



Macquarie Marshes Adaptive Environmental Management Plan

Synthesis of information projects and actions



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Synthesis of information projects and actions



Australian Government
Water for the Future

Cover photographs (anticlockwise from main image):

Aerial of Macquarie Marshes (Grenville Turner); River red gum (W. Johnson); reed warbler (Grenville Turner); wavy marshwort (W. Johnson); green tree frog (W. Johnson).

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Summary

The Macquarie Marshes are a large, diverse wetland system on the lower Macquarie River in north-western New South Wales. The marshes have supported some of the largest waterbird breeding events in Australia and provide essential habitat for hundreds of species of animals and plants. They are an important refuge for wildlife during dry times. The values of the marshes are recognised at all levels of Australian government. The Macquarie catchment comprises some of the more agriculturally diverse rural landscapes of central NSW, and includes a wide range of intensively farmed and broad-acre crops. It also includes a relatively large range of urban centres as well as many smaller, traditional rural service centres.

In the Macquarie Marshes Adaptive Environmental Management Plan (MM AEMP or 'the plan') and its supporting documents, knowledge about the marshes has been gathered and analysed. The intention of the plan is to inform land and water management, and to guide strategies, projects and tasks for restoring and maintaining critical ecological functions and habitats in the Macquarie Marshes.

The marshes are described in terms of their assets and values, and on the basis of water supply, management and geomorphological boundaries. The water needed to maintain the values of semi-permanent wetlands has been identified. The extent of inundation has been calculated using water and vegetation signatures for October each year from 1979 to 2006. These maps have been used to produce an index of the frequency of inundation of different parts of the marshes. Since 1979, the area of the marshes that receives the flood frequency and duration necessary for maintaining the values of identified semi-permanent wetland assets has declined. This decline has accelerated during the very dry period since 2001 until the present time.

Much of the 72,000 hectares of semi-permanent wetland mapped in the marshes in the early 1990s no longer supports wetland vegetation. Less than half of this area is now in fair or better condition, and many areas are still in decline. According to CSIRO, it is likely that future rainfall will be less than that experienced during the 1970s, 80s and 90s. Four scenarios of water availability and area of wetland that can be sustained are outlined. While considerable uncertainty exists under each scenario – particularly in relation to the volume of unregulated flow that may benefit the marshes – the scenarios provide context for water planning, environmental water recovery and environmental water management.

Prioritising the delivery of environmental water will involve an annual planning process; the Macquarie–Cudgegong Environmental Flows Reference Group will be integral to this process. This plan includes information that will inform planning and management actions in the context of the actual climatic circumstances and environmental condition of the ecological assets at that time. The primary objective for the Macquarie Marshes for the duration of this plan is to support the ecological functions and processes necessary to sustain the diversity of type, and extent of, the ecological assets described within the plan. As further progress is made in recovering water for the environment, and depending on the climatic conditions experienced, enhanced ecological function and condition should begin to restore resilience to the marshes ecosystem. Objectives and priorities for restoring former wetlands areas that no longer support wetland values may then be possible.

Acronyms and abbreviations

| | |
|---------|---|
| AEMP | adaptive environmental management plan |
| AWD | available water determination |
| BMP | best management practice |
| CAP | catchment action plan |
| CHD | Cultural Heritage Division (of DECCW) |
| CW CMA | Central West Catchment Management Authority |
| DAA | Department of Aboriginal Affairs |
| DECC | Department of Environment and Climate Change |
| DECCW | Department of Environment, Climate Change and Water |
| DEWHA | Department of the Environment, Water, Heritage and the Arts |
| DLWC | Department of Land and Water Conservation |
| DPI | Department of Primary Industries |
| DWE | Department of Water and Energy |
| DWR | Department of Water Resources |
| EPRG | Environmental Protection and Regulation Group |
| I&I NSW | Industry and Investment NSW |
| LHPA | Livestock Health and Pest Authorities (formerly Rural Lands Protection Board) |
| LGA | local government area |
| LPMA | Land and Property Management Authority |
| MER | monitoring, evaluation and reporting |
| MM AEMP | Macquarie Marshes Adaptive Environmental Management Plan |
| MMNR | Macquarie Marshes Nature Reserve |
| NAP | national action plan |
| NMSF | national metering standard framework |
| NHT | Natural Heritage Trust |
| NOW | NSW Office of Water |
| NPWS | National Parks and Wildlife Service |
| NRC | Natural Resources Commission |
| NWQMS | National Water Quality Management Strategy |
| PWG | Parks and Wildlife Group (of DECCW) |
| RERP | Rivers Environmental Restoration Program |
| SLATS | Statewide Land and Tree Survey |
| UNE | University of New England |
| UNSW | University of New South Wales |
| WRC | Water Resources Commission |
| WRP | wetland recovery program |
| WSP | water sharing plan |

