Macquarie–Castlereagh region

Macquarie Marshes

The Macquarie Marshes hydrologic indicator site is an extensive wetland system on the lower reaches of the Macquarie River in central New South Wales. The marshes begin downstream of Warren and extend about 120 km to Carinda, as shown in Figure 1.1 (NSW Department of Water Resources 1991).

The Macquarie Marshes cover about 200,000 ha and include areas inundated by flows from the Macquarie River and its streams and anabranches, specifically the Macquarie River, Marebone Break, Bulgeraga Creek, Buckiinguy Creek, Monkeygar Creek, Old Macquarie River, Bora Channel, the Ginghet, Mullins Swamp, Gum Cowal – Terrigal Creek to its confluence with Marthaguy Creek, Long Plain Cowal and Dusty Swamp (NSW Department of Water Resources & NSW National Parks and Wildlife Service 1996; NSW National Parkes and Wildlife Service & Department of Lands and Water Conservation 1996; NSW Department of Environment, Climate Change and Water 2009a).

Most of the marshes are privately owned, except for about 22,300 ha managed by the NSW Department of Environment, Climate Change and Water, which includes the Macquarie Marshes Nature Reserve and the property Pillicawarrina (NSW Department of Environment, Climate Change and Water 2010a, 2010e). The Macquarie Marshes Ramsar site includes the Macquarie Marshes Nature Reserve as well as the privately owned Wilgara Wetland and Mole Marsh, and covers 18,726 ha (Department of the Environment, Water, Heritage and the Arts 2010a). The nature reserve and Mole Marsh were listed as Ramsar sites in 1986 and the Wilgara Wetland was listed in 2000 (NSW Department of Environment, Climate Change and Water 2010a; Department of the Environment, Water, Heritage and the Arts 2010a).

The Murray–Darling Basin Authority (MDBA) used the *Directory of important wetlands in Australia* dataset (Department of the Environment, Water, Heritage and the Arts 2001) to map the lateral and longitudinal extents of the Macquarie Marshes. The Ramsar Wetlands in Australia dataset was used to define the western extent of the system. Spatial data used in this map is listed in Table B1.3.

The marshes support a variety of flood-dependent vegetation types that include extensive water couch (*Paspalum distichum*) and common reed (*Phragmites australis*) grasslands, river red gum (*Eucalyptus camaldulensis*) forest and woodland, coolibah (*E. coolabah*) and black box (*E. largiflorens*) woodland, and lignum (*Muehlenbeckia florulenta*) and river cooba (*Acacia stenophylla*) shrublands (Paijmans 1981; Bowen & Simpson 2009b). They are an important example of associations of these vegetation types (NSW National Parks and Wildlife Service 1993; Department of the Environment, Water, Heritage and the Arts 2010a). Species and communities that do not depend on flooding to complete their life cycle occur on the edge of flooded areas and as pockets within the marshes. These areas are flooded rarely or not at all, and include weeping myall *(A. pendula*), belah (*Casuarina cristata*), and poplar box (*E. populnea*) woodlands, chenopod shrublands, and grasslands (Paijmans 1981; Bowen & Simpson 2009b).

