and Water Quality Allowance) and NSW Office of Environment and Heritage being responsible for discretionary environmental water (Ecological Contingency Allowance).
- State Water as the water-delivery authority, which has extensive experience in operational aspects of the river, creeks and environmental water.
- NSW Office of Environment and Heritage as the managers of the water under the Lachlan Environmental Water Use Plan No. 1, and which have more recently become significant owners of wetland sites in the lower Lachlan. NSW Office of Environment and Heritage currently deliver Commonwealth environmental water under a temporary water-transfer arrangement.
- Lachlan CMA has sponsored the development of the draft Lachlan Environmental Water Management Plan and hosts the LRWG. The LRWG includes representatives from the LCMA, NSW Office of Water, NSW Office of Environment and Heritage, State Water, and conservation and community representatives, with staff from Commonwealth Environmental Water participating as observers. The LRWG advises the NSW Office of Environment and Heritage and the general manager of the Lachlan CMA on the management of the environmental water by assimilating a range of knowledge, experience and opinion in local community stakeholder groups and regional government agencies. Watering priorities are required to be consistent with the Lachlan Catchment Action Plan. The LRWG also provides advice on environmental needs in relation to regulated river operation on occasions when the Lachlan Water Sharing Plan is suspended.

## 6.2 Approvals, licences, legal requirements and other administrative issues

The RiverBank Lachlan Water Use Plan No. 1 sets out the legal requirements which are applicable to Water Use Plans. A Water Use Plan is a requirement for water access licences with Adaptive Environmental Water conditions under section 8E(7) of the *Water Management Act 2000* (NSW).

For environmental water managers who do not have a Water Use Plan allocated, environmental water can be transferred to the NSW Office of Environment and Heritage RiverBank for delivery. In this context, there are some relevant rules in the Water Use Plan No. 1 which are important:

- objectives of the plan
- accounting of water use which is undertaken at the following sites based on the areas targeted for water delivery:
  - Brewster Weir
  - Merrowie Offtake Regulator
  - Torriganny Weir
  - Merrimajeel Regulator
  - Muggabah Regulator
  - Booligal Weir—importantly, this site is used for accounting of all environmental water to the several downstream water-dependent assets
  - Yarnel Weir in Condobolin.

## 6.3 Lake Brewster arrangements

The Lake Brewster Water Efficiency Project, which was jointly funded by the Australian Government through the Water Smart Initiative, Lachlan CMA, State Water and Lachlan Valley Water, was implemented to:

- improve water quality and wetland environment within the lake
- increase hydraulic efficiency, thereby generating water savings
- enhance the role of Lake Brewster as an effective operational storage
- promote the wetland as a demonstration site for adaptive management of a large-scale constructed wetland.

The project's objectives were to improve hydrologic efficiency by reducing evaporation losses through the division of the lake into two cells and upgrading the regulator and channels. Water-quality improvements are to be achieved through increased aquatic plant growth and enhanced wetland function. Adaptive management will be achieved through the development and implementation of operational and monitoring plans.

As part of the Lake Brewster water efficiency works, a general security environmental water entitlement of 12,000 megalitres was created from the water savings and is vested with the Australian Government, subject to a draft Water Use Plan which is administered by the NSW Office of Environment and Heritage. The draft Water Use Plan makes up to 12,000 megalitres available for use in the Lake Brewster constructed wetlands to enhance opportunities for threatened and other native fish and waterbirds in Lake Brewster and the lower Lachlan, and to enhance river and wetland habitat in Lake Brewster and the lower Lachlan. This water used within the lake is accounted for at the Lake Brewster Inlet Regulator for environmental water use within the lake, or at Brewster Weir for use at the downstream sites specified under the RiverBank Water Use Plan above.

## 6.4 Relevant trading rules and constraints

The Water Sharing Plan prohibits:

- any dealing (trading) which would increase the total share components of access licences allowed to take water from the Lachlan River downstream of Booligal
- trading of access licences or share components between upstream of Lake Cargelligo and downstream of Lake Cargelligo until a full review is completed (see plan amendments); at the time of drafting this report it was not known if this review had proceeded
- any dealing that would result in the total share component in Willandra Creek exceeding 23,457 unit shares
- trading of access licences from the Lachlan Regulated River to effluent creeks which receive their water from the Lachlan.

These rules apply to permanent trades. Temporary trades are permitted but restricted between the areas upstream and areas downstream of Lake Cargelligo Weir, which may influence where water is purchased for environmental use. The reason for the trading prohibitions to Willandra, the effluent creeks and Lachlan downstream of Booligal is to protect the environment of these areas from potential irrigation expansion and consequent further changes to the flow regimes of these watercourses.

The Lake Cargelligo barrier was instituted to:

- prevent licences being transferred downstream of the lower lakes and therefore putting more demand on Wyangala water, which would reduce overall system water reliability
- allow for the assessment of the social, economic and environmental impacts of licences being transferred downstream of the lakes.

## 7. Risk assessment and mitigation strategies

This section outlines a number of system scale risks associated with the delivery of environmental water. Asset scale risks are outlined in the Lachlan asset profiles, included at Appendix 2.

The risk assessment outlined in Table 10 provides an indication of the risks associated with the delivery of environmental water in the Lachlan catchment. It should be noted that risks are not static and require continual assessment to be appropriately managed. Changes in conditions will affect the type of risks, the severity of their impacts and the mitigation strategies that are appropriate for use. As such, a risk assessment must be undertaken prior to the commencement of water delivery. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 5. Note that the risk level in Table 10 is the unmitigated risk (i.e. prior to the implementation of any mitigation measures).

A number of risks may arise from environmental watering, particularly following prolonged dry periods. Some risks include poor water quality, ecological risks associated with inundation periods and timing, socio-economic risks associated with flooding, and hydrologic risks associated with inappropriate flow regimes. Mitigation measures to reduce these risks are addressed in Table 10 and will be important in informing appropriate environmental water delivery. Some examples of risks associated with water delivery are outlined below:

- Following a prolonged period of drought, the Lachlan River downstream of Condobolin ceased to flow in late 2009. The resumption of operational flows and tributary inflows to the lower Lachlan resulted in a blackwater event within the river channel, with low oxygen levels culminating in fish kills in residual pools downstream of Condobolin. Recession flows from the inundated floodplain around the Moon Moon Swamp area in 2010 also resulted in a minor black water event, however no fish kills were recorded. Some of the impacts resulting from blackwater events may have been mitigated by continuous in-channel flows, flushing flows or timing of water releases to reduce the influence of organic material.
- Environmental releases have resulted in major waterbird breeding events, where risks have been mitigated by constant monitoring, adaptive management and communication between landholders and water managers. These actions have resulted in the successful fledging of thousands of waterbirds.
- Carp breeding has also been noted following recent inundation of the Great Cumbung Swamp (GCS), Lake Brewster and Cargelligo, which are known carp breeding hotspots. The increase in carp numbers is likely to have adverse effects on native fish and possibly inhibit aquatic plant growth. The Lachlan River Revival Project has been established to address these issues and is a collaboration between the LCMA, Invasive Animals Cooperative



Research Centre, Investment and Infrastructure NSW—Fisheries, South Australian Research and Development Institute (SARDI), and a number of other agencies and Lachlan community groups. The project involves a number of strategies to reduce carp numbers, including targeting breeding locations with mechanical control structures known as carp separation cages. This work has shown that carp control during low-flow periods may be as important as during wet years, and that drying out of remnant habitats during summer may contribute greatly to reducing the population once high flows return. Commercial fishing of the mid and lower Lachlan has also occurred and produced the most significant removal of carp, with over 11 tonnes of carp taken from Lake Cargelligo between May and August 2009.

**Table 10:** Risk associated with water delivery in the Lachlan catchment.

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Salinity	<p>Lakes Brewster and Cargelligo—often sources for environmental water delivery—frequently have salinity levels higher than those normally found in the river due to evaporative processes. Released water from these sources may increase salinity levels in the river and delivery targets.</p> <p>Salinity may also increase in weir pools during low flow or no-flow periods.</p>	Likely	Moderate	Medium	<p>The Water Sharing Plan has a 20,000 ML Water Quality Allocation available in Wyangala Dam for relief of water quality problems. See also blue-green algae below.</p> <p>Continuous flows during summer months.</p>
Blue-green algal blooms	Toxic blue-green algal blooms have occurred frequently on the Lachlan, primarily on the lower river around and downstream of Lakes Cargelligo and Brewster, generally starting in summer months and extending into the late autumn. Releases from Lake Brewster have commonly been a seeding source for these blooms in the river downstream.	Likely	Major	High	<p>The Water Sharing Plan has a 20,000 ML Water Quality Allocation available in Wyangala Dam for relief of water quality problems. Historically the water required from Wyangala to relieve algal blooms has been at relatively low discharges, 100–300 ML/d.</p> <p>If there are blue-green algal blooms in the Lake Brewster, the release of environmental water would be restricted.</p>
Blackwater	Blackwater events can occur with periods of high flows following dry or low flow periods. This is due to the build-up of organic material in channels and on floodplains. Managed releases of environmental water could contribute to triggering a blackwater event following low flow periods.	Possible	Major	High	<p>Timing of flows may reduce blackwater impacts, e.g. water delivered in cooler months. Dilution flows may also reduce blackwater impacts. Monitoring responses to inflows entering previously dry areas is required to inform management actions.</p>
Acid sulphate soils	Acid sulphate soils have been found in a number of lower Lachlan Weir pools and Lake Cargelligo surrounds (Wallace 2010). Reduced water levels in these weir pools or Lake Cargelligo could result in releases from acid sulphate soils.	Possible	Major	High	<p>Ensure weir pools are adequately inundated and/or flushed. Monitor weir pools and Lake Cargelligo for acid sulphate soils impacts.</p>
Streambank/channel erosion	Delivery of water may result in increased rates of erosion in streambanks and channels, particularly if rapid changes in water level occur.	Likely	Minor/moderate	Medium	<p>Delivery of water in a manner to reduce impacts on streambanks and channels.</p>

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Inappropriate inundation of floodplain vegetation	Floodplain inundation of inappropriate duration resulting in the drowning or drying of vegetation.	Unlikely	Moderate	Low	<p>Ensure floodplain surfaces are inundated for appropriate periods.</p> <p>Manage the release of environmental water so as not to extend the duration of flood events beyond the thresholds for key vegetation species.</p>
Invasive species	<p>Major carp-breeding hotspots have been identified in the Lachlan. These include Lake Cowal, Lake Cargelligo, Lake Brewster and Great Cumbung Swamp. Carp breeding is likely to increase when these areas are inundated.</p> <p>Lippia is an environmental threat found in most wetlands and riparian areas throughout the lower Lachlan. It can cause severe bank erosion, degradation of soil and water and displacement of native plant species. It is difficult to control once established.</p>	Likely	Moderate	Medium	<p>Lachlan River Revival Program underway investigating appropriate carp control mechanisms including carp separation cages (Gilligan et al. 2010).</p> <p>Inundation of wetlands for appropriate length of time to 'drown' lippia. Appropriate land management (e.g. grazing regime) to protect native vegetation.</p>
Incomplete bird breeding	Drawdown of bird-breeding rookeries resulting in the abandonment of nests. Poor water quality resulting in bird illness or death (botulism).	Possible	Major	High	Monitoring of breeding sites—including water levels and water quality. Timely delivery of water to maintain water levels.
Fish stranding	Cease-to-flow within river and creek channels or rapid fall in wetland water levels can lead to a fish strandings, which may significantly reduce fish populations.	Possible	Major	High	Manage flows to prevent weir pool drying and ensure that recession is not too rapid.
Flooding	Flooding and isolation of properties, roads and irrigation pumps during environmental water delivery.	Possible	Moderate	Medium	Ensure water levels do not exceed flow recommendations (see section 5.1.3); communicate increases to landholders.

Note: Risk level is indicative of the unmitigated risk, prior to the implementation of mitigation measures.

## 8. Environmental water reserves

### 8.1 Environmental water provisions and holdings

The Lachlan Regulated River Water Sharing Plan (WSP) has the following provisions for providing environmental water (DIPNR 2004a).

All water above the plan extraction limit (a mean of 305,000 ML/yr) is reserved for the environment. This ensures that there is no erosion of the long-term average volume of water available to the environment during the life of the plan. On a long-term average basis, approximately 75 per cent of yearly flows in the river are protected for the maintenance of environmental health.

As noted in section 2, the WSP provides for the release of up to 350,000 megalitres of translucency flows between May and November, in addition to specified environmental water. Translucency flows are only released if more than 250,000 megalitres has entered Wyangala Dam since 1 January of that year.

Translucency flows can be released from Wyangala Dam from mid-May to mid-November. Inflows are passed through the dam and water extraction from some tributary inflows and Lakes Brewster or Cargelligo may be prohibited. Translucency flows may also be released from Lakes Cargelligo or Brewster, from the start of June to the end of November, if releases from Wyangala Dam are likely to cause flooding. Environmental water can be opportunistically released on top on an appropriately sized translucency event to improve efficiency and by increasing flow capacity lower in the system.

The Lake Brewster flow targets vary between 3,500 ML/d and 8,000 ML/d, depending on the inflows that are occurring at the time, the volume of water in Wyangala Dam, the volume of flows that have entered Wyangala Dam, and the volume of flows that have already passed Lake Brewster that year.

The total volume of translucent and tributary flows is up to 350,000 ML/yr measured at Brewster Weir (although Willandra Weir is more appropriate due to the complex flow arrangements at Lake Brewster and Brewster Weir).

The plan also provides for the following reserves of water (with no carryover):

- 10,000 megalitres of water in Wyangala Dam and 10,000 megalitres in Lake Brewster whenever the total volume of water available to general security access licences exceeds 50 per cent of the access licence share volume at the beginning of a water year, or reaches 75 per cent during a water year. Release of this water is to support waterbird or fish breeding, wetland watering or increase flow variability.
- 20,000 megalitres of water in Wyangala Dam each water year for the purpose of reducing salinity levels or mitigating blue-green algae outbreaks.