1 Introduction

1.1 The purpose of the Macquarie Marshes Adaptive Environmental Management Plan

Compelling evidence exists that the resilience of the Macquarie Marshes – the capacity of its ecological and social systems to adapt to and shape change – is declining. In some parts it has already been lost. If this trend is not reversed, the marshes will almost certainly cease to exist as a large, diverse and complex wetland system. The challenges are both ecological and social. According to the information gathered and analysed for this plan, much of the knowledge needed to restore and maintain critical ecological functions and habitats of the marshes exists. There is a reasonable understanding of the ecological aspects of these problems, and their solutions, but understanding of the social aspects is not as strong. The over-arching challenge is to apply this knowledge to the complex and closely linked ecological and social systems of the marshes to protect this important wetland.

The plan describes the marshes and the conditions under which management decisions will be made. It aims to guide actions – strategies, projects and tasks – for restoring and maintaining critical ecological functions and habitats in the Macquarie Marshes. People are an integral part of the system that includes the Macquarie Marshes and the Macquarie River – the future of communities in the Macquarie Valley is tied to the health of the river and the marshes.

The Macquarie Marshes Adaptive Environmental Management Plan (MM AEMP or ‘the plan’) is *not* a guide to returning the marshes to some past and inevitably disputed condition *or* to managing them to maintain a fixed state. It is a guide to restoring ecological structure and function in agreed priority areas. In the broadest sense, the plan is a guide to restoring resilience. Before resilience can be restored, the trajectory of decline must be halted and the condition of the wetlands stabilised.

1.2 The context for the plan

A number of policies and Acts exist at the local, state, national and international levels which support and complement the AEMP. Internationally the Ramsar Convention provides an outline for the conservation and wise use of wetlands and their resources. The Convention on Wetlands of International Importance, generally known as the Ramsar Convention, refers to an intergovernmental treaty made during a wetlands convention held in Ramsar, Iran, in 1971. About 19,000 hectares of private and public land are collectively listed as the Macquarie Marshes Ramsar site and Australia is responsible for maintaining the ecological character of this site. Under the Ramsar Convention, Australia is also obliged to develop national water and land use policy to achieve wetland conservation. Nationally, the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides protection for matters of national environmental significance, including the ecological character of declared Ramsar wetlands. The EPBC Act also establishes a framework for managing Ramsar wetlands.

The Wetlands Policy of the Commonwealth Government of Australia was developed in 1997. The goal of the policy is ‘to conserve, repair and manage wetlands wisely.’ The NSW Wetlands Management Policy 2010 also identifies the ‘active restoration’ of degraded wetlands and their habitats as a key principle. The AEMP is consistent with both these policies as it highlights the current degradation of the marshes but at the same time identifies the continuing values and provides an objective baseline for restoration activities.

At a basin scale, the Commonwealth *Water Act 2007* provides for the Murray–Darling Basin Authority to develop a Basin Plan which will establish sustainable diversion limits for each of the basin’s water sources, including the Macquarie River. The definition of assets and their watering needs within the AEMP will inform the Basin Plan. The Basin Plan will include an environmental watering plan to guide the management of environmental water.

The *Water Act 2007* also established the Commonwealth Environmental Water Holder to manage the Commonwealth’s environmental water to protect or restore the environmental assets of the Basin so as to give effect to international agreements.

At a statewide scale, the Water Sharing Plan for the Macquarie–Cudgegong Regulated Rivers Water Source (2003) is the legal document made under the *Water Management Act 2000*, which provides for water for the environment and directs how the available water for extraction in the Macquarie–Cudgegong is to be shared. Other state legislation assists in the protection of elements of the marshes including the *Native Vegetation Act 2003* which signalled an end to broadscale clearing. This Act has importance in conserving vegetation throughout the greater marshes area, including the semi-permanent wetland vegetation listed within the AEMP.