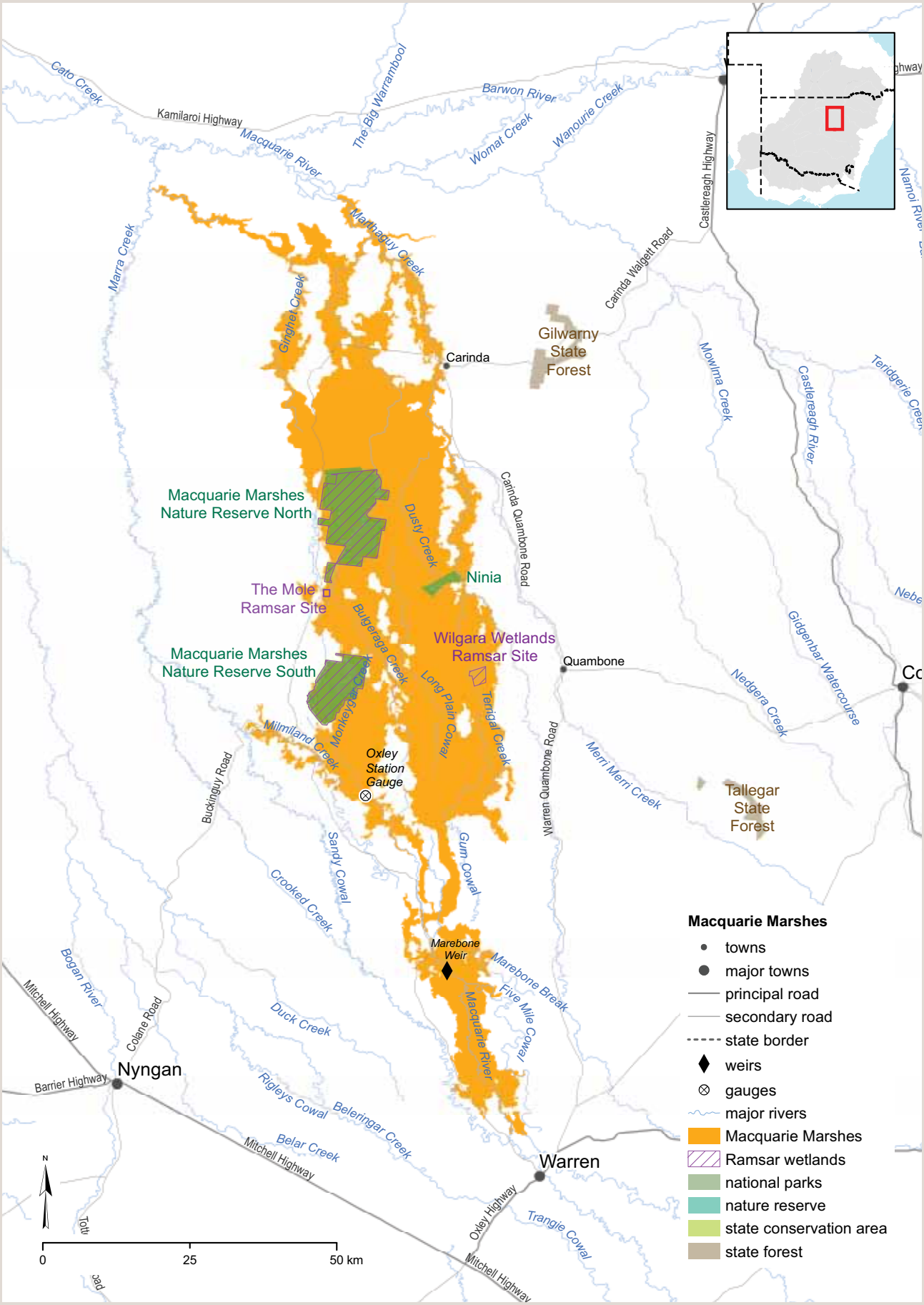

Figure B10.1 Location and extent of hydrologic indicator site: Macquarie Marshes

Waterbird habitat typically include sites with vegetation for shelter and nest sites, the water needed to flood breeding sites and feeding areas, and the availability of preferred food items. The Macquarie Marshes have long been regarded as an important refuge for waterbirds during dry times, as well as supporting some of Australia's largest recorded waterbird breeding colonies (Macquarie Marshes Investigation Committee 1951; Marchant & Higgins 1990; Kingsford & Johnson 1998; Kingsford & Auld 2005).

Seventy-six waterbird species have been recorded in the marshes, 42 of which have been recorded breeding. Species include some listed as being threatened both in New South Wales and nationally, as well as the only recorded pied heron (*Ardea picata*) breeding in New South Wales (NSW Department of Environment and Climate Change 2009c). Most breeding sites are located in semipermanent wetland vegetation and river red gum forest and woodland, requiring frequent and prolonged flooding (Kingsford & Auld 2005; NSW Department of Environment and Climate Change 2009c).

The Macquarie Marshes are one of the more important wetlands in Australia for breeding of colonial nesting waterbirds (Kingsford & Auld 2005). Sixteen species have been recorded breeding, with the eastern great egret (*A. modesta*), intermediate egret (*A. intermedia*), little egret (*Egretta garzetta*), rufous night heron (*Nycticorax caledonicus*), glossy ibis (*Plegadis falcinellus*), Australian white ibis (*Threskiornis molucca*), straw-necked ibis (*T. spinicollis*), little pied cormorant (*Phalacrocorax melanoleucos*) and little black cormorant (*P. sulcirostris*) occurring in the largest numbers (Kingsford & Johnson 1998; Kingsford & Auld 2005).

Table B10.6 lists species recorded in the Macquarie Marshes, and identifies their status under legislation and international agreements.

Values

The Macquarie Marshes hydrologic indicator site has been identified as a key environmental asset in the Murray–Darling Basin by meeting all five MDBA key environmental asset criteria (Table B10.1).

Hydrology

The Macquarie River rises on the western side of the Great Dividing Range, south-east of Bathurst, and flows about 500 km north-west and north before joining the Barwon–Darling River in northern New South Wales. The main tributaries enter the river upstream of Narromine and most are upstream of Burrendong Dam, the river's largest water storage. As the Macquarie flows onto the Darling riverine plain downstream of Narromine, it develops distributary streams and forms extensive floodplain wetlands (NSW Department of Water Resources 1991). These streams flow north and north-west to join the Bogan and Barwon–Darling Rivers. The main Macquarie River channel continues north, forming the Macquarie Marshes about 50 km north of Warren. The marshes extend for about 120 km to Carinda before the river reforms and flows to the Barwon–Darling River between Walgett and Brewarrina (NSW Department of Water Resources 1991).

The upper Macquarie catchment has winter-dominant rainfall of between 600 mm and 1,000 mm per year and evaporation of about 1,300 mm/y. The climate of the lower Macquarie is hot and semi-arid, with summer-dominant rainfall averaging about 400 mm/y and evaporation of about 2,000 mm/y. Most of the river flow comes from rainfall in the catchments upstream of Narromine.