Supplementary extraction (or 'off-allocation' extraction) previously occurred when the dam spilled or high unregulated flows entered the regulated river. These flows, which were not allocated to specific users, were able to be extracted and did not count against the extractor's licenced allocations. Under the WSP, supplementary extraction is not permitted within the regulated Lachlan Valley. The regulated Lachlan does not include the regulated Belubula River where supplementary extraction is allowed. A WSP is currently being developed for the Belubula River and the status of supplementary extraction under this plan is currently unknown.

In the Lachlan, the following environmental water holdings exist as licensed water entitlements (Table 11).

**Table 11:** Environmental water entitlements on the Lachlan River

Holder	High security	General security
Commonwealth environmental water holdings <sup>1</sup>	733 unit shares	82,709 unit shares
NSW	1,000 unit shares	24,575 unit shares
Commonwealth environmental water holdings (Lake Brewster water savings)		12,000 unit shares
Others	None known	None known

<sup>1</sup>Note – Holdings as at October 2010.

## 8.2 Available water determinations and seasonal allocations

Available water determinations are announced following an ongoing resource assessment process, which firstly takes into account the essential requirements for running the river and for providing town water, stock and domestic supplies. Prior to the recent drought the resource assessment process on the Lachlan accounted for the water in storages (primarily Wyangala Dam) and the minimum inflow recorded over a 24-month period. With the recent drought it is understood that the minimum sequence for the resource assessment has been extended to cover a 36–48 month period of minimum inflows. It is not known what effect, if any, this change has on general security reliability.

The NSW Office of Water administers the following rules of the Water Sharing Plan for high and general security entitlements with assistance from State Water. These rules are listed below and are taken from the Lachlan WSP (DIPNR 2004a):

### *High security*

The water supply system shall be managed so that available water determinations for regulated river (high security) access licences of 1 megalitre per unit share can be maintained during a repeat of the worst period of low inflows to this water source represented in flow information held by the department.

### *General security*

An available water determination is not to be made for regulated river (general security) access licence holders in any water year until the sum of available water determinations for regulated river (high security) access licences for the water year is equivalent to 1 megalitre per unit share.

Immediately following the withdrawal of water allocations for high security, an available water determination for regulated river (general security) access licences shall be made. When Lachlan storages (Wyangala, Lake Brewster and Lake Cargelligo) spill, all general-security access licence accounts will be equalised. When Lachlan storages are full it should be possible for each general-security access licence account to hold a maximum 1.36 megalitres per unit share.

The available water determination for regulated river (general security) access licences shall be based on the volume available after making provision for:

- (a) the environmental water provisions established by this plan
- (b) requirements for domestic and stock rights
- (c) requirements for native title rights
- (d) requirements for domestic and stock access licences
- (e) requirements for local water utility access licences
- (f) requirements for regulated river (high security) access licences
- (g) requirements for regulated river (conveyance) access licences
- (h) allocations remaining in access licence water allocation accounts from previous available water determinations
- (i) water loss associated with the holding and delivery of water to meet the requirements identified in subclauses (a) to (g)
- (j) an appropriate volume to meet water losses associated with the holding and delivery of water resulting from the available water determination
- (k) any other relevant matters.

## 8.3 Storage accounting rules

Water accounts for each type of entitlement are managed as described below (DIPNR 2004b).

A water allocation account has been established for each access licence. Water is credited to the account when an available water determination is made, or when water allocation is moved into the account from another access licence. Water is debited from the account when water is extracted or moved to another access licence.

The accounts of high-security access licences continue to be managed on an annual basis. This means that any water remaining in an account at the end of a water year is forfeit, and the account receives a new water allocation in the next water year. There is no account limit for high-security access licences during the year.

The accounts of general-security access licences operate continuously (i.e. continuous accounting of water account). There is no forfeit of water from accounts at the end of a water year. However, the volume that may be held in a general-security account at any time is limited to 2 megalitres per unit share. The accounts are split into two sub-accounts: one contains water that may be taken in the current water year (take water); the second contains water that can only be held for extraction in a future water year (hold water). Annually, at the start of each year, a take limit is announced by NOW and this will determine how much water is kept in the take account. The take account can be increased by trading in take account water. Whenever the Lachlan water storages fill, all water in general security accounts is 'withdrawn' and a new available water determination is made. This results in all general-security accounts being refilled equally to approximately 1.36 megalitres per unit share.

The following is a plain English version of the above based on LVW (2011)<sup>3</sup> and includes information on trade arrangements:

### *Continuous accounting limits, spill and trade arrangements:*

- 200 per cent of entitlement is the maximum water that can be held in an account at any time.
- When all storages are full the general security share of the total system storage is 811,000 megalitres or 136 per cent of entitlement (this is the basis of the 1.36 unit share above).
- When there is a storage spill, all general-security accounts will be reset to a maximum of 136 per cent.
- There is no limit to the volume that can be transferred in any year, except that the account limit must always remain under 200 per cent.

### *Take and hold accounts:*

- Each general-security water account has two sub-accounts:
  - The take sub-account is for water that can be used in the current year (also called A account).
  - The hold sub-account is for water that can be used in future years (also called B account).
- Water can be assigned (temporarily traded) from both the take and hold sub-accounts but cannot change its status as a result of trade. That is, water can be assigned from one take account to another take account or from one hold account to another hold account.

<sup>3</sup> This fact sheet also provides a worked example of how an account might progress over a water year similar to 2011–12.

### *Take limit:*

- An annual 'take limit' or use limit is applied to all general-security accounts to ensure that total valley usage remains within the WSP limit.
- The take limit sets the percentage of general-security entitlement that is available for use in that year, regardless of how much water is in the account.
- The take limit can vary up or down from one year to the next, but cannot exceed 100 per cent.
- The take limit runs for a full year and is not reset when there is a storage spill.
- The take limit is reset at 1 July every year. Unused take limit does not carry forward from one year to the next.
- The take limit for 2010–11 is 75 per cent of entitlement, not 75 per cent of the allocated water.
- The take limit for 2011–12 will be 100 per cent of entitlement (NOW February 2011).

## 8.4 Water delivery costs

The water charges which apply to water entitlements and water use in the Lachlan are listed in Table 12.

**Table 12:** Water charges for Lachlan water entitlements and use.

Charges to 30 June 2011*	High security	General security
Entitlement charge (\$/ML)	\$8.83	\$3.96
Usage charge (\$/ML)	\$15.29	\$15.29
Resource management (Office of Water) charge (\$/ML)	\$2.12	\$1.17

\*Charges rise progressively until June 2014 when the next IPART determination is made

Costs incurred for infrastructure maintenance by State Water is covered by these charges.

At the time of writing there is no pumping of water to assets in the Lachlan and therefore no costs associated with this.







## **PART 3:** Monitoring, evaluation and improvement



## 9. Monitoring, evaluation and improvement

While the MDBA has developed a monitoring and evaluation framework, the details of compliance, monitoring and reporting methods are yet to be determined. A number of monitoring programs are being undertaken by a variety of agencies in the Lachlan with some having a Basin-wide focus. These programs range from ecological to hydrological in nature and are listed below.

### 9.1 Current monitoring and reporting

#### 9.1.1 Water quality and ecological reporting

The NSW Office of Water carries out monitoring of basic water-quality indicators such as nutrient and algal sampling across the Lachlan catchment. Salinity is also measured continuously at 17 sites. State Water undertakes water quality monitoring in Lachlan storages, particularly algal sampling during the warmer months. Both river and storage water quality information can be found on the NSW Water Information website. Water-quality monitoring that was undertaken as part of the Integrated Monitoring of Environmental Flows (IMEF) program is described below.

Established in 1997, the IMEF program was managed by the NSW Office of Water, with support from Industry and Investment NSW and researchers. The program finished in 2011.

The program assessed the ecological benefits of the environmental flow rules. The objectives of the IMEF program were:

- to investigate relationships between water regimes, biodiversity and ecosystem processes in the major regulated river systems, and the Barwon-Darling River
- to assess responses in hydrology, habitats, biota and ecological processes associated with specific flow events targeted by environmental flow rules
- to use the resulting knowledge to estimate likely long-term effects of environmental flow rules and provide information to assist in future adjustment of rules.

IMEF provided scientific information to review and inform water sharing plans, as well as adding to the understanding of the biodiversity and ecological processes in NSW rivers and wetlands. Projects conducted as part of IMEF included:

- examining how environmental flows can improve the ecology of NSW's rivers by increasing the supply of dissolved organic carbon to nourish the aquatic food chain
- assessing the ecological benefits of protecting natural low flows, and protecting or restoring the natural peak flows from Burrinjuck Dam to the Murrumbidgee River
- investigating the benefit of environmental flows for wetland habitat and biodiversity in the Lachlan and Namoi Rivers and in the Macquarie Marshes and Gwydir/Gingham wetlands
- investigating how environmental flows affect stratification of temperature and dissolved oxygen within the weir pools of the lower Darling River—it is hoped the flows can be used to avoid conditions that encourage excessive growth of blue-green algae and kill fish by oxygen starvation
- investigating the use of environmental flows released from dams to maintain the abundance of fish hatchlings when their survival is threatened by drought and unnatural patterns of water flow in regulated rivers.

In 1998–2000, five lower-Lachlan weir pools were monitored to assess the effects of flows on flushing algal blooms from the weir pools (Mitrovic et al. 2005). Water-quality variables, including nutrients, turbidity, temperature and algal cell numbers were measured in each weir pool.

It was found that Lakes Brewster and Cargelligo were likely contributors to blue-green algae in downstream weir pools. When water from Wyangala Dam replaced the lake flows, algal numbers dropped significantly. The reduction of blue-green algae concentrations occurring concurrently with water delivery from Wyangala Dam resulted in the Lower Lachlan Storages Algal Protocol being developed by the NSW Office of Water to manage blue-green algal blooms in the lower weir pools, and the development of the Water Quality Allowance as part of the WSP.

Detailed ecological monitoring of wetlands and fish was undertaken as part of the IMEF program to assess the effects of environmental flow rules. A number of variables were measured at 12 wetland sites located downstream of Forbes to the Cumbung Swamp. Variables measured included wetted area, macroinvertebrates, plants, frogs and birds (Driver et al. 2010). An assessment of fish populations was also undertaken at 10 river sites along the length of the Lachlan. Fish population assessments (species, size and condition) and habitat descriptions, were undertaken at each site (Growth 2008).

## 9.1.2 Sustainable Rivers Audit

The MDBA's Sustainable Rivers Audit (SRA) is a systematic assessment of the health of river ecosystems in the Basin. It is overseen by a panel of independent ecologists—the Independent Sustainable Rivers Audit Group (ISRAG)—and carried out by a number of agencies including the NSW Office of Water and Industry and Investment NSW. Quantitative information on environmental indicators is collected in valleys throughout the Basin. The indicators provide an insight on particular components of the river ecosystems. At this stage there are 'themes' for hydrology, fish and macroinvertebrates.

Within each valley there are zones defined by altitude, with sampling sites randomly located within the zones to enable unbiased statistical analyses and representative reporting. Indicators are combined to form quantitative measures of environmental condition for each theme. Condition is rated on a five-point scale from good to extremely poor, depending on how different the theme components are from their respective reference benchmarks.

SRA studies have found that the flow regime has significantly changed from the reference condition in the Lachlan and Belubula Rivers downstream of Wyangala and Carcoar storages. These reaches showed significant changes in the magnitudes of high, low and annual flows, and in flow variability and seasonality.

The SRA fish assessment in the Lachlan resulted in the catchment receiving the equal fifth-lowest score in the Basin. The Slopes Zone community showed a significant difference from the reference condition, with extremely low nativeness and exceptionally low native biomass (0.4 per cent of total fish biomass). The macroinvertebrate assessment was in the mid-range of scores in all valleys, with most site communities showing a large difference from the reference condition, and the Slopes Zone in poorest condition. In general, the Lachlan Valley river ecosystem was found to be in very poor health (Davies et al. 2008).

### 9.1.3 Rivers Environmental Restoration Program monitoring and reporting

The NSW Office of Environment and Heritage undertakes a number of ecological response projects as part of the Rivers Environmental Restoration Program (RERP). These projects are intended to improve knowledge of target wetlands by understanding the trophic dynamics of food webs, surveying fish and waterbirds, determining the extent of vegetation communities and their response to flooding. Other projects include understanding how the endangered (*Threatened Species Conservation Act 1995* (NSW)) southern bell frog (*Litoria raniformis*) responds to environmental flows and predators in the Lowbidgee floodplain, and documenting the ecological character of the Lowbidgee floodplain and lower-Lachlan wetlands.

### 9.1.4 Hydrological monitoring and reporting

The NSW Office of Water has an extensive hydrographic network which records river water levels and flows, storage elevations, volumes and discharges, and continuously monitors electrical conductivity from locations across NSW. This provides critical information in determining flow heights and durations required to appropriately inundate wetland targets.

The Integrated Quantity and Quality Hydrological Model (IQQM) has been developed to support water management planning, including the allocation and management of environmental water. IQQM runs simulate 'undeveloped' long-term flow conditions as well as current river flow scenarios.

The Lachlan IMEF project links ecology and hydrology, and looks at the effects of releasing water to restore a portion of the natural variability of river flows, including peak flows and the effectiveness of environmental flows on replenishing Lachlan wetlands (Driver et al. 2005). This knowledge is used to estimate the long-term effects of environmental flows provided under the Lachlan Regulated Source Water Sharing Plan.

The results of this project have confirmed the importance of the pattern of flow and inundation of wetlands in the Lachlan Valley. They have shown that:

- Booligal swamp requires flooding to be maintained for about 90 days to start a breeding event that could establish between 20,000 and 100,000 ibis nests.
- In 2005 the WSP succeeded in delivering extra flows to some targeted wetlands, while reducing the supply of irrigation water by about 3 per cent.
- Environmental flows were not equally shared, with the greatest volume of extra water going to Willandra Creek.
- The Great Cumbung Swamp needed more flooding to sustain its river red gums.