The *Threatened Species Conservation Act 1995* (TSC Act) aims to protect threatened species, populations and ecological communities and their habitats. A number of threatened species are mentioned within the AEMP, including coolibah–black box woodlands and myall woodlands, and their protection under the TSC Act is outlined. The *Fisheries Management Act 1994* (FMA) has relevance to aquatic species, aiming to conserve threatened species, populations and ecological communities of fish and marine vegetation. Silver perch and the aquatic ecological community of the natural drainage system of the lowland catchment of the Darling River are listed under the FMA and are included as assets in the AEMP.

At a regional level, the Central West Catchment Management Authority’s catchment action plan identifies 12 broad catchment targets for natural resource management. Actions within the AEMP complement these targets, and the Central West CMA will assist DECCW to review the implementation of the AEMP on an annual basis.

The NSW Wetland Recovery Program (NSW WRP) is funded by the NSW and Australian governments to deliver permanent benefits to the Macquarie Marshes and Gwydir Wetlands by restoring and protecting critical ecological functions and habitats. This AEMP for the Macquarie Marshes has been developed under this program and is complemented by the NSW RiverBank Program and the Rivers Environment Restoration Program (RERP) funded by the NSW and Australian governments. Collectively, NSW WRP, RiverBank and RERP include significant planning, water purchase, research, infrastructure development and land management projects.

The AEMP is not a statutory document, and will require support from the NSW and Australian governments, and local people, for its implementation. The Department of Environment, Climate Change and Water is the lead agency for implementing the plan within NSW. The Central West CMA’s catchment action plan will be responsive to much of the information and many of the recommendations in the plan.

1.3 The plan: expectations and structure

The NSW and Australian governments have the following 10 clear expectations for the plan:

1. Define the ecological assets and values to be protected and establish condition benchmarks.
2. Define desired ecological outcomes.
3. Identify water requirements (volume, timing, duration, frequency and security) for meeting ecological outcomes.
4. Identify activities to address the effects of land- and water-management practices on the wetlands.
5. Identify methods to enable stakeholders to be included in managing the river and wetlands.
6. Recognise Aboriginal cultural values in managing and planning for the Macquarie Marshes and Macquarie River, and provide recommendations to enable Aboriginal people to reconnect with Country.
7. Integrate different disciplines of study and sources of knowledge to start developing an understanding of the entire system.
8. Provide advice about how to build community ownership of scientific research and knowledge.
9. Provide advice about monitoring, evaluating and reporting management activities and the system's condition.
10. Identify requirements for adaptive management.

The plan identifies ecological assets and values defined from a review of the ecological system, ecological outcomes and the water requirements to achieve them. It lists ecological and social issues, includes a brief description of water-management infrastructure, policies and procedures, refers to natural climatic variability and how climate change affects water availability, and provides details of Aboriginal cultural values. Finally, in providing implementation guidelines, it identifies who has to be informed and involved and who is responsible for administering and implementing the plan.

1.4 The Macquarie Marshes

The Macquarie River is a large, regulated river in the Murray–Darling Basin with a catchment of about 75,000 square kilometres. The river rises on the western side of the Great Dividing Range, south-east of Bathurst, and flows for about 500 kilometres north-west and north before joining the Barwon–Darling River in northern New South Wales, as shown in the map in Figure 1.1.



Figure 1.1 Location of the Macquarie catchment in the Murray–Darling Basin.

The Macquarie River's main tributaries enter the river upstream of Narromine, and most are upstream of Burrendong Dam, the river's largest water storage (DWR 1991). As the Macquarie River flows on to the Darling Riverine Plain, downstream of Narromine, it develops distributary streams and extensive floodplain wetlands (WRC undated). These streams flow north and north-west and join the Bogan and Barwon–Darling rivers. The main Macquarie River channel forms the Macquarie Marshes about 50 kilometres north of Warren. The marshes extend for about 120 kilometres to near Carinda, as shown in the map in Figure 1.2.