Table B10.1 MDBA key environmental assets criteria: Macquarie Marsh

Criterion	Explanation
1. The asset is recognised in and/or is capable of supporting species listed in international agreements	The Macquarie Marshes are formally recognised in or are capable of supporting species listed in the Japan–Australia, China–Australia or Republic of Korea – Australia migratory bird agreements. The Macquarie Marshes Nature Reserve, Mole Marsh and the Wilgara Wetlands meet the five criteria for Ramsar listing. For a full list of species listed under Commonwealth legislation that have been recorded at Macquarie Marshes, see Table B10.6.
2. The asset is natural or near-natural, rare or unique	The Macquarie Marshes are one of the largest inland semipermanent wetlands in south-east Australia. They are an inland floodplain wetland in the semi-arid region of the Murray–Darling Basin, and rely on water from a higher rainfall upper catchment. The Macquarie Marshes asset is rare in terms of both its size and diversity of wetland types (Paijmans 1981; NSW National Parks and Wildlife Service 1993; NSW Department of Environment and Climate Change 2009c).
3. The asset provides vital habitat	The Macquarie Marshes are renowned for supporting large waterbird breeding events. The marshes are one of the few places in Australia that support large breeding colonies of straw-necked ibis, as well as some of the largest breeding colonies of intermediate egret, rufous night heron and royal spoonbill (*Platalea regia*) in southern Australia. Many other waterbirds, including cormorants, herons and ducks, also breed there. The marshes are one of the few sites in New South Wales where magpie geese (*Anseranas semipalmata*) breed (Kingsford & Auld 2005; NSW Department of Environment and Climate Change 2006, 2009c). These remaining wetlands have become a regionally important refuge for wildlife, and an important drought refuge.
4. The asset supports Commonwealth-, state- or territory-listed threatened species and/or ecological communities	The Macquarie Marshes meet this criterion because they support species listed as threatened under state legislation. The Ramsar site supports permanent populations of several state-listed threatened species. For a full list of species that have been recorded, see Table B10.6.
5. The asset supports, or is capable of supporting, significant biodiversity	The Macquarie Marshes support significant biodiversity (NSW National Parks and Wildlife Service 1993; NSW Department of Environment and Climate Change 2009c). They regularly support more than 20,000 waterbirds and over 500,000 in large floods, including substantial numbers of cormorants, herons, ibises, spoonbills, swans, geese, ducks, raptors and migratory waders (Department of the Environment, Water, Heritage and the Arts 2010a).

Annual flows in the Macquarie River are extremely variable. Recorded flows at Dubbo range from 2% to 900% of average flow since records were first kept in 1898 (NSW Department of Water Resources 1991). Studies using measured and modelled flow data have found significant changes to the flow regime of the river, including:

- reduced moderate-to-high flows in the Macquarie River and end-of-system flows (CSIRO 2008b)
- an increase in the average period between large flows (114%, from 2.2 years to 4.7 years) and a reduction in the average volume of these events, from 328 GL to 278 GL per event (CSIRO 2008b)
- a reduction in the number of small flows greater than 1 GL/d likely to cause flooding passing the Oxley gauge since construction of Burrendong Dam (Jenkins & Wolfenden 2006, in NSW Department of Environment and Climate Change 2009c)
- permanent low flows in previously intermittent streams (Grimes 2001)
- a significant reduction in the frequency of floods in the marshes and the area inundated (Thomas et al., in prep. (b); NSW Department of Environment and Climate Change 2009c).

Forecasts for 2030 suggest that:

- the average period between important inundation events in the Macquarie Marshes will increase by 10%
- the number of flood events will be reduced by 5%
- the average annual flood volume will be reduced by 16%
- the scale of waterbird breeding will be reduced — an increase of 24% in the average period between events and an average annual flood volume reduction of 38% (CSIRO 2008b).

Environmental objectives and targets

Environmental objectives for the Macquarie Marshes have been determined using the key environmental asset criteria. Targets to achieve these objectives have been specified for flood-dependent vegetation considered essential to support wetland processes and to provide crucial habitat for identified flora and fauna species. The targets are directed to maintain three groups of flood-dependent vegetation communities as well as waterbird breeding. The vegetation communities are:

- semipermanent or amphibious wetland communities that depend on frequent flooding to maintain their structural integrity and community condition. They include common reed, water couch grassland, cumbungi (*Typha domingensis*) and mixed marsh
- river red gum forest and woodland
- lignum and river cooba shrubland, and coolibah and black box woodland.

Each of these communities is found within a range of flood frequencies and the boundaries of their distribution overlap in some areas. For example, water couch, common reed and cumbungi are widespread within the wetter parts of river red gum communities. Lignum is found throughout the marshes, from open water lagoons where water can stand for many months to associations with coolibah.

Justification of targets

Understanding the current ecological extent and condition of the Macquarie Marshes' major vegetation communities has been integral in setting vegetation targets.

Extensive grasslands of common reed and water couch and stands of cumbungi require regular, frequent and prolonged flooding. Water couch generally requires flooding in spring and summer at least once per year. Common reed needs flooding every one to two years (Bennett & Green 1993; Roberts & Marston 2000; NSW Department of Environment and Climate Change 2009c). These species provide critical habitat for waterbirds and other wetland animals in the marshes (NSW Department of Environment and Climate Change 2009c). Much of the 19,000 ha that supported these communities in 1991 no longer contains flood-dependent vegetation. More than half has been replaced by chenopod shrubland (Wilson 1992; Bowen & Simpson 2009b).

River red gum forests and woodlands are also a distinctive feature of the marshes. They are among the most diverse of the wetland communities in the marshes, and many have an understorey of common reed, water couch, cumbungi, rushes, sedges and aquatic species (Bowen & Simpson 2009; NSW Department of Environment and Climate Change 2009c). River red gum provides critical habitat for waterbirds and other wetland animals, and is the tree species most used for nesting by colonial nesting waterbirds in the marshes. River red gums also provide important habitat for hollow-nesting waterbirds and many woodland species (Oliver & Parker 2006; NSW Department of Environment and Climate Change 2009b; Blackwood et al. 2010).