Hydrological projects undertaken by the NSW Office of Environment and Heritage, as part of RERP, aim to improve knowledge about wetland flood regimes and patterns. This is achieved through the development of hydrodynamic models of water movement through wetlands, by the expansion of river hydrology models to include floodplain wetlands, and the development of maps showing the historic inundation of wetlands.

Other projects include a project funded by the NSW Office of Water to provide technical information to support the implementation of the Water Sharing Plan, and to manage licensed environmental water by determining flow relationships under different climatic conditions for a selection of nationally important wetlands. The project also examined the effectiveness of translucency, environmental contingency allowance (ECA) and other environmental water in meeting flow objectives (Barma et al. 2010).

A complementary study, funded by the Lachlan Catchment Management Authority (LCMA), aimed to provide support to the LCMA in managing selected wetlands for improved biodiversity conservation. The project explored the relationship between flow magnitude and duration at each wetland offtake, and the duration and extent of inundation within the wetlands. It assessed the change in natural frequency, timing and duration of critical inundation events, and identified all of the feasible river operational and structural options that could be applied to restore ecologically significant components of the natural inundation (BWR 2010).

LCMA is also funding a project which involves spatially explicit flood monitoring to target small areas within the Great Cumbung Swamp. This project will enable the prediction flow inundation relationships in relation to given inflows and climatic conditions, and also assess the influence of floodplain structures once inflow events spread onto the floodplain. This will be achieved by incorporating recently acquired LiDAR data and hydrologic modelling to assess flow distribution for existing and proposed conditions in the Great Cumbung Swamp.

The CSIRO, in collaboration with other groups, has been developing and linking hydrological models to provide support for integrated surface water planning across the Basin, including modelling of river flows and water availability. The CSIRO has linked models to assist the MDBA to evaluate alternative scenarios and has included environmental water demands in the models.

The CSIRO has also reviewed water availability in the Lachlan in the context of future climate and development impacts, and predicted that these impacts would reduce the average end-of-system flows by a total of 15 per cent. Development would impact high-security town water supplies, and reduce the ECA by 4 per cent in addition to the climate change impacts. However, projected future catchment and groundwater development would have no additional effect on the frequency of floods reaching the Booligal Wetlands, and result in only small additional increases in the average period between winter-to-spring flood events for the Great Cumbung Swamp (CSIRO 2008).

## 9.2 Proposed monitoring and reporting

Table 13 lists possible monitoring options to measure and report environmental watering outcomes.



**Table 13:** Lachlan River system: monitoring parameters for environmental watering.

WMA	Objective	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and other considerations
Whole of river channel	Provide fish refuge during low-flow periods.	Pools within Lachlan channel will support native fish species during low/no-flow periods.	Baseflow	Native fish survival	Fisheries sites	To coincide with low flows.	Complement monitoring undertaken as LCMA drought refuge study.
Whole of river channel	Provide fish passage through weir drowned out.	Fish will traverse weirs when drowned out by high flows.	High flows	Native fish movement	Fisheries sites	To coincide with high flows.	Complement existing NSW I&I monitoring programs.
Whole of river channel	Appropriate flow regime will provide habitat and breeding opportunities for native fish.	Sufficient flows will provide habitat and breeding opportunities for native fish.	Under all flow conditions.	Native fish population diversity, condition and numbers. Successful breeding events.	Existing NSW I&I sites.	1–3 years.	Existing NSW I&I monitoring.
Lower-Lachlan floodplain	Provide connectivity for the transport of sediments, nutrients and energy. Provide for the movement of aquatic biota.	Hydrologic connectivity through the inundation of floodplain wetlands will achieve energy exchange and allow movement of aquatic biota.	Medium to high flows.	Water level and timing, magnitude and flow frequency.  Inundation area (mapping).	Lower Lachlan wetland sites	Flow-dependent	IMEF and community monitoring.
Channels and inundated wetlands	Provide appropriate flows to maintain or improve water quality.	Appropriate flow management will assist in maintaining and/or improving water quality.	Under all flow conditions.	Physicochemical responses to environmental flows.	Existing riverine NoW water quality sites. Existing IMEF wetland sites.	Dependent on season and inundation.	NoW, State Water water quality sampling; IMEF
Floodplain wetlands	Provide appropriate flooding to maintain and/or enhance semi-permanent and permanent wetland vegetation.	Appropriate flooding regimes will assist in maintaining or improving wetland vegetation (e.g. common reed, river red gum, lignum, black box) provide important feeding, breeding and refuge habitats.	Under all flow conditions.	The condition and extent of wetland vegetation communities.	Existing IMEF sites and key water-delivery targets.	Pre and post inundation.	IMEF and community monitoring.

WMA	Objective	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and other considerations
Bird breeding sites	Provide sufficient flows to provide waterbird habitat and complete breeding.	Sufficient flows will provide habitat and breeding opportunities for waterbirds.	Moderate to high flows	Waterbird population diversity, condition and numbers. Successful waterbird breeding events.	Waterbird breeding sites e.g. Merrowie and Booligal systems.	Inundation events	IMEF; existing community waterbird surveys
Floodplain wetlands	Appropriate flow regime will provide habitat and breeding opportunities for frogs.	Sufficient flows will provide habitat and breeding opportunities for frogs.	Moderate to high flows	Frog population diversity, condition and numbers. Successful frog breeding events.	Floodplain wetland sites	Inundation events	Existing OEH and IMEF monitoring.
Floodplain wetlands	Determine wetland antecedent condition.	Accurate determination of antecedent condition will better inform watering decisions.	All flows	Soil moisture or time since last inundation.	Floodplain wetland sites.	Prior to watering decisions.	Methods to be determined; may be linked to community monitoring.



# 10. Operational constraints and opportunities

## 10.1 Constraints

The operational constraints for delivering water in the lower parts of the Lachlan catchment are largely covered in previous sections, however, the following points are re-emphasised:

- There is considerable travel time from Wyangala Dam to many of the lower-river assets. It takes up to 60 days for water to travel from Wyangala Dam to the Great Cumbung Swamp (GCS). There are also major channel capacity constraints for the efficient delivery of large discharge releases from the dam, starting with the reduced channel capacity of the Condobolin Anabranches including a channel capacity of approximately 4,000 ML/d in Island Creek, 2,000 ML/d in the Goobang/Bumbuggan system, 390 ML/d in the Wallamundry and 175 ML/d in Booberoi Creek (S. Sritharan, State Water, pers. comm.).
- The generally long water delivery travel times for most of the assets on the lower river, even with delivery from the lower lakes, is an important consideration for environmental water management.
- Releases from the lower lakes will be the most efficient for delivery of environmental water to the lower river assets. However, there is significant potential for water loss to Willandra Creek, which has a lower commence-to-fill due to the current regulator than under natural conditions. Releases above 2,400 ML/d at Willandra Weir are also around the commence-to-fill for several of the downstream assets.
- Delivery of environmental water to the GCS is greatly complicated by the operation of water control structures, some of which are unauthorised, within the swamp. It should also be noted that many of these structures have existed in the GCS for many years and have resulted in changes in associated vegetation due to altered hydrology.

## 10.2 Opportunities

As indicated by the information presented in previous sections, the use of environmental water is often conducted in conjunction with 'other' water. The 'other' water includes translucency events, unregulated events (which may or may not be accounted as translucency), stock and domestic replenishment flows and other water orders. The stock and domestic replenishments offer particular opportunities for watering of assets along Willandra Creek, Merrowie Creek and the Muggabah/Merrimajeel creeks systems. Translucency and unregulated flow events offer the opportunity for integrated watering of multiple sites depending on their hydrological characteristics. These events can be enhanced with releases of environmental water, particularly if there is sufficient water in the lower lakes.

Water management infrastructure is available to divert water to several sites (i.e. Willandra Creek, Merrowie Creek and the Booligal System) but not to others (i.e. Moon Moon Swamp, Lachlan Swamps, Ita Lake and Baconian Swamp). However, there are other potential opportunities for environmental watering based on the previous work of BWR (2010), which are summarised in Table 14. A similar analysis for other sites (e.g. Lachlan Swamps) could be undertaken.

The BWR (2010) study was undertaken for the LCMA with the specific purpose of identifying delivery constraints and options for improving water delivery to a number of lower Lachlan wetlands. The study assessed water requirements and water-delivery options using limited available data for the sites noted in Table 14. It relied on the limited satellite imagery used for the Barma et al. (2010) hydrological modelling study and interpolations of limited flow events to identify the areas of wetlands flooded, volume-to-fill and commence-to-fill thresholds.

The study was unable to establish a commence-to-fill for Lower Gum Swamp, but did identify reasonably accurate commence-to-fill levels for the other wetlands with the exception of Ita Lake (refer to Appendix 2). For some off-river sites (e.g. Moon Moon Swamp), while it was possible to identify reasonably accurate volume and commence-to-fill thresholds, it was not possible within the study to identify with any degree of accuracy the duration of the commence-to-fill needed to be maintained to achieve the required volume-to-fill, and therefore more accurately identify the flow volumes required in the river to achieve substantial, or the 'required', inundation.

**Table 14:** Summary of environmental watering opportunities for selected Lachlan assets (amended from BWR 2010).

Wetland	AEW release	Piggybacking	Existing irrigation
Moon Moon Swamp	<p>A release of 25,000 ML and discharge of 2,800 ML/d at Willandra Weir is likely to flood a core area.</p> <p>Significant losses will occur at Willandra, Middle and Merrowie creeks.</p>	Possible.	"Gunbar Station" has existing irrigation infrastructure including a channel which could be modified to deliver water directly to the swamp. This channel follows adjacent to the Booligal-Gunbar Road near Moon Moon Swamp, a distance of about 4 km.
Murrumbidgee (Angora) Lake Merrimajheel	<p>Good efficiency with existing infrastructure if water from Brewster.</p> <p>A release of about 5,000 ML, but only in cold months.</p> <p>Warm month release not likely to reach swamp.</p>	<p>1,000 ML for Murrumbidgee Swamp on top of the stock and domestic replenishment.</p> <p>Similar volume required for Lake Merrimajheel.</p>	There is a possible option to extend irrigation channels which supply nearby properties from Booligal Weir and pump sites. A channel of some 3.5 km would have to be constructed to the swamp from a channel adjacent to Boxyards Road.
Lower Gum	<p>Good efficiency with existing infrastructure if water from Brewster.</p> <p>Lower Gum Swamp is not inundated by the stock and domestic flow. CTF is not known. More investigation required.</p>	<p>A possible option once CTF established.</p>	There is an irrigation layout about 1.2 km south-east of the swamp and an irrigation channel some 1.6 km to the south, adjacent to Boxyards Road (this is the same channel which runs closest to Murrumbidgee Swamp). There is also a smaller channel which is used to fill a stock dam at the western edge of the swamp.
Ita Lake	A specific environmental water release is an unrealistic option due to the high level CTF and water losses upstream <sup>1</sup> .	Piggybacking of environmental releases on top of transclusency releases or floods could be undertaken but with very high losses <sup>1</sup> .	<p>Existing irrigation infrastructure, if rehabilitated, offers opportunity for watering of parts of the lake but more investigations are required, particularly:</p> <ul style="list-style-type: none"> <li>the capacity of the current pump and channel to flood (parts of) the lakebed</li> <li>the extent of potential water losses along the supply channel.</li> </ul>
Baconian Swamp	A release of around 35,000 ML at 2,800 ML/d at Willandra Weir is likely to flood at least some parts of the swamp.	A possible option.	<p>Existing 30 cm pump, channel and irrigation layout to the south of the swamp offers opportunity. It may require upgrading to meet swamp inundation requirements.</p> <p>Also, two pumps and channels just downstream of the swamp.</p>

<sup>1</sup> Subsequent to the BWR (2010) study the regulator on the inflow channel to Lake Ita was removed. During the 2011 flood event the commence-to-fill to the lake was determined to be at around 800 ML/d at Corrong. Inflows to the lake also occurred during this event via Pimpara Creek but the source of this water remains unknown.