The Macquarie Marshes are a large and diverse wetland system that is the core of the traditional country of the Wailwan people. They marshes were an important location for traditional Aboriginal settlement in this dry region because they contained rich and reliable resources. The wetlands, and the specific places and the plants and animals that the wetlands supported, held an important place in the Aboriginal cultural world. Since European settlement, the marshes have continued to be important for Wailwan and other Aboriginal people.

In 1882, the NSW Government declared parts of the marshes a water reserve, and in 1900, the government gazetted a reserve for game preservation in the marshes (NSW Government 1900). In 1902, landholders on the lower Macquarie River formally expressed their concerns about the effects of development on the marshes (Royal Commission 1902; Sinclair Knight and Partners 1984). In the 1940s, the NSW Government established the Macquarie Marshes Investigation Committee to plan for the protection of the marshes after Burrendong Dam was built (Cooper 1949; MMIC 1951; Johnson 2005).

The values of the marshes are now recognised formally at all levels of government in Australia, including in the Coonamble Local Environmental Plan and the Ramsar Convention. Parts of the marshes are listed as a nature reserve under the *NSW National Parks and Wildlife Act 1974*. They are included in the *Directory of Important Wetlands in Australia* (Australian Nature Conservation Agency 1996) and as areas of conservation importance by the National Trust of Australia and the Australian Heritage Commission (NPWS 1993). The floodplain wetlands are recognised in the migratory bird agreements that Australia has made with Japan, China and Korea (Kingsford & Auld 2005).

For the purpose of this plan a wetland is defined as under the Ramsar Convention as:

'Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres'
(Ramsar Convention 1971).

These marshes include a variety of wetland types, ranging from semi-permanent marshes and lagoons to ephemeral wetlands that are inundated by only the largest floods (Keyte & Johnson 1999). The core areas of semi-permanent wetland are typified by river red gum forest and woodland and large areas of common reed (reedbeds), tall grassland and water couch low-grassland, which are inundated by overbank and overland flooding from many small channels.

Ephemeral wetlands include coolibah and black box woodlands (Paijmans 1981; DLWC & NPWS 1996). The marshes have supported some of Australia's largest waterbird breeding events and provide essential habitat for hundreds of species of animals and plants (Kingsford & Johnson 1998; Jenkins & Wolfenden 2006). Their role in absorbing, recycling and releasing nutrients and in trapping sediment is especially valuable. The marshes are an important refuge for wildlife during dry times.