Table B10.2 Environmental objectives and targets: Macquarie Marshes

Objectives	Justification of target	Target
1. To protect and restore ecosystems that support migratory birds listed under international agreements (from Criterion 1)	To breed successfully, colonial nesting waterbirds require, at a minimum, flooding of sufficient volume and duration for colony sites and feeding areas to be inundated for at least four to five months between August and March (NSW Department of Environment and Climate Change 2009c). These flows are also critical for maintaining wetland vegetation and to complete aquatic invertebrate life cycles (Jenkins & Wolfenden 2006). Objective 1 will be fulfilled if conditions are provided that support migratory birds listed under international agreements.	Provide flow conditions to support successful breeding of colonial nesting waterbirds.
2. Protect and conserve natural or near-natural, rare or unique water-dependent ecosystems (in their current state) (from Criterion 2) 3. protect and restore water-dependent ecosystems that provide vital habitat (from Criterion 3) 4.To protect and restore water-dependent ecosystems that support Commonwealth-, state- or territory-listed threatened species and/or communities (from Criterion 4) 5.To protect and restore water-dependent ecosystems that support, or are capable of supporting, significant biodiversity (from Criterion 5)	Wetland vegetation is the critical component that provides both diversity and waterbird habitat. It is highly likely that insufficient flow size, frequency, duration and timing will cause a decline in the health of wetland vegetation, waterbird habitat, aquatic ecology and waterbird breeding sites at the Macquarie Marshes Nature Reserve Ramsar site. Threats associated with water availability and water management are applicable to both this Ramsar site and the entire Macquarie Marshes (NSW Department of Environment and Climate Change 2009d). Objectives 2 to 4 will be fulfilled if the dominant vegetation communities are retained in a healthy condition. Bowen and Simpson (2009b) outline changes in extent and condition of the vegetation communities of the Macquarie Marshes in the period 1991–2008. This information has been used as a basis for the vegetation targets. Given the extent of changes to the hydrology and ecology of the Macquarie Marshes, maintaining the extent of flood-dependent vegetation communities at 1991 levels is considered to be unachievable through the Basin Plan.	Maintain 100% (about 2,400 ha) of water couch, common reed, cumbungi and mixed marsh communities recorded as in good condition in 2008. Restore 100% (about 3,850 ha) of water couch, common reed, and cumbungi and mixed marsh communities, recorded as in intermediate condition in 2008, to good condition. Restore 65% (about 8,000 ha) of water couch, common reed, and cumbungi and mixed marsh communities, recorded as in poor condition in 2008, to good condition. Maintain 100% (about 1,950 ha) of river red gum forest and woodland recorded as in good condition in 2008. Restore 100% (about 21,000 ha) of river red gum forest and woodland, recorded as in intermediate and intermediate–poor condition in 2008, to good condition. Maintain in good condition 100% (about 3,000 ha) of lignum and river cooba shrubland recorded in the marshes in 2008. Maintain in good condition 100% (about 24,500 ha) of coolibah and black box woodland recorded in the marshes in 2008.

About 39,000 ha of river red gum forest and woodland were mapped in the marshes in 1991 (Wilson 1992). The condition of large areas of forest and woodland has changed since 1991 because of changes in flow regime. Most areas now have an understorey dominated by chenopod shrubs (Bowen & Simpson 2009b; NSW Department of Environment and Climate Change 2009c). Many areas show a significant decline in canopy condition, with more than half the area mapped in 1991 now having more than 40% dead canopy (Bowen & Simpson 2009b).

Lignum and river cooba shrubland and coolibah and black box woodland are important flood-dependent species in the marshes, providing critical habitat for many birds and animals (NSW Department of Environment and Climate Change 2009c). Lignum occurs in areas flooded at frequencies of once in 2 to 10 years for durations of 3 to 12 months (Roberts & Marston 2000). Found throughout the marshes as an understorey plant, lignum provides critical breeding habitat for waterbirds, especially ibis. The optimal flood times for growth and recruitment are spring and summer. Lignum flowers and produces seeds rapidly in response to flooding. Seeds disperse on floodwaters and germinate under moist soil conditions (Young et al. 2003; Chong & Walker 2005). River cooba provides valuable nesting habitat, especially for colonial nesting species (Kingsford & Johnson 1998; Kingsford & Auld 2005).

Coolibah is found in some of the wetter parts of the marshes in association with river red gum, although it is more common in less frequently flooded areas, where it forms coolibah and coolibah – black box woodlands (Bowen & Simpson 2009b; NSW Department of Environment and Climate Change 2009c). Coolibah requires flooding for regeneration. Black box is found in the marshes on less frequently flooded parts of the floodplain where it forms black box and coolibah – black box woodlands. Coolibah and black box provide important habitat for both waterbirds and woodland birds. Coolibah – black box woodland is listed as an endangered ecological community under the *Threatened Species Conservation Act 1995* (NSW) (NSW Department of Environment and Climate Change 2009c, 2009b).

These targets are not aimed at restoring all the flood-dependent vegetation communities recorded in the marshes in 1991 (see Table B10.4). Many areas of the marshes no longer support wetland vegetation. Erosion and channel formation mean it will not be possible to return flows to many areas without substantial structural works. The nature and extent of these works is beyond the scope of the Basin Plan. For this reason, complete restoration of several flood-dependent communities to their 1991 extent has been assessed as unachievable.

Environmental water requirements

Flows required to achieve the specified targets have been determined based on MDBA assessment of a range of reliable and rationalised scientific information.

Vegetation communities

Roberts and Marston (2000) provide the most up-to-date ecological information on wetland species in the Murray–Darling Basin. Based on this work, water requirements for the flood-dependent vegetation communities identified by Bowen and Simpson (2009) have been detailed (Table B10.4).

The NSW Department of Environment, Climate Change and Water (2010b) analysed historical inundation patterns of the Macquarie Marshes. These inundation extents were then matched to river flow data at Marebone Weir. As a result of this analysis, the range of key flow volumes determined were 100 GL, 250 GL, 400 GL, 700 GL and 1,300 GL.