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## Appendix 1: Lachlan species list

Key: LC = Least concern; NT = Near threatened; V and VU = Vulnerable; E and EN = Endangered; M = Migratory; Y = Yes

Type	Common name	Scientific name	Status	Presence of species/ species habitat	Breeding status	Water dependency (Yes/No)	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	state gov. listing
Bird	Australasian bittern	<i>Botaurus poiciloptilus</i>	Endangered (NSW)	Known	Unknown	Yes					EN	E
Bird	Great egret	<i>Ardea alba</i>		Known	Likely	Yes	M	Y	Y		LC	
Bird	Blue-billed duck	<i>Oxyura australis</i>	Vulnerable (NSW)	Known	Known	Yes					NT	V
Bird	Freckled duck	<i>Stictonefha naevosa</i>	Vulnerable (NSW)	Known	Likely	Yes					LC	V
Bird	White-bellied sea eagle	<i>Haliaeetus leucogaster</i>	Vulnerable (NSW)	Known	Likely	Yes	M	Y			LC	
Bird	Painted snipe	<i>Rostratula australis</i>	Vulnerable (EPBC)	Likely	Unknown	Yes	V, M	Y				E
Bird	Brolga	<i>Grus rubicunda</i>	Vulnerable (NSW)	Known	Likely	Yes		Y	Y		LC	V
Bird	Black-tailed godwit	<i>Limosa limosa</i>	Vulnerable (NSW)	Likely	unlikely	Yes	M	Y	Y		NT	V
Bird	Latham's snipe	<i>Gallinago hardwickii</i>		Likely	Unknown	Yes	M	Y	Y	Y	LC	
Bird	Pink-eared duck	<i>Malacorhynchus membranaceus</i>		Known	Likely	Yes					LC	
Bird	Magpie goose	<i>Anseranas semipalmata</i>	Vulnerable (NSW)	Likely	Unlikely	Yes					LC	V
Bird	Glossy ibis	<i>Plegadis falcinellus</i>		Known	Known	Yes		Y			LC	
Bird	Superb parrot	<i>Polytelis swainsonii</i>	Vulnerable (EPBC)	Known	Likely	No	V				VU	V
Fish	Purple-spotted gudgeon (relocated)	<i>Mogunda adspersa</i>	Endangered (NSW)	Likely	Likely	Yes						E



Type	Common name	Scientific name	Status	Presence of species/ species habitat	Breeding status	Water dependency (Yes/No)	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	state gov. listing
Fish	Olive perchlet	<i>Ambassis agassizii</i>	Regionally endangered (NSW)	Known	Known	Yes						RE
Fish	Murray cod	<i>Maccullochella peelii peellii</i>	Vulnerable (EPBC)	Known	Known	Yes	V				VU	
Fish	Macquarie perch	<i>Macquaria australasica</i>	Endangered (EPBC)	Known	Known	Yes	E				EN	E
Fish	Golden perch	<i>Macquaria ambigua</i>		Known	Known	Yes						
Fish	Silver perch	<i>Bidyanus bidyanus</i>	Vulnerable (NSW)	Known	Likely	Yes						V
Fish	Freshwater catfish	<i>Tandanus tandanus</i>	Endangered (NSW)	Known	Likely	Yes						E
Fish	Southern pygmy perch	<i>Nannoperca australis</i>	Endangered (NSW)	Known	Likely	Yes						
Fish	Unspecked hardyhead	<i>Craterocephalus fluviatilis</i>	Critically endangered (NSW)	Likely	Likely	Yes	V					
Fish	Northern river blackfish	<i>Gadopsis marmoratus</i>	Threatened (NSW)	Unknown	Unknown	Yes						T
Frog	Southern bell frog	<i>Litoria raniformis</i>	Vulnerable (EPBC)	Known	Unknown	Yes	V					E
Frog	Yellow-spotted bell frog	<i>Litoria castenea</i>	Endangered (EPBC)	Known	Likely	Yes	E					
Frog	Sloane's froglet	<i>Crinia sloanei</i>	Vulnerable (NSW)									V
Turtle	Broad-shelled snake-necked turtle	<i>Chelodina expansa</i>		Likely	Unknown	Yes						
Turtle	Eastern snake-necked turtle	<i>Chelodina longicollis</i>		Known	Known	Yes					LC	

Type	Common name	Scientific name	Status	Presence of species/ species habitat	Breeding status	Water dependency (Yes/No)	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	state gov. listing
Turtle	Murray short-necked turtle	<i>Emydura macquarii</i>		Known	Known	Yes						
Vegetation	River red gum	<i>Eucalyptus camaldulensis</i>		Known	Known	Yes						
Vegetation	Black box	<i>Eucalyptus largiflorens</i>		Known	Known	Yes						
Vegetation	Lignum	<i>Muehlenbeckia floruenta</i>		Known	Known	Yes						
Vegetation	Weeping myall	<i>Acacia pendula</i>	Endangered (EPBC)	Known	Known	No	E					
Vegetation	Common reed	<i>Phragmites spp</i>		Known	Known	Yes						
Vegetation	River cooba	<i>Acacia stenophylla</i>		Known	Known	Yes						
Vegetation	Nitre goosefoot	<i>Chenopodium nitariaceum</i>		Known	Known	Yes						

## Appendix 2: Lachlan asset/WMA delivery descriptions

### Asset: Lachlan River channel

Environmental water could be used to contribute to baseflows and provide freshes to the Lachlan River channel, to support longitudinal and lateral connectivity, habitat values and healthy ecosystem function.

### Water Management Area: Wyangala Dam to Jemalong Weir

Murray cod, golden perch and the newly stocked olive perchlet are important fish species in this section of the river. Important considerations for this WMA will be the maintenance of fish habitat and relevant flows under extreme-dry-to-dry conditions, when dam releases are restricted for town water supply purposes.

Also weir drownout to improve fish passage under median and wet conditions will be important. Cottons Weir at Forbes is the main barrier (as there is no fishway) and it requires 9,250 ML/d for drownout to occur.

### Water Management Area: Jemalong Weir to Lake Cargelligo (includes Goobang Creek)

Murray cod and golden perch are again important fish species in this section of the river. Important considerations for this WMA will be the maintenance of fish habitat and relevant flows under extreme-dry-to-dry conditions, when dam releases are restricted for town water supply purposes.

For fish passage, Condobolin Weir requires 4,100 ML/d and West Condobolin Weir requires 3,800 ML/d for drownout. Jemalong Weir is a gated structure and, for significant periods of time, the gates are lifted and therefore provide some fish passage.

### Water Management Area: Lake Cargelligo to Lake Brewster

This section of the river and also to the Great Cumbung Swamp generally has permanent water supplies. However, during the recent critical water-shortage, flows to this part of the river and further downstream were severely restricted. In such circumstances, refuge pools are at risk of drying out and poor water-quality conditions may develop (e.g. stratification), putting aquatic life at risk. These circumstances are particularly notable at weir pools which generally provide permanent water such as Lake Cargelligo Weir and those downstream.

Weir drownout for fish passage is not such a consideration for this section of the river as fishway construction is underway at Cargelligo Weir.

### Water Management Area: Lake Brewster to Great Cumbung Swamp

As above, regarding flow and water-quality considerations for refuge pools.

Weir drownout to improve fish passage is a major consideration for this section of the river because of the number of weirs and the progressive reduction in flows. Fishway construction is underway on Booligal Weir. Willandra Weir requires some 8,500 ML/d and Hillston Weir requires 4,750 ML/d for drownout (both are fixed crested). However, Brewster Weir is the main barrier (for the entire Lachlan River) with drownout requiring flows in excess of 15,000 ML/d.

## Asset: Burrawang West Lagoon

Burrawang West Lagoon is a small wetland (21 hectares) located near the junction of Goobang and Yarrabandai Creeks, about 20 kilometres east of Condobolin. Water levels within the creek system and in the lagoon are maintained by a weir on the junction of Goobang and Yarrabandai Creeks, which was constructed in the 1890s. This resulted in a wetland which was almost permanently inundated, and the development of habitats that support a wide variety of wetland-dependent species.

The site consists of a 30 metre-long channel acting as a control weir maintaining water levels in the lagoon, inlet channel, Yarrabandai Creek and an extensive length of Goobang Creek. Flows are diverted from Bumbuggan Creek into the inlet channel through a 230 millimetre-diameter pipe. Other natural inflows occur from run-off.

A draft Burrawang West Lagoon Management Plan has recently been completed and addresses water management and accounting issues that have arisen at this site (LCMA 2011).

## Asset: Yarnel Lagoon

The lagoon is directly connected to Wallaroi Creek on its north-west side. The creek is the most southerly of the anabranching creeks in the middle reaches of the Lachlan River. It is generally narrow and shallow. The flow travelling down Wallaroi Creek is first diverted out of the Lachlan River into Island Creek, from Island Creek into Wallamundry Creek, and out of Wallamundry Creek into Wallaroi Creek, eventually reaching Yarnel Lagoon close to the end of Wallaroi Creek.

The NSW Office of Environment and Heritage is developing a management plan for this lagoon which addresses water requirements to achieve ecological outcomes, particularly with regard to supporting frog breeding (OEH, in prep.).

## Asset: Booberoi Creek

The Booberoi Weir was built in 1902 to divert flows down Booberoi Creek for stock and domestic use and some irrigation flows. The creek, an anabranch of the Lachlan, leaves the river halfway between Condobolin and Lake Cargelligo and rejoins downstream of Lake Cargelligo. The creek is regulated for stock and domestic supply along its length. The WSP provides up to 12,500 megalitres for replenishment flows each year, with a target of maintaining visible flow at Ginniguldrie Road bridge. The current supply is nearly a continuous flow when the water is available. In extreme dry circumstances, as in the recent drought, this water is not provided. State Water advise that a flow of 4,000 megalitres will reach the end of the system. It is not possible to provide higher flow diversions into Booberoi Creek without incurring large losses, as the channel near the regulator is highly silted.

Anecdotal evidence from local anglers and landholders indicate that fish species including freshwater catfish, golden and silver perch, and Murray cod occur in the area. The creek supports sections of native riparian and aquatic vegetation and is considered to contain important ecological features.

## Asset: Lake Brewster

Lake Brewster is located downstream of Mountain Creek on the southern side of the Lachlan River. Originally the lake would have only flooded during very large flood events, where flows would have travelled down Mountain Creek and across the floodplain. To capture flows from the upper Lachlan and re-regulate flows to the lower Lachlan, a large weir and channels to and from the Lachlan River were constructed in the 1950s. The length of the Lachlan and the distance from Wyangala Dam makes Lake Brewster an important structure for delivering water to the lower Lachlan and its wetlands.

The lake receives water via an inflow channel from the Brewster Weir and water is stored until required for downstream use. This operation has resulted in increased frequency and length of inundation. Originally a dead storage area of about 20,000 megalitres remained in the deepest part of the lake, which was unable to be released. The lake has recently been modified with the objectives of improving water efficiency by reducing the dead storage, and improving water quality and ecological health. Following the modifications, Lake Brewster can now store approximately 105,000 megalitres with minimal dead storage. To improve water quality the lake has been divided to form an inflow wetland (1,500 megalitres), which receives flows via the inlet channel and delivers them to the main storage area. To further improve water quality, water released from the main storage area (98,000 megalitres) can travel via three outflow wetlands (5,000 megalitres) to the outlet channel. Alternatively, this water may be released directly to the Lachlan River via the outlet channel.

The inlet regulator has a maximum capacity of 6,000 ML/d. The outlet regulator has a maximum planned capacity of 2,000 ML/d. As part of the reconfiguration of the lake, water passes through inflow and outflow wetlands to improve the quality of water entering and leaving the lake. Water retention times in these wetlands are dependent to some extent on water quality, e.g. fill rates of inflow wetland vary from six hours to three days.

Lake Brewster is operated to receive operational surpluses, unregulated tributary flows and Wyangala Dam spills. Up until 2000, inflows were regularly stored in the lake in winter and spring and released for downstream use in late spring and summer. This was likely to occur approximately eight out of 10 years prior to 2000. Due to drought conditions, since 2000 the lake had only received one small inflow in 2005, which sparked a bird breeding event. Flows during the spring of 2010 resulted in the lake being filled to 75 per cent, but the lake was not completely filled due to a pelican breeding event.

The lake has major importance for the management of environmental water because it can hold large volumes of environmental water allocations. Under the Water Sharing Plan, the lake can hold a reserve of 10,000 megalitres for environmental purposes under certain conditions. As part of the water efficiency works, a general security environmental water entitlement of 12,000 megalitres was created from the water savings and is subject to a draft Water Use Plan. The draft Water Use Plan makes 12,000 megalitres available for use in the Lake Brewster constructed wetlands, in order to enhance opportunities for threatened and other native fish and waterbirds in the lake and the lower Lachlan, and to enhance river and wetland habitat in Lake Brewster and the lower Lachlan.

The release capacities from the lake and Brewster Weir are very important for downstream water orders. Lake Brewster, in conjunction with the conduit for Brewster Weir, previously had a release capacity of 3,500 ML/d. The current arrangements for releases are between 1,800 and 3,000 ML/d as per the following:

- 1,200 ML/d via Brewster Weir conduit
- 600–1,800 ML/d via the lake depending on storage capacity.

## Water Management Area: inflow wetland

The Lake Brewster inflow wetland is 300 hectares and requires 1,500 megalitres to fill. Filling occurs via a regulator and channel extending from Lake Brewster Weir on the Lachlan River. The wetland was originally part of the larger area of Lake Brewster but a block bank has been constructed to retain water in this area for longer periods. The main objective for the retention of water within this area is to improve water quality by promoting aquatic plant growth and consequently to act as a refuge for wetland-dependent species. To date, aquatic plant growth within the inflow wetland has responded well to inundation, which first occurred in September 2010.

## Water Management Area: outflow wetland

The outflow wetland is comprised of a series of cells. The eastern side of the wetland is divided into two areas. The first (cell 1) covers an area of approximately 180 hectares, which when full, hold water at an average depth of approximately 0.4 metres (850 megalitres). The second area (cell 2) on the eastern side covers another 120 hectares. Once the first cell is full it will overflow into this second area. When both cells 1 and 2 are full they will store 300 hectares at an average depth of 0.4 metres (1,200 megalitres). The third area of the outflow wetland (cell 3) is located on the western side and covers an area of approximately 300 hectares and will store another 1,200 megalitres when full. An additional area of approximately 1,100 hectares lies to the north of the outflow wetlands; this area will generally hold water when the Lake Brewster storage holds more than 98,000 megalitres.

There is a preliminary design report for the operation of the outflow wetland (GHD 2005) which indicates that a retention time of five to six days is required for water quality improvement to be achieved. As retention times increase, the release capacity is reduced.

Water may also be passed into the outflow wetland to meet ecological requirements under two scenarios:

1. as part of a release that would otherwise be discharged directly via outlet channels, or
2. independent of any release, where the ecological requirement in the wetland does not coincide with normal release operations.

Where water is passed through the wetlands under scenario 1, any additional losses incurred as a result of wetland operations may be debited from the 12,000 megalitres of water savings environmental allocation. Alternatively, if the wetland requirements are in alignment with prescribed uses for the 10,000 megalitres Lake Brewster ECA, the volume may be debited from the ECA account. Under scenario 2, where water is released solely for the wetlands, the full volume passed into the wetlands may be debited from either the 12,000 megalitres or the 10,000 megalitres ECA account.

Following inundation at the end of 2010, a large pelican colony began breeding, nesting on the outlet channel banks and outflow wetland banks. The first batch of chicks hatched in December 2010, with breeding continuing until May 2011. This event became the largest pelican breeding to occur in NSW for at least five years (P Packard (OEH) 2010, pers. comm.). The presence of the pelican nests has affected the operation of the storage, as the water level in the outflow wetland was required to remain relatively stable and the opportunity to store further unregulated tributary flows was lost. Accounting for the loss in storage opportunity is to be resolved but is likely to involve an offset from planned environmental water, Lake Brewster environmental water savings and some contribution from consumptive licence holders.