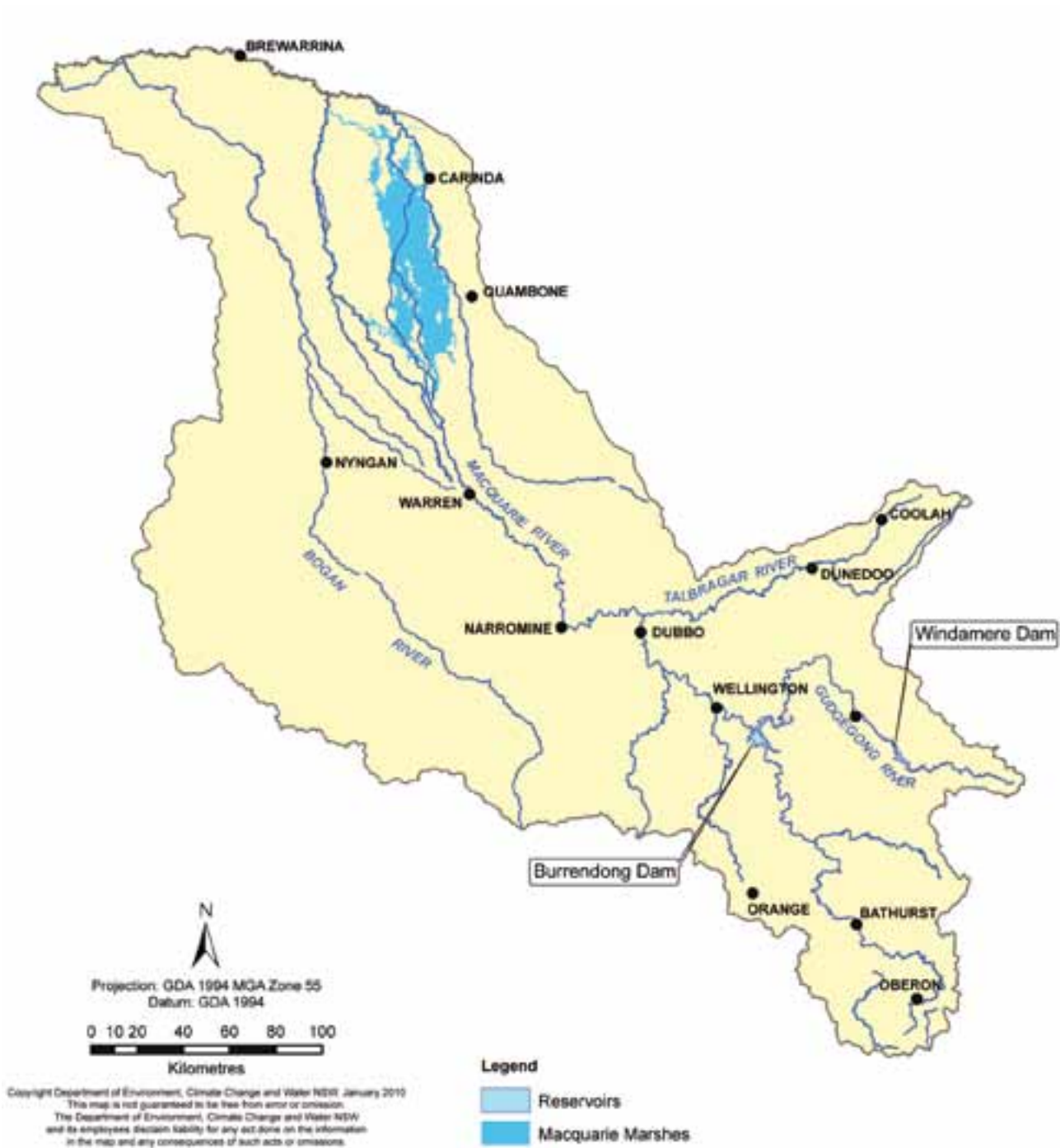


Figure 1.2 The Macquarie River catchment.

1.5 Ecological systems

An ecosystem is a basic functional unit of nature. It comprises both organisms and their non-living environment and is linked by a variety of biological, chemical and physical processes. A general definition of an ecological system, or ecosystem, is a dynamic system of local ecological relationships, including relationships between organisms and between organisms and their environment. An ecosystem includes humans if they are present in the system (Barnhart 1986; Meffe et al 2002).

The Macquarie Marshes ecosystems include the plants and animals, places, the processes or relationships between the different parts of the system, and functions such as flooding, drying and nutrient cycling that are the foundations of the marshes and contribute to their ecological character. The river system outside the marshes must also be considered. Managing the marshes requires consideration not only of the defined ecosystem but of the Macquarie catchment and the hydrology and geomorphology of the river and the floodplain.

Much is known about the key ecological components of the marshes, their structure, including their biological, physical and chemical make-up, what they look like, where they are and the nature of different parts of the overall system. However, there is much less detail about their ecological processes and functions, and how the different parts interact and change in time. Knowledge of both structure and function is necessary for adaptive management.

Like most other major rivers in the Murray–Darling Basin, the Macquarie has been highly regulated since the mid–20th century (Mussared 1997; Young 2001). The valley’s social systems depend on the regulated river and the relatively reliable water supply it provides (DWR 1991). Managing the marshes and river requires sound information about their social systems and their ecosystems.

1.6 Aboriginal cultural values

Aboriginal cultural values are related to the history of Aboriginal interaction with the marshes, and to the values, interests and aspirations of contemporary Aboriginal communities that have a custodial relationship with the marshes. Aboriginal cultural values are related to specific places, plants and animals, and to the landscape as a whole. The Aboriginal ethos of ‘caring for Country’ can assist with sustainably managing wetlands through its emphasis on the connections between people and the natural world and the sense of responsibility of caring for the natural world.

The NSW Government is committed to protecting Aboriginal cultural values of wetlands and to working in partnership with Aboriginal communities in managing and conserving the environment (DAA 2003; DECC 2006). The three main elements of protecting and strengthening cultural values in the Macquarie Marshes are:

1. Acknowledging Aboriginal connection to Country.
2. Protecting Country by maintaining the health of the wetlands, protecting sites of Aboriginal cultural heritage, and protecting plants and animals that have cultural values.
3. Improving access to Country for cultural activities, facilitating working on Country, and increasing participation of Aboriginal people in managing the environment.