Using modelled flow data for the period 1895 to 2009, MDBA determined the without-development frequencies of the five flow volumes. This analysis showed that the 1,300 GL volume would have occurred in 3% of years. Published estimates of water requirements (Roberts & Marston 2000) suggest that flows of this frequency are unlikely to be critical to ensure the resilience of flood-dependent vegetation.

Comparison of inundation extents with vegetation mapping undertaken by Bowen and Simpson (2009b) in 2008 enabled the proportions of vegetation communities inundated by the specified flow volumes to be determined. Table B10.3 was been adapted from New South Wales Department of Environment, Climate Change and Water (2010b) and shows the amounts of key flood-dependent vegetation likely to be inundated by the selected flow volumes.

Coolibah and black box woodlands are generally found in the marshes on the less frequently flooded parts of the floodplain. As a result, the NSW Department of Environment, Climate Change and Water (2010b) included these with a range of dryland floodplain communities in a functional group it called 'floodplain vegetation'. For the four selected flow volumes, the inundation extents for floodplain vegetation varied between 1,400 ha and 75,000 ha.

Given that Bowen and Simpson (2009b) mapped 8,412 ha of coolibah woodland and 16,114 ha of black box woodland, MDBA has assumed that most of these communities will be inundated by the 700 GL flood volume.

Analysis of modelled without-development flows between 1895 and 2009 show that the flow volumes selected from those determined by the NSW Department of Environment, Climate Change and Water (2010b) would provide sufficient inundation to ensure the resilience of most flood-dependent vegetation in the Macquarie Marshes. For this reason, these flows form the basis for the environmental water requirements for the Macquarie Marshes.

Table B10.3 Expected areas of inundation for selected flow volumes: Macquarie Marshes

Flow volume (GL)	Area of floodplain inundated (ha)	Area of common reed, mixed marsh, water couch and cumbungi communities inundated (ha)	Area of river cooba and lignum communities inundated (ha)	Area of red gum communities inundated (ha)
100	19,000	7,744	477	9,705
250	50,000	13,395	1,728	23,437
400	80,500	16,325	2,353	29,674
700	145,160	19,884	2,890	35,526

Table B10.4 Vegetation targets linked to the extent and condition of vegetation communities: Macquarie Marshes

Targets	Vegetation communities	Water requirements	Extent of vegetation communities in the Macquarie Marshes 1991 and 2008 (ha)		Condition of vegetation communities in 2008 (ha)			
			Area in 1991	Area in 2008	Good	Intermediate	Intermediate/ poor	Poor
Maintain 100% (about 2,400 ha) of water couch, common reed, cumbungi and mixed marsh communities recorded in good condition in 2008.	Water couch Common reed Cumbungi Mixed marsh Open water lagoons	Optimal flood frequency near annual. Water couch can recover from 1–3 year dry period but cannot tolerate repeated dry spells. Common reed tolerates a range of flood frequencies from permanent inundation to infrequent flooding. Cumbungi rhizomes can survive without flooding for up to 2 years if established.	18,837	6,213	2,378	3,835		12,262*
Restore 100% (about 3,850 ha) of water couch, common reed, cumbungi and mixed marsh communities, recorded in intermediate condition in 2008, to good condition.								
Restore 65% (about 8,000 ha) of water couch, common reed, cumbungi and mixed marsh communities, recorded in poor condition in 2008, to good condition.								
Maintain 100% (about 1,950 ha) of river red gum forest and woodland recorded in good condition in 2008.	River red gum forest and woodland	Average flood frequency once every 1–2 years. Average duration 4–7 months (maximum 24 months).	39,201	38,428	1,932	12,994	7,976	15,526
Restore 100% (about 21,000 ha) of river red gum forest and woodland, recorded in intermediate and intermediate–poor condition in 2008, to good condition.								

... continued

Table B10.4 Vegetation targets linked to the extent and condition of vegetation communities: Macquarie Marshes (continued)

Targets	Vegetation communities	Water requirements	Extent of vegetation communities in the Macquarie Marshes 1991 and 2008 (ha)		Condition of vegetation communities in 2008 (ha)			
			Area in 1991	Area in 2008	Good	Intermediate	Intermediate/ poor	Poor
Maintain in good condition 100% (about 3,000 ha) of lignum and river cooba shrubland recorded in the marshes in 2008.	Lignum River cooba River cooba/ lignum River cooba/ river red gum Lignum/coolibah	Lignum — average flood frequency of once every 2–8 years. Average duration 3–12 months. Flood timing probably spring–summer.	6,526	2,978				
Maintain in good condition 100% (about 24,500 ha) of coolibah and black box woodland recorded in the marshes in 2008.	Coolibah (including coolibah/black box (endangered ecological community) Black box	Coolibah — long-term average flood frequency of 1 in 10 to 20 years, but some areas in the marshes are flooded more frequently. Drought or flood duration tolerated by coolibah is unknown. Black box — long-term average flood frequency of once every 3–5 years, but can tolerate 7–10 year cycles, average duration 2–4 months.	25,350	24,526				
Provide flow conditions to support successful breeding of colonial nesting waterbirds.		The flow conditions required to meet the needs include: inundation between June and March, for a minimum of 4 months and preferably up to 6 months no more than 3 consecutive years without breeding of colonial nesting waterbirds.						