## Asset: Willandra Creek

Willandra Creek is a major distributary (effluent) creek which leaves the Lachlan River upstream of Hillston. It runs many kilometres to the west, now terminating in Gunnamby Swamp. In prior wetter times the creek terminated in the Willandra Lakes. Flows to the creek are controlled by Willandra Weir and the nearby regulator for the creek. Willandra Creek offtake is an excavated channel constructed in 1891, which is at a much lower commence-to-flow than the natural channel (see below).

The upstream portion of the creek receives regulated flows from the Lachlan River for irrigation and stock and domestic purposes. The regulated section finishes at the Willandra National Park 'Homestead' Weir. The maximum allocation allowed for extraction from the creek is 23,457 megalitres (DIPNR 2003).

The Water Sharing Plan provides for a 12,000 ML/yr replenishment flow. The downstream target for this flow is the Balranald/Ivanhoe Road west of Morrison's Lake.

There are important environmental assets along the creek, including:

- the creek itself
- Willandra National Park—which is substantially a terrestrial park with a significant creek frontage
- Morrison's Lake—which is a nature reserve
- Gunnamby Swamp at the end of the creek—this site is not considered in this document as it only receives large floods.

Hydrological modelling (Hameed et al. 2005) has demonstrated that Willandra Creek under current conditions takes a much greater share of water than it did under pre-development conditions, and this effect is noticeable in flow changes at Oxley.

## Water Management Area: Willandra Creek reaches

Love (1999) divided Willandra Creek into four reaches based on riparian vegetation and channel structure. The following descriptions are provided by Love (1999):

- Natural offtake—this is the original natural channel for the creek which starts some 2 kilometres upstream from Willandra Weir. The channel meanders for several kilometres but only flows when the river reaches the commence-to-fill of some 8,000 ML/d at Willandra Weir. The channel is deep with considerable woody debris. Riparian vegetation is dominated by river red gum and river cooba.
- The cutting—this is the excavated channel which cuts off the natural offtake channel. It runs some 16 kilometres to join the creek. It has a more trapezoidal channel shape and there is little riparian vegetation with less dense stands of river red gum and river cooba.
- Upper reach—this reach runs to the Cobb Highway beyond Willandra National Park. It is a well defined channel with riparian vegetation dominated by black box and river cooba.
- Lower reach—Cobb Highway to Gunnamby Swamp. This creek channel is less well defined, particularly proceeding further west. Riparian vegetation is dominated by lignum.

There have been no systematic ecological studies of the Willandra Creek system to provide more information on water management of these areas. Therefore the following information is based on very limited information.

## Water Management Area: Morrison's Lake

Morrison's Lake is about 300 hectares in size and is a nature reserve located on the downstream reach of Willandra Creek. The lake was previously part of the Ivanhoe Town water supply with water being provided via Willandra Creek as part of the 12,000 ML/yr replenishment flow. When Willandra Creek is filled, water can be directed into the lake via regulators. Morrison's Lake is now not part of the town water supply as it has been replaced by a 350-megalitre concrete storage.

During the recent drought there were supply constraints in providing water to Ivanhoe because of the low water levels in Wyangala Dam. Consequently a commitment has been made to provide Ivanhoe with alternative water via groundwater bores. The effect these arrangements will have on the water regime of Morrison's Lake is yet to be investigated, and it is understood that the NSW Office of Environment and Heritage is preparing a management plan for the lake.

Water delivery to the lake is achieved with a flow target of 150 ML/d at Willandra Homestead Weir with flows taking up to 90 days to reach the lake. The volume-to-fill for the lake is estimated at between 1,560–3,700 megalitres depending on antecedent conditions. State Water has advised a volume-to-fill of 4,000 megalitres.

## Asset: Merrowie Creek

Merrowie (aka Marrowie) Creek is an effluent distributary which leaves the Lachlan River just upstream of Hillston. It is an extremely long creek, along with its conjoined Box Creek which starts downstream of Lake Tarwong. Box Creek runs north and then west of the Great Cumbung Swamp and eventually joins the Murrumbidgee River.

Cuba Dam and Lake Tarwong to Chilchil Swamp are nationally important wetland sites along the creek.

The Lachlan Water Sharing Plan makes provision for an annual stock and domestic replenishment flow of up to 9,000 megalitres for the Merrowie Creek Water Trust area. Water for the replenishment is provided by unregulated flows when possible and by storage releases when these flows do not occur. The replenishment fills the weir pools along the creek with Cuba Dam being the terminus of the trust area. Gonowlia Weir is used to divert this water from the Lachlan into the creek. The creek also has a regulator near its source to exclude other flows if necessary.

There are 14 licenced weirs along the creek. The replenishments are provided at about 150–200 ML/d for about 6–8 weeks to reach Cuba Dam, generally in the late autumn to winter period. Flows above this level will result in the Box Creek (see below) Regulator being overtopped. Therefore, under these conditions, there is no freeboard (which refers to the vertical distance between the water level and the top of the structure) in the creek and piggybacking using environmental water would need to be done by extending the duration of the replenishment flow.

Box Creek leaves Merrowie Creek some 60 kilometres downstream of the offtake from the Lachlan River. Some flows in Box Creek can be controlled by a regulator. Flows down Box Creek enter Merrimajeel Creek just upstream of the Booligal Swamp.

Other flows, mostly unregulated, enter Merrowie Creek when the flows are in excess of 2,500 ML/d. It is these flows which can extend beyond Cuba Dam, reaching the Tarwong Lake and Swamp system and beyond, depending on the size of the flood event. Beyond Lake Tarwong, water flows into (another) Box Creek and onto Chilchil Swamp, but only in large flood events.



## Water Management Area: Merrowie offtake to Toms Lake

The upper Merrowie Creek area supports valuable riparian vegetation, particularly lignum. The creek also delivers water to a number of ecologically valuable weir pools, such as Mutherumbung which has provided nesting sites for colonial waterbirds, and Toms Lake which supports a variety of waterbirds including the blue-billed and freckled ducks. The weirs along the creek are all drop board structures and the boards are removed during the replenishment flow, which provides connectivity along the creek and with the Lachlan River for 6–8 weeks. Cuba Dam also has drop boards but is drowned out at 400 ML/d (a large flow for this site).

## Water Management Area: Toms Lake Weir pool

Toms Lake Weir pool is located towards the downstream end of the Merrowie Creek Water Trust area and receives stock and domestic replenishment flows. In 2005, water was released from the weir pool by the landholder and Water Trust to provide top-up water for the waterbird breeding event at Mutherumbung Weir (see below).

The riparian vegetation surrounding the weir pool is dominated by river red gum, black box, river cooba and cooba. The pool appears to extend about 4 kilometres in a direct line upstream of the weir, but the channel is meandering so a larger area would be inundated when full. The volume-to-fill requirement are not known.

## Water Management Area: Mutherumbung Weir pool

Mutherumbung Weir pool is located towards the downstream end of the Merrowie Creek Water Trust area and received the 2005 stock and domestic replenishment flow. The riparian vegetation along the weir pool is dominated by lignum with scattered black box, river cooba and cooba.

In November 2005, 8,000–10,000 ibis pairs were found breeding on the weir pool. This event provides information about water management for this site at this time of the year. The stock and domestic replenishment flow to the area had ceased but evaporation was high and the water level in the weir pool was dropping. Actions taken to maintain the water level included:

- the landholder delayed pumping from the weir pool, which was intended for stock purposes around the property
- a release of water from Toms Lake Weir pool was organised, because the travel time for water to reach the site from the Lachlan River would have resulted in the water reaching Mutherumbung too late
- a ‘replacement’ diversion from the Lachlan River to Toms Lake and Mutherumbung was commenced—a release of 117 ML/d commenced on 8 December 2005 and was completed on 4 January 2006 with a total of 5,532 megalitres provided.

## Water Management Area: Cuba Dam Weir pool

Cuba Dam Weir pool is located at the end of the Merrowie Creek Water Trust area and receives stock and domestic replenishment flows. The dam was constructed in the mid-1880s by James Tyson to provide stock water.

The dam fills in four to five weeks under uncontrolled flow conditions (1,500 ML/d or more at Hillston) or in 6–7 weeks under controlled replenishment flows of 200 megalitres. The volume-to-fill is approximately 800 megalitres (Barma et al. 2010).

The riparian vegetation surrounding the weir pool is dominated by lignum. The site has provided for several large colonial waterbird breeding events including in 1984, 1989, 1990 (Whitehead & McAuliffe 1993). Some 40 species of waterbirds and nearly 50,000 breeding ibis were recorded by Magrath (1992) in 1990.

In 2010, a replenishment flow, supported by environmental flow releases which were used to enable flooding all the way to Cuba Dam, sparked a waterbird breeding event. On 3 November 2010 it was confirmed that inundation at Cuba Dam had triggered colonial nesting of straw necked ibis (approximately 500 pairs) 2.5 kilometres upstream of the dam. Subsequent observations on the ground indicated that the colony was actively expanding. Analysis of high-resolution digital vertical photography captured more than 10,000 nests in the area on 12 December 2010.

The aim of the second phase of environmental watering was to deliver 3,000 megalitres to Merrowie Creek at 120 ML/d to support the completion of the bird breeding event and to inundate Lake Tarwong. Environmental water flows into Merrowie Creek commenced on 16 November 2010 and concluded on 13 December. The head of the environmental flow arrived at Tarwong on 26 December 2010. The total volume of environmental water delivered was 3,000 megalitres.

## Water Management Area: Lake Tarwong system

Merrowie Creek is approximately 135 kilometres long and terminates into the Lake Tarwong swamp system. At about 25–30 kilometres upstream (below Cuba Dam), the channel braids into the wider floodplain. When the lake is full, backwater flows into swamps upstream. Backflow first goes to the southern swamp and then into the more open northern swamp.

When the lake fills, water also flows into Box Creek downstream. There is a licenced regulator at the exit from the Lake to Box Creek.

The lake filled in 2010 from local rainfall, replenishment and environmental flows (see Cuba Dam description for details) with 3,830 megalitres of environmental water delivered to Merrowie Creek in 2010. Prior to this the lake was last filled in 2000 (this was the 350,000-megalitre translucency flow event) and just started to run into Box Creek but with no flow into the upstream swamps. The 1996 and 1998 flood events filled the lake and associated swamps.

State Water advises that about 2,000 megalitres is required to get water from Cuba Dam to Lake Tarwong. Based on their sizes and antecedent conditions, the volume-to-fill estimates are:

- Lake: 150 hectares = 750–1,800 megalitres
- South swamp: 150 hectares = 750–1,800 megalitres
- North swamp: 400 hectares = 2,000–4,800 megalitres.

## Asset: Moon Moon Swamp

Moon Moon Lake/Swamp is adjacent to the Lachlan River about 30 kilometres upstream by road from Booligal. A part of the swamp was previously the Moon Moon State Forest and is now part of the Riverina Red Gum Forests National Park (the actual area of the park is to be established). Inflows to the swamp occur from two channels from the Lachlan River, with the most easterly channel being the main carrier. The swamp is some 300 hectares and part of a larger floodplain of some 8,000 hectares. In larger floods, water spills past the swamp into a lignum dominated depression that has been reported to support ibis breeding and likely other species. Only the 300-hectare area is considered in this document.

The following water management information is from BWR (2010):

- travel time from Wyangala Dam is about 37 days, and 17 days from Lake Brewster
- CTF is around 2,000 ML/d at Whealbah
- estimated volume-to-fill for the 'critical area' of 210 hectares of the lake is between 1,050 megalitres and 2,520 megalitres depending on antecedent conditions.

As an indication of what would be required to deliver environmental water to Moon Moon, the following information is provided on the February–March 2010 unregulated flow event. This event reached the CTF for Moon Moon and some water filled the lower parts of the swamp (P Packard (OEHL) 2011, pers. comm.) but the extent of flooding has not been determined:

- the combined flow at Willandra Weir and regulator was some 26,100 megalitres between February 21 and March 12 (includes flows above 200 ML/d)—the maximum discharge reached 2,869 ML/d at the weir with a maximum of some 100 ML/d down Willandra Creek
- the flow at Hillston Weir reached 2,170 ML/d and therefore some water may have passed into Middle Creek
- over the 30 days associated with the event, some 25,000 megalitres passed Whealbah gauge with a maximum of 2,200–2,300 ML/d for five days.

In 2010, further flow events have occurred in the Lachlan, and analysis of these and earlier events, and the extent of flood inundation of Moon Moon using remote sensing sources, is proposed to better establish environmental water delivery requirements.

## Asset: Booligal Wetland system

The Booligal Wetland system consists of four WMAs: Murrumbidgee Swamp, Merrimajeel Swamp, Booligal Swamp and Lower Gum Swamp. The hydrology of this system is amongst the best known of all the assets covered by this document.

The Booligal Wetland system receives water from Torrigan Creek which is an anabranch of the Lachlan River. The Creek carries about 66 per cent of the total river flow. Muggabah and Merrimajeel Creeks are natural effluents from Torrigan Creek and provide the water to the wetland system.

Muggabah and Merrimajeel Creeks are part of a longstanding Stock and Domestic Water Trust. The replenishment under the Water Sharing Plan is up to 9,000 ML/yr and can be provided from unregulated flows in the river or releases from upstream storages. Recent replenishments of about 7,000 megalitres were provided during the severe drought (BWR 2010). Water for stock and domestic purposes are diverted into the creeks via Torrigan Weir generally in the colder months. Torrigan Weir is on Torrigan Creek and there are also new regulators on Merrimajeel and Muggabah Creeks. Generally the stock and domestic replenishment is delivered at around 100 ML/d. Murrumbidgee Swamp is the downstream target for the stock and domestic replenishment on Merrimajeel Creek and 'Little Lake' on the Muggabah.