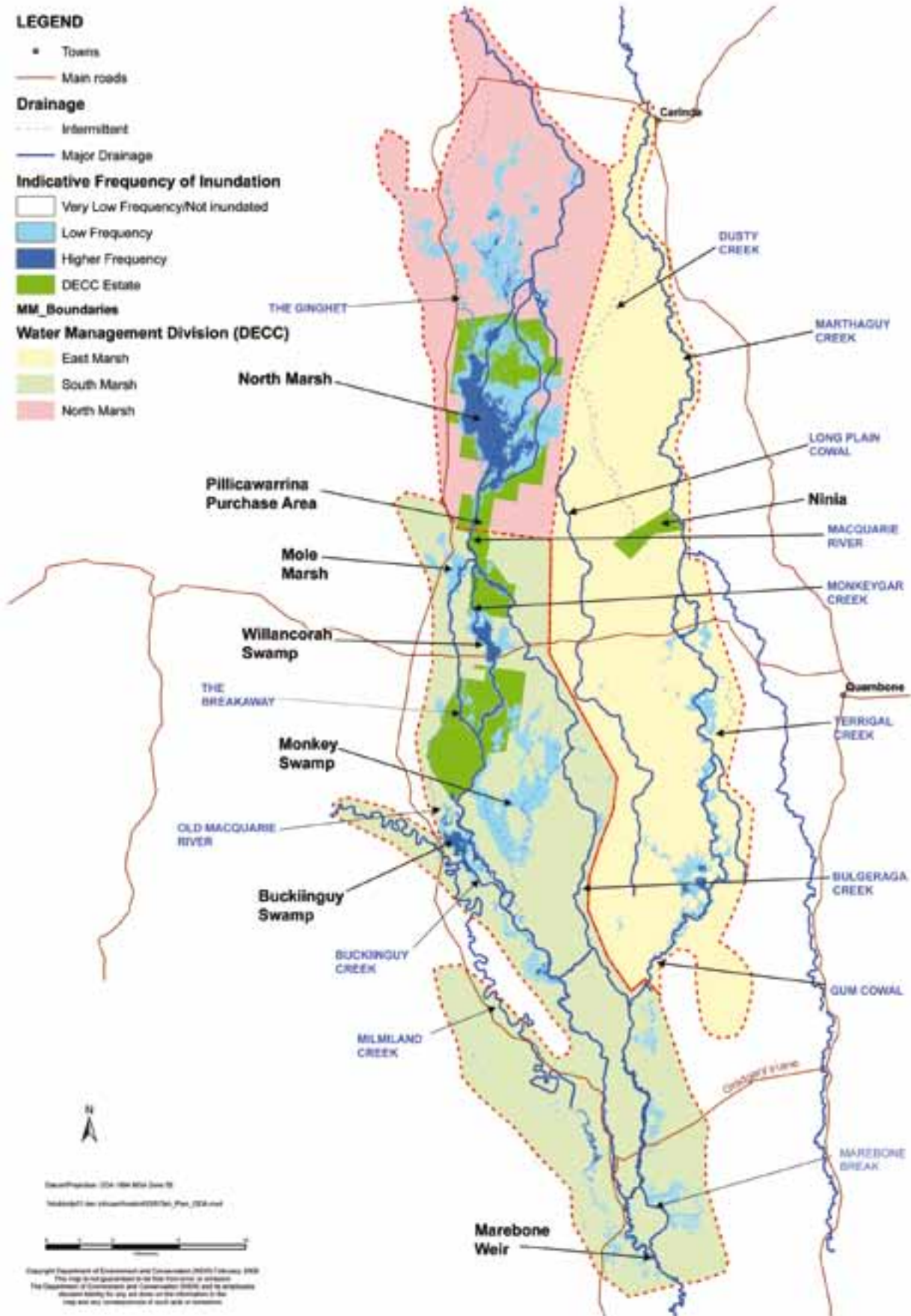


Figure 1.3 Streams, locations and water management divisions in the marshes.