* Water couch, common reed, cumbungi, mixed marsh condition: intermediate — invaded by chenopod shrubland; poor — replaced by chenopod shrubland (based on Bowen & Simpson 2009b)

River red gum condition — good = <10% dead canopy; intermediate = 10–40% dead canopy; intermediate/poor = 40–80% dead canopy; poor = >80% dead canopy (based on wwater requirements, Roberts & Marston 2000)

Extent and condition of vegetation based on Bowen and Simpson 2009b

Water requirements of aquatic invertebrates based on Jenkins and Wolfenden 2006

Waterbirds

The Macquarie Marshes are renowned for supporting some of Australia's largest waterbird breeding events. The Macquarie Marshes Water Management Plan 1996 (NSW National Parks and Wildlife Service & NSW Department of Land and Water Conservation 1996), work undertaken by Kingsford and Auld (2005) and the draft report on the ecological character of the Macquarie Marshes Nature Reserve Ramsar site (NSW Department of Environment and Climate Change 2009d) link flood size and duration to the size of breeding events for waterbirds.

The Macquarie Marshes Water Management Plan 1996 (NSW National Parks and Wildlife Service & Department of Land and Water Conservation 1996) indicates that a minimum volume of 250 GL over a seven-month period (measured at Marebone Weir) is required to ensure the success of colonially breeding waterbirds. At flows below this threshold, the area and duration of inundation might not be sufficient to support a successful breeding event. As the volume of water increases above this threshold, there is

a sharp increase in the number of birds breeding. For instance, in 1990 when the water volume over a seven-month period was 485 GL, there were 17,200 pairs of intermediate egrets and 65,000 pairs of ibis breeding in the Marshes (NSW National Parks and Wildlife Service & NSW Department of Land and Water Conservation 1996).

Annual flows, measured at the Oxley gauge on the Macquarie River, are significantly related to total colony size (number of nests) of waterbird species, including intermediate egret, rufous night heron, glossy ibis, straw-necked ibis, Australian white ibis and royal spoonbill. Analysis of breeding data between 1986 and 2001 indicates significant positive relationships between numbers of colonies established and flow and flooded area. It also indicates that the best predictor of nest numbers for all species is the amount of water flowing past Oxley in the three months before breeding, although the strength of this relationship varies among species (Kingsford & Thomas 1995; Kingsford & Johnson 1998; Kingsford & Auld 2005). Between 1978 and 2000, colonial nesting waterbird breeding events commenced in the marshes once inflow volumes exceeded 200 GL (based on flow measured at the Oxley gauge), and the size of breeding events increased with larger inflow volumes (Kingsford & Thomas 1995; Kingsford & Johnson 1998; Kingsford & Auld 2005).

The draft report on the ecological character description of the Macquarie Marshes Nature Reserve Ramsar site (NSW Department of Environment and Climate Change 2009d) states that the minimum flow requirement for successful colonial nesting waterbird breeding throughout the entire marshes is flooding of sufficient volume and duration to inundate colony sites and feeding areas for at least five consecutive months between August and March. According to the report, this requires between 180 GL and 300 GL, depending on preceding conditions.

Since 2000, only two breeding events of colonial nesting waterbirds have occurred in the marshes, both on relatively low flows. In 2008 and 2010, egrets — mostly intermediate egrets — nested successfully in river red gum forest (R Jones, pers. comm.).

The above information indicates that an inflow volume of around 250 GL to 300 GL (measured at Marebone Weir) forms a basis for waterbird breeding. As outlined in Kingsford and Thomas (1995), Kingsford and Johnson (1998), and Kingsford and Auld (2005), the size of breeding events increases with larger inflow volumes. Given this, MDBA has determined that three inflow volumes — 250 GL, 400 GL and 700 GL — will be required to provide a range of conditions to support successful breeding of colonial nesting waterbirds based on watering the targeted vegetation communities (see Table B10.5).

Summary

The identified flow volume categories are linked to low and high uncertainty frequencies of inundation. Table B10.5 and Figure B10.2 show how the environmental water requirements relate to without-development and current arrangements.

These targets provide indications of flow volumes and frequencies needed to meet targets; they are not intended to constrain management of the site to achieve objectives. It is understood that boundaries of vegetation communities overlap and that more than one target might be met by a single flow event. Achieving the stated targets and objectives will require a series of events and an adaptive approach to management, both in the medium and the long term.