The Booligal system is known to flood extensively when flows exceed 2,500 ML/d over 30 days or more, measured at Booligal Weir gauge. An example is the 1984 flood where flow at Booligal Weir was 3,000 ML/d for some 75 days, with flows of 500 ML/d into Merrimajeel Creek and 300 ML/d into Muggabah Creek over this period (or a total of 37,500 megalitres and 22,500 megalitres respectively) (Wettin & Bennett 1988).

Dwyer and Bennett (1988) provide a detailed assessment of the results of intentional diversion of flows into this system during the 1986 unregulated flow event. Of the 235,000 megalitres passing Willandra Weir, some 20,000 megalitres entered the creek system with some 3,500 hectares flooded. There was no waterbird breeding created by this event.

## Water Management Area: Booligal Swamp

The Booligal Swamp (aka 'block bank') is widely known as a site for major waterbird breeding events during flooding. Since the 1980s, bird breeding events have occurred in 1984, 1989, 1990, 1992, 1993, 1996, 1998 and 2000 (Driver et al. 2005, 2010). The site has been the target for environmental water management/releases on all occasions since 1984 to allow for the completion of waterbird breeding. A temporary block bank was constructed in 1984 to assist in holding and stabilising water levels beneath colonial nesting birds to prevent abandonment by adults. This bank was replaced by a larger, more permanent structure with a drop board regulator in 1992, which was positioned in a more downstream location. The block bank has been used in all waterbird breeding events since 1984, in conjunction with environmental water diversions from Toriganny Weir. The translucency flow event in 2000 resulted in significant waterbird breeding.

As indicated above, Dwyer and Bennett (1988) identified that large volumes of water are required to create significant flooding of the Booligal Swamp area. All major flooding of the area and waterbird breeding events have been the result of natural flooding events.

Driver et al. (2005, 2010) have undertaken an analysis of waterbird breeding events and correlated the events with the hydrology of the Booligal system. Based on this work the threshold for waterbird breeding to commence is 2,500 ML/d at Booligal Weir. Significant breeding events occur when this flow exceeds 60 days (or a total of 150,000 megalitres), but with a minimum duration of 19 days for a small breeding event in 1996 (a total of 47,500 megalitres). The 1996 event is the smallest flood with a recorded breeding event and could be considered as a threshold event.

Diversions to the swamp to support waterbird breeding have been at a rate of around 50 ML/d, with the releases originating from Lake Brewster and taking about 18 days' travel time to Toriganny Weir and three days from the weir to the breeding area. Volumes of water used to support these events have varied between up to 11,500 megalitres in 1992–93, and 650–3,800 megalitres for more recent events (e.g. 2,080 megalitres in 2000–01 after the 350,000 megalitre translucency event).

In 2010, a waterbird breeding event at Booligal was triggered by local rainfall and a managed stock and domestic replenishment flow in the Merrimajeel Creek. On 21 October 2010, preliminary stages of a breeding event were observed in the Lachlan Valley State Conservation Area (Booligal Station) involving more than 15,000 straw-necked ibis. Small numbers of glossy ibis were also observed congregating on the Merrimajeel Creek upstream of the main colony. Following the conclusion of the replenishment flow, intervention was required to prevent the water levels at the colony site receding rapidly which would likely lead to abandonment of nests and failure of the breeding event. Environmental water was ordered to support the event. To maintain water levels at the site prior to arrival of the environmental water from Lake Brewster, and subsequently during the breeding event, it was necessary to install and adjust boards in the block bank regulator.

Environmental water was delivered for 59 days at an average rate of 40 ML/d (approximately 2,360 megalitres) to support the event.

## Water Management Area: Murrumbidgee Swamp

Murrumbidgee Swamp (locally known as Angora Clump) is located at 'Woorandarah' on Merrimajeel Creek, about 40 kilometres from Toriganny Creek which is its water source. Prior to regulation, the site flooded seasonally forming a river red gum, river cooba, cooba, black box and western grey box wetland association. In November 2010, the swamp filled following the combined inputs of local rainfall, replenishment and environmental flows.

The swamp is the downstream target for the annual stock and domestic replenishment for Merrimajeel Creek as part of the Muggabah and Merrimajeel Creeks Water Trust. The replenishment is generally provided during the cooler late autumn to early spring months for delivery efficiency reasons. Flows in warmer months result in plant growth in the creek channel, which inhibits water passage and prevents water from reaching the swamp.

The following water supply information is from BWR (2010):

- Stock and domestic flows in the Merrimajeel Creek channel are delivered at a rate of about 60 ML/d. Channel flow capacity is about 100 ML/d before water starts to break out. This equates to approximately a 40 ML/d freeboard.
- Travel time is about 70 days from Torriganny Weir, which equates to about 4,000 megalitres total flow reaching the swamp.
- The CTF for Merrimajeel Creek, with no boards in Torriganny Weir, is about 250 ML/d. Water reaching the swamp is dependent on the duration of these flows due to its distance from the water source. Hydrology modelling by Barma et al. (2010) has indicated that Murrumbidgil Swamp has a CTF level of 1,560 ML/d at Booligal gauge.
- The volume-to-fill is estimated to be between 600 megalitres (wet conditions) and 1,400 megalitres (dry conditions).
- Based on the 600–1,400 megalitres volume-to-fill, a release at Torriganny Weir of 4,600–5,400 megalitres into Merrimajeel Creek is required. The 600–1,400 megalitres can be provided 'on top' of the stock and domestic replenishment as there is about a 40 ML/d freeboard in the creek channel. The release would be required for about 15–35 days to fill the swamp.

## Water Management Area: Lake Merrimajeel

Lake Merrimajeel is located at 'Woorandarah' on Merrimajeel Creek, about 42 kilometres from Torriganny Creek, its water source. The site is intermittently flooded, with lignum and nitre goosefoot the dominant vegetation. The lake is just downstream from Murrumbidgil Swamp, which is the downstream target for the annual stock and domestic replenishment for Merrimajeel Creek. The lake received flows in November 2010 following local rainfall, replenishment and environmental flows.

Much of the hydrological description provided above for Murrumbidgil Swamp applies here with the following additional information:

- Hydrology modelling by Barma et al. (2010) determined the volume-to-fill to be 500 megalitres. However, BWR (2010) estimated a volume-to-fill of between 500 megalitres (wet conditions) and 1,200 megalitres (dry conditions).
- Based on a volume-to-fill of 600–1,200 megalitres for the lake, a total release of some 5,600–6,660 megalitres into Merrimajeel Creek would be required which is inclusive of the stock and domestic, and Murrumbidgil Swamp filling. This water can be provided 'on top' of the stock and domestic replenishment as there is about a 40 ML/d freeboard in the creek channel (BWR 2010). The release would be required for about 12–30 days to fill the lake after the swamp has filled.

## Water Management Area: Lower Gum Swamp

Lower Gum Swamp is on Muggabah Creek, about 6 kilometres west of the Booligal township and some 20 kilometres from Toriganny Weir via the creek channel. Muggabah Creek also receives stock and domestic replenishment flows and the delivery of this water extends well downstream of Lower Gum Swamp to 'Little Lake'. Lower Gum Swamp is not inundated by stock and domestic flow.

The control sill for the flows into the swamp is at the southern end, adjacent to the creek channel. Higher (but undetermined) creek flows are required to fill the swamp and some of the water drains from the swamp once creek flows decrease.

Barma et al. (2010) provides the following information:

- travel time to the swamp estimated to be 30–40 days from Toriganny Weir
- a volume-to-fill of 160–384 megalitres based on wet to dry antecedent conditions
- piggybacking on the stock and domestic replenishment is possible and likely the most efficient way to conjunctively provide the water—the CTF information is needed to confirm this option.

## Asset: Lachlan Swamp System

The Lachlan Swamps floodplain area (and some high country) on the northwest bank of the river covers about 10,000 hectares (Barma et al. 2010). There is a similar area of floodplain on the south-east bank (Barma et al. 2010).

The Lachlan Swamp system has been divided into four WMAs: Lake Waljeers, Peppermint Swamp, Lake Bullogal and Ryans Lake. The latter two sites are not covered in this document as they are only inundated during flood events.

The swamp system receives flow primarily from the Lachlan River. Infrequently, water can also enter the system from Mirrool Creek which joins the Lachlan (after passing through the Murrumbidgee Irrigation Area) adjacent to Lake Waljeers, and from Muggabah Creek which enters near the Peppermint Swamp area.

Lake Waljeers is the first asset to receive water from the Lachlan River, while Peppermint Swamp is the second asset within the Lachlan Swamp to receive water. Barma et al. (2010) identifies that the floodplain upstream of Lake Waljeers requires 19,000–50,000 megalitres to flood. The floodplain downstream of the lake requires 20,000–35,000 megalitres.

The following information is provided in Barma et al. (2010), as a general indication of how this system responds to river flows and as a guide on a possible environmental water release. It is based on the spring 1995 unregulated flow event in August and September:

- On 15 August, water reached Lake Waljeers. Travel time from the river was three to four days.
- Water flows through creeks to the north of the lake. These creeks supply the lake and also bypass the lake toward Peppermint Swamp.
- On 5 September water reached Peppermint Swamp.
- Flow south-west from the lake is blocked by a levee bank around the south-west margin of the lake. This levee was constructed in 1967. Prior to 1967, the floodplain downstream of the lake would be flooded. There are gates in the levee but they have been kept closed.
- Total flow in August for this event was some 20,000 megalitres at Booligal with a peak flow of 1,200 ML/d.
- Water in the 1995 event did not reach Lake Bullogal or Ryans Lake. They only receive water in large floods, e.g. 1984, 1989, 1990.



The MDBA (2010) also provides information on the characteristics and hydrology for this area. It is notable that the MDBA report also includes Lake Ita, Baconian Swamp and floodplains in its Lachlan Swamps assessment.

There is considerable potential for piggybacking, but these arrangements have not been fully investigated for this area.

## Water Management Area: Lake Waljeers

Receiving flows in November 2010, the lake is about 520 hectares and consists of an open water area with a margin of largely river red gum. The following information is from Barma et al. (2010) unless otherwise cited:

- travel time is about five to seven days from Booligal Weir
- CTF point is about 5–6 kilometres upstream of the lake, with another breakout from the river about 2 kilometres upstream
- CTF from Barma et al. (2010) is 800–1,200 ML/d for the upper Lachlan swamp floodplain and Lake Waljeers. MDBA (2010) used 850 ML/d
- the volume-to-fill identified from Barma et al. (2010) is 5,000–10,000 megalitres; an alternative estimate, which assumes 5–12 megalitres per hectare, is a volume-to-fill of 2,600–6,240 megalitres
- depth of the lake is about 2.5 metres at maximum flooding. As inflows cease, water drains into the channels to the north that supply the Peppermint Swamp area. Final lake depth is about 1.5 metres. The lake holds water for 18 months assuming no further inflows.

## Water Management Area: Peppermint Swamp

The swamp is about 120 hectares in area. According to Barma et al. (2010) the CTF is between 950 ML/d and 1,350 ML/d at Booligal Weir. The volume-to-fill is identified as 400 megalitres, or alternatively 600–1,440 megalitres if 5–12 megalitres per hectare is assumed (Barma et al. 2010).

## Asset: Ita Lake

Ita Lake covers about 1,200 hectares and is located on the Kalyarr State Conservation Area (previously the property 'Norwood') some 20 kilometres upstream of Oxley. Located in Kalyarr State Conservation Area and part of the nationally significant Lachlan Swamp complex, Lake Ita has important cultural and ecological values. It is a wetland typical of many fed by the lower Lachlan during medium-to-high flows, big enough to sustain significant ecological values and small enough to respond to the volumes that licenced environmental water can deliver. There is substantial evidence of Aboriginal cultural relationships that will serve as a benchmark for assessing restoration potential of a moderately degraded wetland. It may also provide a comparison of the relative condition between wetlands, with those close to natural versus those with altered flow regimes. However, the infrastructure does not support efficient watering at present.

The lake bed is south of the Lachlan and set back from the river by about 3 kilometres. A series of inflow channels from the river feed into a main supply channel which flows into the north-west part of the lake. These channels cover a large area and it is likely they absorb considerable water before flows reach the lake bed. A regulator<sup>4</sup> was located on the main inflow channel near the head of the lake. This regulator appears to have been constructed in 1976 and could have been used to influence inflows, and therefore the results for the individual flood events, satellite image analysis and hydrology results of BWR (2010) below.

Pimpara Creek, a high-level effluent of the Lachlan, runs adjacent to the south end of the lake to join the Murrumbidgee River. This creek only flows when there is large flooding of either the Lachlan or Murrumbidgee Rivers (via backwater).

The following is based on BWR (2010):

- CTF is currently estimated at 1,800–2,000 ML/d at Corrong—this is a very high flow for this section of the river
- the volume-to-fill for the entire lake, based on the wet to dry antecedent condition estimates (i.e. 5–12 megalitres per hectare), is between 6,000 megalitres and 14,400 megalitres—smaller volumes will fill portions of the lake
- travel time from Wyangala to Corrong is about 75 days, travel time from Lake Brewster to Corrong is about 55 days, and Ita lake would be several days of travel time past the Corrong gauge. The Lachlan catchment has an extremely low gradient in this section of the river.

Based on the above, BWR (2010) concluded that a specific environmental water release to Ita lake is an unrealistic option. The lake CTF of 2,000 ML/d at Corrong requires a flow of some 12,000 ML/d at Brewster Weir (S Sritharan 2011, pers. comm.) and this flow cannot be achieved with combined Lake Brewster, Lake Cargelligo and Wyangala Dam maximum releases without causing flooding conditions to sections of regulated upper and mid-Lachlan River.

However, during the high flows experienced in the lower river in January 2011, some water entered the lake via the north-west channel representing a much lower CTF for the lake of around 650 ML/d at Corrong. This was the first high river flow experienced following removal of the unapproved regulator on the inflow channel which had been acting to prevent or restrict river flows from entering the lake (P Packard (OEH) 2011, pers. comm.). Therefore it may be possible to deliver some environmental water into the lake, particularly through piggybacking onto other flows in the system.