1.7 Economic activity

The Macquarie catchment comprises some of the more agriculturally diverse rural landscapes in central NSW, and includes cultivation of a wide range of intensively farmed and broad-acre crops. The catchment also encompasses a relatively large range of urban centres as well as many smaller traditional rural service centres (Argent et al 2007).

Consistent with regional areas throughout Australia, the catchment has shown signs of demographic decline relative to the rest of NSW. Population has not grown at the same rate, and youth out-migration has led to a faster rate of ageing of the catchment's population. According to economic indicators, compared with NSW as a whole, the catchment has a stronger dependence on agriculture for employment, higher rates of unemployment and lower income levels (Hassall & Associates 2007a).

These trends are not uniform throughout the catchment. Compared with its more accessible communities in the higher rainfall areas to the east, its more remote communities have a much greater dependence on agriculture. Larger regional centres in more accessible areas tend to have a broader economic base that includes more people in professional and managerial occupations and fewer people in more vulnerable, less skilled occupations, so the larger centres are less dependent on agriculture. Also, compared with smaller, more remote settlements, larger centres have higher individual incomes and are less affected by youth out-migration (Argent et al 2007).

1.7.1 Agriculture and other industries

In 2005–06, the total agricultural output for the Macquarie catchment was worth \$400 million, 57 per cent of which was attributable to crops and 43 per cent to livestock. In the same financial year, fruit and vegetables contributed an extra \$17 million (ABS 2006a).¹ In 1996–1997, the manufacturing sector had a turnover of \$355 million (based on figures reported for the Dubbo, Wellington and Mudgee LGAs). Tourism also made a significant contribution: in the June 2006 quarter, accommodation takings (for Dubbo, Narromine and Mid-Western Regional LGAs) were \$8.5 million (Hassall & Associates 2007a).²

In relation to employment, in 2006 the retail trade sector was the largest employer, accounting for 12.3 per cent of total employment, followed by agriculture, forestry and fishing (12 per cent); health care and social assistance (11.4 per cent); education and training (8.4 per cent) and manufacturing (7.1 per cent). Over time, the importance of agriculture has declined both absolutely and relatively. Between 1996 and 2006, although the number of people employed in the catchment increased, the number of people employed in the agriculture, forestry and fishing sector declined. That sector's share of total employment also declined, from 15 to 12 per cent – the largest decline of any sector. The largest gains in the share of employment were in health care and social assistance (1.7 per cent), public administration and safety (1.4 per cent) and construction (1.2 per cent) (ABS 1996, 2006b).

1. This section of the Macquarie catchment comprises the Brewarrina, Dubbo, Mid-Western Regional, Narromine, Warren and Wellington LGAs, which essentially run down the centre of the catchment along the Macquarie River and include most of the area of irrigated agriculture. This area is smaller than the official Macquarie catchment area. Unfortunately, the LGA boundaries do not match the official catchment boundaries. Comparable statistics have been compiled for a larger area that comprises a number of other LGAs, which are only partially included in the official Macquarie catchment boundary.
2. Data for other LGAs was not available from ABS (2007) NSW Regional Statistics.

1.7.2 The irrigation industry

Cotton is the dominant irrigation enterprise in the lower catchment. Cereal, pulse and oilseed cropping also occurs. These crops can be watered on a limited scale, especially cereals (such as wheat) and chickpeas. However, there are few alternatives to irrigated cropping that generate the gross income associated with cotton (Hassall & Associates 2007b).

Irrigated enterprises are highly spatially concentrated in the catchment.³ In 2000–01, irrigated agriculture was worth \$255 million and accounted for slightly less than half the total value of agricultural production in the catchment (Hassall & Associates 2007a).

1.7.3 Cotton production

Although the irrigated cotton industry grew significantly during the 1980s and 1990s, the momentum of the growth has slowed as a result of recent dry climatic conditions and relatively more favourable price movements for other commodities. According to ABS figures for 1996–1997, almost 60,000 hectares were irrigated each year from all sources of water, that is, groundwater, regulated and unregulated supplies, farm dams and supplies of reticulated water.