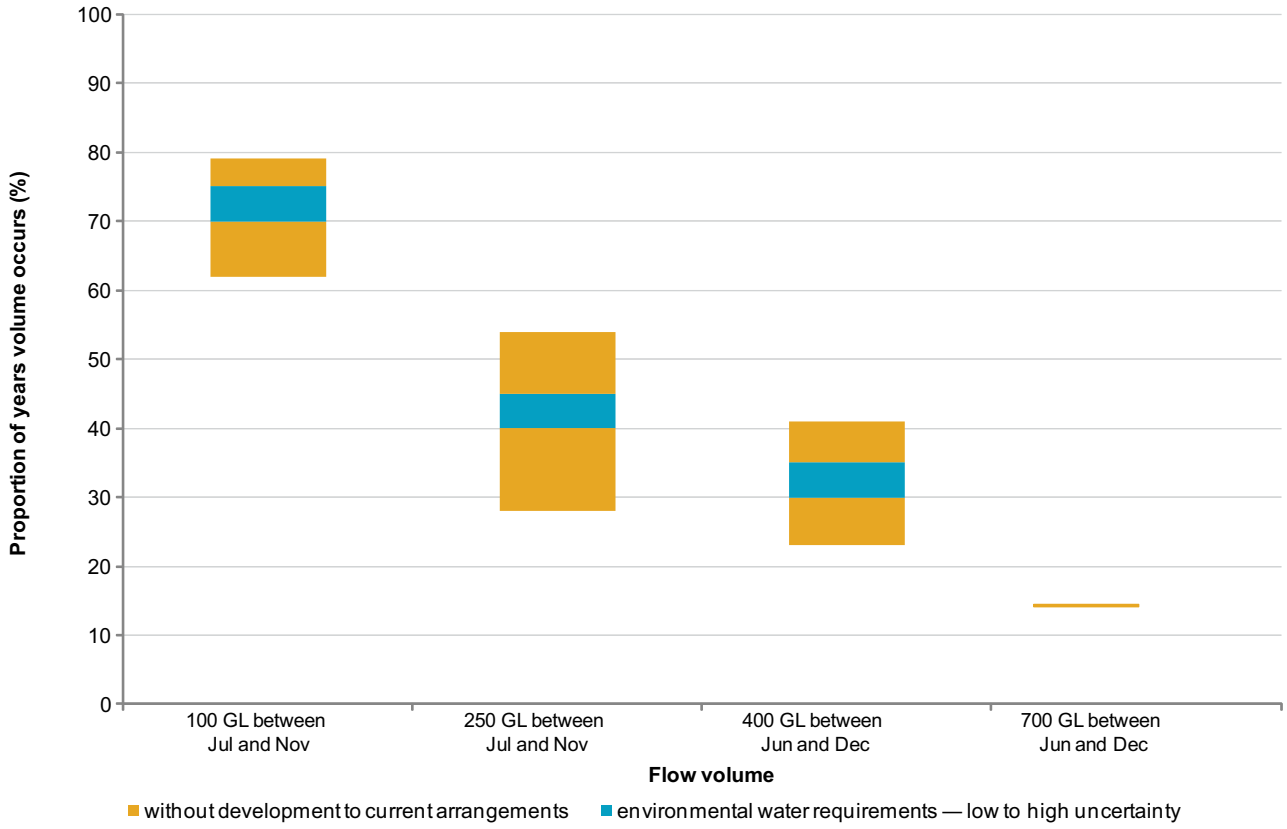

Figure B10.2 Recommended environmental water requirements and associated proportions of occurrence under modelled flows without development and for current arrangements, 1895–2009: Macquarie Marshes

Risks

When determining water requirements for the Macquarie Marshes, the following assumptions were made:

- the environmental values of the Macquarie Marshes will be maintained through achieving the environmental targets
- the indicator vegetation communities identified in the environmental targets are representative of a healthy Macquarie Marshes ecosystem
  - the water requirements determined for the Macquarie Marshes do not include any other consumptive take and use of water (e.g. irrigation, stock and domestic).

Factors that pose risks to achieving the identified environmental objectives and targets include:

- land management activities that may affect the health of the Macquarie Marshes wetland ecosystem (including vegetation clearing, poor grazing practices and fire)
- pests such as feral pigs and lippia (*Phyla canescens*)
- climate variability and climate change
- effects of existing water management infrastructure, including banks, weirs, regulators and diversion channels in the marshes from Marebone Weir to the North Marsh (Hogendyk 2008; Steinfeld & Kingsford 2008)
- vegetation communities have insufficient resilience to enable restoration to good condition
- release of cold water low in oxygen from the bottom of Burrendong Dam has a significant effect on the aquatic ecological community for some

distance downstream from Burrendong Dam (NSW Department of Environment and Climate Change 2009c)

- water quality and salinity
- the South Marsh Nature Reserve has undergone significant geomorphic change (Ralph 2008), and so flow provision alone will be unlikely to achieve Ramsar Convention objectives for the area; determining appropriate management actions for the nature reserve is outside the scope of the Basin Plan, but determining environmental water requirements for the broader Macquarie Marshes has taken this issue into account.

Table B10.5 Environmental water requirements: Macquarie Marshes

Target	Event		Proportion of years event required to achieve target (%)		Proportion of years event occurred under modelled without-development conditions (%)	Proportion of years event occurred under modelled current-arrangements (%)
	Flow volume required (GL)	Timing[a]	Low uncertainty	High uncertainty		
Maintain in good condition 100% (about 2,400 ha) of water couch, common reed, cumbungi and mixed marsh communities recorded as in good condition in 2008.	100	Minimum 5 successive months between June and April.	75	70	79	62
Restore to good condition 100% (about 3,850 ha) of water couch, common reed, cumbungi and mixed marsh communities recorded as in intermediate condition in 2008. Restore 65% (about 8,000 ha of water couch, common reed, cumbungi and mixed marsh communities, recorded in poor condition in 2008, to good condition. Maintain in good condition 100% (about 1,950 ha) of river red gum communities recorded as in good condition in 2008. Provide conditions conducive to successful breeding of colonial nesting waterbirds.	250	Minimum 5 successive months between June and April.	45	40	54	28
Restore to good condition 100% (about 21,000 ha) of river red gum communities recorded as in intermediate and intermediate/poor condition in 2008. Maintain in good condition 100% (about 3,000 ha) of lignum and river cooba shrubland recorded in the marshes in 2008. Provide conditions conducive to successful breeding of colonial nesting waterbirds.	400	Minimum 7 successive months between June and April	35	30	41	23
Maintain in good condition 100% (about 24,500 ha) of coolibah and black box woodland recorded in the marshes in 2008. Provide conditions conducive to successful breeding of colonial nesting waterbirds.	700	Minimum 8 successive months between June and May	15	N/A	15	15

a Timing, preferred and minimum frequencies reported above have been drawn from Roberts and Marston (2000) and the NSW Department of Environment and Climate Change (2009c).