In 2010–11, flows were found to enter Lake Ita from the river following removal of the inflow regulator, and from localised storm events providing flows to Pimpara Creek. There were some local observations which suggested that water in Lake Ita returned to the river via the inlet channel once river levels had dropped (and with no regulator to contain this water). The extent of inundation and the volume of water entering and leaving the lake is currently unknown.

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4 It is has been reported that this regulator has been removed in recent months.



## Asset: Baconian Swamp

The swamp is located just upstream of Oxley on the property 'Tupra' and is dominated by river red gum with a margin of black box trees. The swamp is about 800 hectares but is associated with a broader floodplain (see BWR 2010). There are two natural offtake channels from the river to the swamp—the most easterly passes near the 'Tupra' homestead and the western channel leaves the river near the Oxley road bridge. This latter offtake is the main water carrier; its bed has been lowered by a channel constructed in the early days of pastoral development. Oxley State Forest covers at least part of the swamp and is now part of the Riverina River Red Gum Forests National Park.

The following water delivery information is from BWR (2010):

- travel time is 90 days from Wyangala Dam and nearly 70 days from Lake Brewster
- CTF is 350 ML/d at Tupra gauge, based on a 2005 unregulated event which delivered water to the swamp
- the volume-to-fill for the swamp, based on the wet to dry antecedent condition estimates (i.e. 5–12 megalitres per hectare), is between 3,990 and 9,576 megalitres
- based on the 2005 event, an environmental water release of approximately 35,000 megalitres and a peak discharge of 2,800 ML/d at Willandra Weir would be required to flood a core area of the swamp
- piggybacking environmental water onto unregulated flows is a good watering option.

## Asset: Great Cumbung Swamp

The Great Cumbung Swamp (GCS) has been a terminal wetland for thousands of years and is listed in *A Directory of Important Wetlands in Australia*, published by the Australian Government. The swamp includes a variety of wetland areas and covers approximately 15,000 hectares. The GCS and its associated floodplain support one of the largest areas of common reed and stands of river red gum in NSW. The Cumbung is now well-inundated after receiving flows in 2010–11. However, prior to this latest inundation the vegetation of the Cumbung was in poor condition as a result of drought conditions experienced over the past 10 years.

The GCS includes a number of water management areas, such as the reed bed. The water management areas have yet to be determined as the Lachlan CMA has not made available the hydrodynamic modelling study by consultancy Parsons Brinkerhoff. Sub-units within GCS include Boocathan (lake and swamp), Bunumburt Lake, Narran Lake, Brittens Lake and Little Brittens Lake, Dead Tree Swamp, Clear Lake, Dry Lake, Hut Swamp and Sapling Swamp.

The GCS, under natural conditions, would have flooded in late winter to early spring and dried under drought conditions. A number of existing (unauthorised) levees, channels and regulating structures, some installed at the time of pastoral settlement, have changed inundation patterns in the GCS. Landholders have generally selectively flooded areas of the GCS to enhance grazing opportunities. There has been no prior systematic analysis of the capability of these structures, although this may have been done as part of the hydrodynamic modelling study.

Relevant water delivery information for the GCS includes:

- Travel time is 90 days from Wyangala Dam and nearly 70 days from Lake Brewster.
- CTF—because the Lachlan River terminates in the GCS all flows entering will result in some flooding. At flows of about 700 ML/d at Booligal Weir there is some flooding of the reed bed. Flows of between 1,500 and 3,000 ML/d at Booligal Weir will start to flood the broader wetland and this flooding will increase depending on the duration of these flows. In this regard the hydrodynamic model could provide further information (if so, the above information can be revised).
- the volume-to-fill is estimated to be 5,000 megalitres for the reed bed and 30,000–45,000 megalitres to achieve river red gum inundation.

## Appendix 3: Probabilities of unregulated flows in the Lachlan River at Willandra and Booligal Weirs

Daily flows for various exceedance percentiles at Booligal and Willandra have also been determined. These are presented for each month for extreme-dry-to-extreme-wet scenarios. These results are based on an analysis of more than 100 years of modelled flows for current development and water-sharing plan rules. Annual flow totals were firstly ranked. Years corresponding to a particular climatic condition were then extracted and daily flows were then analysed to produce information on the percentage of time a flow threshold was exceeded together with the average duration (Avg d) of days above the flow threshold. This was undertaken for each month. For example, in Table 15 a January flow of 336 ML/d will be exceeded for 40 per cent of the time, with events exceeding 336 ML/d for an average duration of five days. January flow will be at least 309 ML/d (i.e. 100 per cent probability of being exceeded) with a maximum flow of about 588 ML/d (i.e. exceeded very rarely).

Further analysis of these events is likely to be required at several sites to determine potential threshold events for the possible use of held environmental water via piggybacking.

**Table 15:** Probabilities of unregulated flows being exceeded under extreme dry conditions—Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	309	31	301	28	295	31	46	30	75	0	30	31	238	30	305	31	301	30	299	31				
90	323	31	317	26	321	31	112	30	80	31	74	30	62	31	210	31	284	30	312	31	317	26	321	20
80	330	19	322	12	483	21	462	30	351	31	75	30	234	31	281	28	288	30	316	19	322	13	324	12
70	333	8	326	8	491	10	518	12	436	14	424	18	283	12	290	12	295	30	318	22	323	13	328	11
60	334	7	328	6	494	7	525	8	439	8	434	7	286	10	290	12	296	30	322	11	326	11	329	8
50	335	6	329	6	498	7	529	7	440	7	435	5	286	8	302	16	303	28	326	10	329	8	330	7
40	336	5	330	4	499	6	531	6	441	4	436	3	288	6	303	11	308	14	329	5	333	12	332	9
30	336	4	332	4	500	5	532	4	443	4	437	3	289	6	303	5	309	11	332	4	340	6	344	8
20	347	4	333	3	502	5	532	3	445	3	439	3	302	5	303	4	316	8	334	3	341	4	346	4
10	355	2	335	2	527	3	532	2	499	4	443	1	305	4	303	4	323	6	336	2	343	3	349	3
0	588	1	404		543	1	611	1	633	1	466	1	310	1	332	1	457	1	344	1	352	1	396	1

**Table 16:** Probabilities of unregulated flows being exceeded under dry conditions—Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
<b>100</b>	519	31	293	28	298	31	360	30	410	31	279	31	252	31	91	31	78	30	334	31	345	30	308	31
<b>90</b>	697	31	339	28	454	31	518	23	435	23	398	30	302	24	303	28	318	30	417	31	518	29	566	31
<b>80</b>	729	21	578	28	492	11	527	12	441	12	434	11	305	15	307	23	366	26	502	19	586	32	621	25
<b>70</b>	746	20	698	13	503	10	530	8	445	12	438	9	308	15	343	18	456	16	617	14	625	23	687	24
<b>60</b>	814	20	725	8	519	10	532	7	448	9	441	12	322	16	394	14	505	16	708	10	745	17	781	26
<b>50</b>	863	7	746	8	551	11	533	7	456	8	445	7	352	25	416	11	606	10	764	8	791	13	825	15
<b>40</b>	907	5	772	8	612	12	542	7	466	8	448	7	373	10	458	11	666	8	842	5	840	11	857	8
<b>30</b>	953	4	897	10	728	6	556	5	483	7	450	4	399	10	525	6	702	5	883	4	907	8	897	5
<b>20</b>	1,020	4	1,165	4	814	5	567	4	522	5	454	4	445	7	549	5	769	4	974	4	961	6	928	4
<b>10</b>	1,196	3	1,274	2	1,020	6	623	3	584	3	504	16	507	5	615	4	914	3	1,194	3	1,056	5	985	3
<b>0</b>	1,417	1	1,723	1	1,472	1	820	1	676	1	593	1	1,915	1	4,501	1	4,829	1	5,096	1	4,996	1	1,367	1

**Table 17:** Probabilities of unregulated flows being exceeded under median conditions—Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
	%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d		
100		715	31	310	28	352	31	420	30	323	31	293	30	76	31	230	31	84	30	324	31	329	30	306	31
90		814	31	688	26	490	24	518	25	442	40	407	25	292	31	365	31	375	30	428	31	509	30	599	31
80		894	14	820	16	529	10	525	12	449	13	434	13	306	31	497	16	456	26	511	31	657	30	779	31
70		957	9	878	14	545	9	530	10	452	9	441	9	342	25	533	16	517	15	628	30	767	23	903	13
60		1,013	9	997	8	570	11	532	9	455	8	447	7	385	10	578	9	576	12	707	23	884	13	943	8
50		1,084	6	1,082	7	666	14	538	13	460	7	451	6	428	9	609	11	679	12	833	13	952	10	988	8
40		1,124	5	1,165	6	800	10	551	7	466	7	454	7	470	8	1,200	18	734	11	988	9	987	6	1,015	6
30		1,191	4	1,200	6	1,030	9	558	6	487	5	461	6	509	6	3,721	13	983	5	1,089	6	1,015	5	1,036	5
20		1,224	3	1,284	3	1,215	5	601	7	524	4	472	7	579	4	4,406	5	1,200	5	1,184	7	1,062	5	1,073	4
10		1,580	10	1,409	2	1,414	4	790	8	624	3	534	6	945	6	5,565	7	4,724	5	1,333	3	1,124	4	1,121	3
0		7,385	1	2,210	1	5,805	1	6,780	1	3,512	1	6,616	1	5,664	1	6,725	1	5,936	1	4,573	1	7,282	1	1,288	1

**Table 18:** Probabilities of unregulated flows being exceeded under wet conditions—Willandra

Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d		
100	1,097	31	640	28	314	30	379	30	366	31	296	30	241	31	84	31	435	30	350	31	304	30	365	31
90	1,200	31	1,104	28	538	22	523	20	446	26	433	25	304	31	352	31	1043	25	642	31	724	30	847	25
80	1,220	6	1,200	20	615	15	527	12	451	18	445	15	318	28	537	35	1,713	16	764	18	819	22	914	18
70	1,242	4	1,229	9	776	14	532	14	462	14	448	9	342	21	1,213	29	3,284	18	1,005	20	923	14	1,001	12
60	1,265	3	1,259	5	982	10	545	9	476	12	451	12	409	23	2,632	14	5,185	15	1,419	17	995	12	1,055	9
50	1,293	3	1,293	4	1,123	10	553	7	488	9	456	9	505	16	4,402	12	5,797	14	3,972	16	1,072	8	1,088	7
40	1,337	2	1,316	3	1,209	7	581	6	496	8	466	16	1,200	23	5,809	14	6,222	10	6,055	11	1,224	9	1,140	7
30	1,370	2	1,349	3	1,257	3	599	5	524	8	487	14	4,010	12	6,613	8	6,615	11	6,530	7	2,459	10	1,215	5
20	1,403	2	1,403	3	1,315	2	638	5	631	9	554	16	5,469	10	7,934	7	8,339	11	7,299	7	5,427	7	1,328	9
10	1,562	3	1,550	5	1,367	2	727	4	3,456	18	2,916	9	6,375	9	9,065	7	10,900	8	8,564	4	6,406	5	3,925	9
0	6,172	1	6,802	1	1,916	1	8,687	1	12,004	1	5,982	1	15,160	1	14,140	1	14,883	1	11,760	1	9,839	1	16,619	1

**Table 19:** Probabilities of unregulated flows being exceeded under extreme wet conditions–Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	
100	1,026	31	1,083	28	440	31	388	30	402	31	279	30	1,213	31	7,018	31	1,429	30	886	31	690	30	875	31
90	1,200	31	1,200	28	573	31	519	23	441	30	421	30	3,680	31	9,956	31	7,235	27	1,903	31	1,002	29	968	15
80	1,215	7	1,231	8	648	15	526	11	457	25	440	30	5,702	31	12,134	31	9,205	24	5,145	31	1,346	37	1,016	9
70	1,239	4	1,266	5	927	15	531	9	465	12	445	30	7,198	31	13,993	22	9,770	26	6,224	17	3,131	25	1,053	8
60	1,247	3	1,303	4	1,172	13	548	12	468	9	448	30	9,880	31	15,161	16	10,116	22	6,456	12	6,299	16	1,116	7
50	1,268	3	1,318	4	1,219	6	551	6	472	7	454	30	10,647	27	16,191	16	10,689	19	6,759	13	7,785	15	1,141	5
40	1,300	2	1,339	3	1,256	4	554	6	480	9	459	30	11,565	12	17,261	16	12,010	15	7,734	12	10,447	20	1,191	7
30	1,322	2	1,371	2	1,285	2	568	5	491	5	491	30	14,947	16	19,104	12	12,893	11	8,084	9	13,260	15	1,287	6
20	1,396	2	1,443	2	1,325	2	596	6	515	4	540	30	22,987	16	20,411	10	14,204	8	9,324	10	15,265	10	1,469	8
10	1,556	5	1,558	1	1,391	2	623	4	586	3	576	30	26,621	8	24,732	8	18,280	15	11,061	8	17,795	15	6,122	8
0	6,875	1	4,546	1	1,838	1	718	1	675	1	14,584	2	66,231	1	30,678	1	29,595	1	21,449	1	25,711	1	7,890	1



**Table 20:** Probabilities of unregulated flows being exceeded under extreme dry conditions - Booligal

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
	%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d		
100	0		0		0		0		0		0	30	0		0		77	30	0		0		0		
90	0		0		0	31	0	45	31	0	31	0	30	20	31	42	31	96	19	0	31	51	30	12	23
80	0	22	0	21	76	21	90	16	12	31	0	30	78	31	88	31	97	13	37	23	77	15	53	25	
70	23	15	0	19	98	11	100	11	93	19	98	13	95	14	97	12	99	10	87	17	91	11	87	15	
60	45	12	37	24	100	6	107	9	97	10	99	8	98	9	100	7	100	7	99	9	100	9	97	9	
50	76	15	94	17	100	5	111	8	100	6	100	5	100	8	101	5	102	7	103	6	104	5	99	6	
40	99	8	99	10	101	3	119	9	101	5	100	4	100	6	102	5	106	6	107	4	106	4	101	5	
30	100	4	100	4	102	3	125	5	105	3	101	4	102	5	106	4	110	4	109	3	108	3	104	3	
20	100	2	100	3	107	2	125	3	115	3	103	4	109	3	112	3	129	4	114	3	110	3	107	3	
10	103	2	108	4	112	3	127	3	126	2	107	2	120	2	124	3	158	3	174	3	116	3	110	3	
0	333	1	255	1	385	1	147	1	159	1	115	1	176	1	255	1	340	1	345	1	373	1	586	1	