Table B10.6 Species relevant to criteria 1 and 4: Macquarie Marshes

Species	Recognised in international agreement(s)[1]	*Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Fisheries Management Act 2004* (NSW)	*Threatened Species Conservation Act 1995* (NSW)
Amphians and reptiles				
Sloane's froglet (*Crinia sloanei*)5				V
Birds				
Australasian bittern (*Botaurus poiciloptilus*)[2]				V
Australian bustard (*Ardeotis australis*)[2]				E
Barking owl (*Ninox connivens*)[2]				V
Bar-tailed godwit (*Limosa lapponica*)[2]	✓			
Black-breasted buzzard (*Hamirostra melanosternon*)[2]				V
Black-chinned honeyeater (eastern subspecies) (*Melithreptus gularis gularis*)[2]				V
Black-necked stork (*Ephippiorhynchus asiaticus*)[2]				E
Black-tailed godwit *(Limosa limosa*)[2, 3]				V
Blue-billed duck (*Oxyura australis*)[2]				V
Brolga (*Grus rubicundus*)				V
Brown treecreeper (*Climacteris picumnus*)[2]				V
Bush stone-curlew (*Burhinus grallarius*)[2]				E
Caspian tern (*Hydroprogne caspia*)[2, 3]	✓			
Cattle egret (*Ardea ibis*)[2, 3]	✓			
Common greenshank (*Tringa nebularia*)[2]	✓			
Common sandpiper (*Actitis hyoleucos*)[2]	✓			
Cotton pygmy goose (*Nettapus coromandelianus*)[2]				E
Curlew sandpiper (*Calidris ferruginea*)[2]	✓			
Diamond firetail (*Stagonopleura guttata*)[2]				V
Eastern great egret (*Ardea modesta*)[2, 3]	✓			
Freckled duck (*Stictonetta naevosa*)[2]				V
Glossy black-cockatoo (*Calyptorhynchus lathami*)[2]				V
Glossy ibis (*Plegadis falcinellus*)[2, 3]	✓			
Grey-crowned babbler (*Pomatostomus temporalis*)[2]				V
Hooded robin (*Melanodryas cucullata*)[2]				V
Latham's snipe (*Gallinago hardwickii*)[2, 3]	✓			
Magpie goose (*Anseranas semipalmata*)[2]				V
Major Mitchell's cockatoo (pink cockatoo) (*Lophochroa leadbeateri*)[2]				V
Marsh sandpiper (*Tringa stagnatilis*)[2]	✓			
Masked owl (*Tyto novaehollandiae*)[5]				V
Osprey (*Pandion haliaetus*)[2]				V
Painted honeyeater (*Grantiella picta*)[2]				V
Painted snipe (*Rostratula benghalensis*)		V		E
Red-backed button-quail (*Turnix maculosa*)[2]		V		V
Red-necked stint (*Calidris ruficollis*)[2]	✓			
Red-tailed black-cockatoo (*Calyptorhynchus banksii*)[2]				V
Sharp-tailed sandpiper (*Calidris acuminata*)[2, 3]	✓			
Square-tailed kite (*Lophoictinia isura*)[2]				V
Superb parrot (*Polytelis swainsonii*)[2]		V		V
Turquoise parrot (*Neophema pulchella*)[2]				V

… continued

Table B10.6 Species relevant to criteria 1 and 4: Macquarie Marshes (continued)

Species	Recognised in international agreement(s)[1]	*Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Fisheries Management Act 2004* (NSW)	*Threatened Species Conservation Act 1995* (NSW)
White-bellied sea-eagle (*Haliaeetus luecogaster*)[3]	✓			
Wood sandpiper (*Tringa glareola*)[2]	✓			
Fish				
Murray cod (*Maccullochella peelii peelii*)[2]		V		
Silver perch (*Bidyanus bidyanus*)[2]			V	
Mammals				
Little pied bat (*Chalinolobus picatus*)[2]				V
Squirrel glider (*Petaurus norfolcensis*)[2]				V
Yellow-bellied sheathtail bat (*Saccolaimus flaviventris*)[2]				V
Koala (*Phascolarctos cinereus*)[5]				V
Eastern freetail bat (*Mormopterus norfolkensis*)[2]				V
Stripe-faced dunnart (*Sminthopsis macroura*)[2]				V
Plants				
Aromatic pepper-cress (*Lepidium hyssopifolia*)[2]		E		
Rock fern (*Cheilanthes sieberi subsp. pseudovellea*)[5]				E
Greenhood orchid (*Pterostylis cobarensis*)[5]				V
Pine donkey orchid (*Diuris tricolor*)[5]				V
Red Darling pea (*Swainsona plagiotropis*)[5]				V
Spiny mint-bush (*Prostanthera spinosa*)[5]				V
Communities				
Aquatic ecological community of the Macquarie Marshes4			E	
Coolibah – black box woodland of the northern Riverine Plains in the Darling Riverine Plains and Brigalow Belt South bioregions[4]				E
Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray–Darling Depression, Riverina and NSW South Western Slopes bioregions[4]				E

E = endangered V = vulnerable

1 Japan–Australia Migratory Bird Agreement, China–Australia Migratory Bird Agreement, or Republic of Korea – Australia Migratory Bird Agreement

2 NSW Department of Environment, Climate Change and Water (2009d)

3 NSW Department of Environment and Conservation (2006b)

4 NSW Department of Environment, Climate Change and Water (2009a)

5 NSW Department of Environment, Climate Change and Water (2009e)