**Table 21:** Probabilities of unregulated flows being exceeded under dry conditions - Booligal

Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d		
100	0		0		0		21	31	9	31	52	30	66	31	32	31	29	30	0	36	30	0		
90	0	20	0		2	31	100	15	87	23	97	17	97	18	90	24	92	18	0	31	73	21	71	31
80	20	28	0	18	71	31	106	11	96	10	99	15	100	11	99	10	98	11	55	21	88	12	92	19
70	70	20	0	16	93	8	112	8	99	8	100	10	101	8	104	10	102	8	93	8	95	7	99	10
60	94	9	25	15	99	5	116	9	102	6	100	8	104	6	109	7	107	6	101	5	103	6	104	10
50	100	7	83	11	103	4	122	6	105	4	100	7	108	5	116	6	110	5	105	4	110	5	107	5
40	104	5	98	5	108	3	124	5	107	3	101	6	110	4	124	5	116	5	114	4	120	5	109	5
30	110	4	107	4	113	3	126	5	110	4	105	9	116	4	153	5	127	4	130	3	160	4	116	5
20	120	3	124	3	119	3	135	5	118	2	108	5	140	3	197	4	179	3	179	3	213	3	152	5
10	174	2	206	3	141	3	150	3	131	2	109	3	173	3	247	3	259	3	282	3	308	2	281	5
0	428	1	695	1	900	1	599	1	375	1	512	1	856	1	1,057	1	1,137	1	732	1	925	1	757	1

**Table 22:** Probabilities of unregulated flows being exceeded under median conditions - Booligal

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	
100	0	0	0	0	0	0	0	0	19	31	53	30	66	41	31	38	30	0	42	30	47	31		
90	0	0	0	0	0	88	17	81	31	95	21	100	20	101	31	96	24	38	31	80	26	89	19	
80	0	28	0	0	0	100	10	95	14	98	16	104	11	107	15	104	18	74	14	95	14	99	14	
70	37	26	0	20	0	104	14	99	9	100	11	107	9	116	10	111	13	100	9	106	9	108	10	
60	69	10	29	13	38	12	112	8	102	7	101	8	109	7	124	9	139	12	113	6	112	7	116	7
50	94	7	55	8	80	7	115	7	105	5	103	6	113	5	159	9	208	13	131	5	127	6	133	7
40	109	6	77	6	98	5	121	6	108	4	105	6	122	5	212	7	386	13	175	5	158	5	188	6
30	168	6	103	5	111	4	126	4	115	4	106	5	157	5	269	9	822	12	264	6	213	5	300	5
20	257	5	258	5	181	3	139	3	125	4	108	4	192	7	1,109	9	1,438	9	467	10	353	6	399	4
10	483	5	511	4	347	3	288	11	159	6	111	3	687	9	1,807	9	1,861	4	1,632	9	1,010	11	550	3
0	1,146	1	2,284	1	1,860	1	1,647	1	2,577	1	287	1	2,284	1	2,731	1	2,908	1	2,788	1	2,568	1	2,913	1

**Table 23:** Probabilities of unregulated flows being exceeded under wet conditions – Booligal

Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d		
100	0		0		0		41	30	35	31	86	30	82		35	31	58	30	0	42	30	32	31	
90	27	17	0		0		77	19	85	31	98	21	99	23	100	31	198	30	105	28	124	20	78	23
80	45	10	15	21	0		99	10	98	14	100	11	104	17	118	28	622	30	184	21	175	16	108	16
70	58	6	46	13	15		109	9	102	9	101	11	109	10	203	22	1,186	26	758	34	313	19	130	16
60	80	6	78	7	39		111	6	106	7	104	11	114	10	786	36	1,559	18	1,803	34	517	20	187	12
50	97	7	117	7	73		118	7	112	6	107	9	121	10	1,286	27	1,867	14	2,319	24	1,133	18	366	9
40	116	5	168	6	106		124	6	119	5	112	15	147	10	2,091	29	2,134	12	2,715	11	1,643	15	512	10
30	151	5	287	5	139		139	4	138	7	126	21	201	17	2,510	18	2,386	9	2,894	13	2,080	12	991	13
20	328	6	440	5	263		185	3	708	35	1,637	14	1,642	19	2,795	12	2,872	16	3,313	12	2,647	17	1,737	11
10	949	15	888	8	475		460	3	3,391	18	2,049	6	2,229	11	3,396	13	3,725	11	3,511	5	3,413	8	2,459	17
0	3,864	1	2,483	1	2,341		3,068	1	5,595	1	3,234	1	2,852	15	4,141	1	4,255	1	4,158	1	3,705	1	3,420	1

**Table 24:** Probabilities of unregulated flows being exceeded under extreme wet conditions - Booligal

Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d		
100	0		0		0		48	30	37	31	59	30	95	31	93	31	884	30	62	31	741	30	83	31
90	47	20	2	18	0		87	16	94	24	94	30	114	29	120	31	2,353	30	459	31	1,850	30	141	31
80	73	11	30	19	0		100	11	100	11	97	16	1,270	93	2,273	31	3,618	30	2,138	31	2,562	27	387	31
70	96	8	71	11	11		108	9	103	11	100	16	2,791	56	3,234	31	3,954	18	2,788	31	2,801	29	632	21
60	109	7	94	7	42		115	6	106	7	103	22	3,363	26	3,918	24	4,124	30	3,327	15	3,081	40	923	23
50	127	6	112	6	70		122	6	109	6	106	18	3,601	28	4,009	13	4,357	12	3,581	15	3,290	35	1,503	19
40	178	7	134	5	90		125	5	113	5	108	10	3,834	9	4,152	22	4,538	15	3,750	12	3,501	21	2,778	20
30	256	4	177	5	116		131	4	121	5	112	18	3,947	10	4,474	23	4,723	15	3,952	9	3,789	21	3,400	15
20	498	5	426	4	148		518	30	694	31	195	47	4,200	8	5,515	16	4,888	8	4,253	16	4,083	16	4,092	10
10	826	8	1,312	15	590		3,054	15	3,286	5	3,914	4	6,824	16	6,113	5	5,203	8	4,826	16	4,470	10	4,453	8
0	3,240	1	2,543	1	1,591		4,136	1	4,178	1	4,131	1	1,0811	1	6,993	1	5,535	1	5,773	1	5,389	3	5,549	



## Appendix 5: SEWPaC risk matrix

	Environmental	People	Property	Operational
Critical	Irreversible damage to the environmental values of an aquatic ecosystem and/or connected waters/ other parts of the environment; localised species extinction; permanent loss of water supplies.	Death, life-threatening injuries or severe trauma.  Serious injury or isolated instances of trauma causing hospitalisation or multiple medical treatment cases.  Sustained and significant public inconvenience.	Severe or major damage to private property.  Significant damage to a number of private properties.  Critical or major damage to public infrastructure.	Predicted water loss will prevent the achievement of planned outcomes of the watering event.
Major	Long-term damage to environmental values and/or connected waters/other parts of the environment; significant impacts on listed species; significant impacts on water supplies.	Minor injury/trauma or first aid treatment case.  Injuries/instances of trauma or ailments not requiring treatment.  Sustained public inconvenience.	Isolated but significant economic and/or social impact.  Damage to private property.  Some damage to public infrastructure.	Predicted water loss will significantly detract from the planned outcomes of the watering event.
Moderate	Short-term damage to environmental values and/or connected waters/other parts of the environment; short-term impacts on species.	Short-term public inconvenience.  No injuries.	Minor economic and/or social impact contained to small number of individuals.	Predicted transmission loss will moderately detract from the planned outcomes of the watering event.
Minor	Localised short-term damage to environmental values and/or connected waters/other parts of the environment; temporary loss of water supplies.	Minor public inconvenience.  No injuries.	No economic impacts.  Minor public inconvenience.	A small amount of water will be lost and this will have a small impact on the environmental outcomes.
Insignificant	Negligible impact on environmental values and/or connected waters/other parts of the environment; no detectable impacts on species.	No public inconvenience.  No injuries.	No impacts on private property.  No infrastructure damage.	Water loss will be minimal and will not affect the planned outcomes of the watering event.

CONSEQUENCE		Minor	Moderate	Major	Critical
Insignificant		Minor instances of environmental damage that could be reversed.	Isolated but significant instances of environmental damage that might be reversed with intensive efforts.	Severe loss of environmental amenity and danger of continuing environmental damage.	Major widespread loss of environmental amenity & progressive irrecoverable environmental damage.
LIKELIHOOD					
	<b>Almost certain</b> Is expected to occur in most circumstances.	Low	High	Severe	Severe
	<b>Likely</b> Will probably occur in most circumstances.	Low	Medium	High	Severe
	<b>Possible</b> Could occur at some time.	Low	Medium	High	Severe
	<b>Unlikely</b> Not expected to occur.	Low	Low	Medium	High
	<b>Rare</b> May occur in exceptional circumstances only.	Low	Low	Medium	High



## Appendix 6: Lachlan seasonal base flow requirements

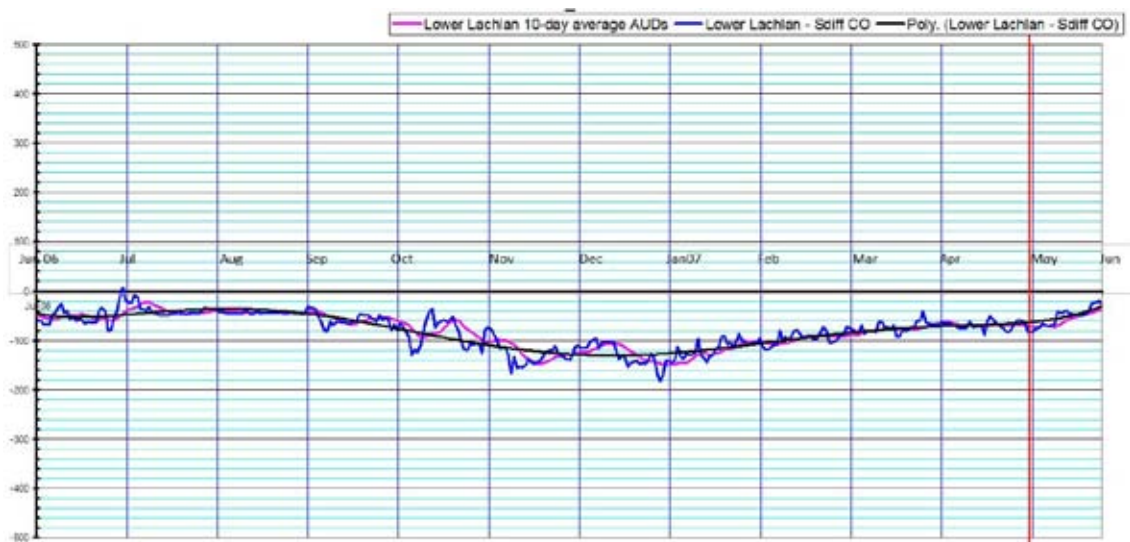
Source: State Water



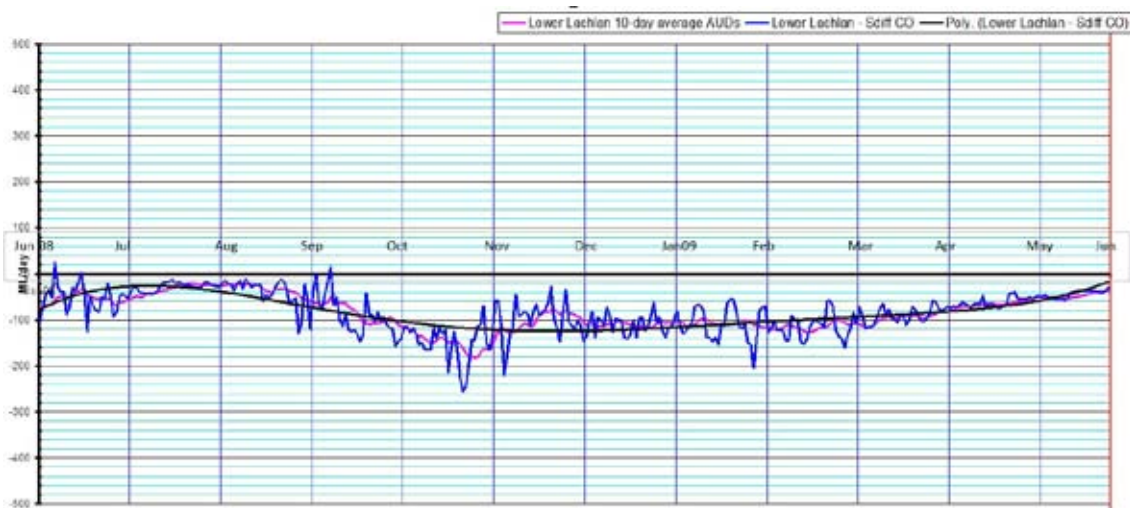
**Upper Lachlan Seasonal Base Flow, June 2006 to June 2007 (to Lake Cargelligo)**



**Upper Lachlan Seasonal Base Flow, June 2008 to June 2009 (to Lake Cargelligo)**



**Lower Lachlan Seasonal Base Flow, June 2006 to June 2007 (Below Lake Cargelligo)**



**Lower Lachlan Seasonal Base Flow, June 2008 to June 2009 (Below Lake Cargelligo)**