In 2000–01, cotton accounted for 69 per cent of all irrigated agriculture in the catchment. By 2005–06, cotton's share of the irrigated area had declined to 38 per cent. This decline corresponded to a reduction in the area of cotton from 50,760 hectares in 2000–01 to 15,125 hectares by 2005–06 (ABS 2001, 2006a). Commensurate declines in water use by the cotton industry have also occurred since 2000, and reflect dry conditions and reduced irrigation allocations. Despite this, per-hectare yields have been increasing. Possible reasons for this increase include an increased emphasis on management when the industry is facing limited water availability and technological change in the industry (Hassall & Associates 2007b).

Cotton processing also contributes to the regional economy. Four cotton gins operate in the Macquarie catchment. Each is reported to employ 30 people on average during the cotton ginning season, which lasts three months a year (Australian Government 2007; Hassall & Associates 2007a). A fifth gin was built near Carinda, although it has not operated since the early 2000s.

Australia's cotton production is forecast to increase to 374,000 tonnes in 2009–2010, up from the low 2007–08 harvest of 132,000 tonnes, which was the smallest since 1982–1983. The world cotton indicator price (the Cotlook 'A' Index) continues its slight rising trend over the last five years with prices up from US41.8 cents per pound in 2001–2002 to a forecast price of US74 cents per pound in 2009–2010. (ABARE 2009).

Cotton could be substituted for other crops if prices change significantly. Recent dry times have led to other crops being identified as options during times of low water availability and high prices for feed grains. These options include the development of grain-based (sorghum or corn) ethanol production in Australia, which has lower per-hectare water requirements. Any shift would depend on factors such as commodity prices, management expertise, and infrastructure and equipment exchangeability (Hassall & Associates 2007b). To date, there has been little evidence that a long-term change will occur in the cropping patterns in the catchment.

3. For example, irrigated cotton is produced in only the Warren and Narromine LGAs.

1.7.4 The grazing industry

Agricultural land in the marsh region is also valuable for livestock grazing, especially in areas where pastures are more frequently flooded. The Dubbo, Brewarrina, Wellington and Mid-Western regional LGAs all differ from Warren and Narromine in that they have much less crop production and higher levels of livestock production.

In 2005–06, the catchment's livestock slaughterings and products were worth \$173 million (ABS 2006a).⁴ Compared with earnings from cropping – both irrigated and dryland, but especially compared with irrigated agriculture – these earnings are spread more evenly throughout the catchment. Cattle and calves provided the largest number of livestock slaughterings (\$71 million), followed by sheep and lambs (\$36 million). Wool provided by far the largest contribution to livestock products (\$53 million).

1.8 The past and present condition of the marshes

Because the Macquarie Marshes are changeable, it is difficult to decide on a date for a baseline condition to compare with the existing condition. The marshes have been in their present location and maintained their general wetland state for the past 6000 to 8000 years, and evidence of landscape change is available for both pre-European and post-European periods (Yonge & Hesse 2007; Ralph 2008).

The Macquarie Marshes were an important focus of settlement for Aboriginal people in traditional times. The Wailwan people had a relatively small country compared to the larger nations that surrounded them – the richness of the marshes as a resource base might account for this. The marshes provided rich and reliable wetlands, floodplains with riverine forests and grasslands, and elevated sandy ridges. Given the richness offered by these resources, the Wailwan would have held an important place in the overall region, between the arid Darling river country to the north and west and the slopes and ranges to the south and east.

Grazing of domestic animals and establishment of cattle stations began in the 1830s. Although irrigated agriculture began in the South Marsh in the 1840s, it was not until Burrendong Dam was completed in 1967 that large-scale irrigation began. By the 1990s, irrigated agriculture on the lower Macquarie floodplain had reached its peak in both area and water use (MRAC 1994).

In 1986 the Macquarie Marshes Nature Reserve was listed as a Ramsar site. In passing the *Environment Protection and Biodiversity Conservation Act 1999*, the Australian Government established a framework for managing Ramsar wetlands. The framework includes an ecological character description and a report about the area's condition at the time of listing. For the period 1981–91, reliable information exists about waterbird breeding, vegetation, geomorphology and hydrology, from studies undertaken in the marshes (Paijmans 1981; Wilson 1992; Kingsford & Johnson 1998), and we can use the information to assess the baseline condition at the time of Ramsar listing of the nature reserve.

4. Again, this area comprises the Brewarrina, Dubbo, Mid-Western Regional, Narromine, Warren and Wellington LGAs, which essentially lie down the centre of the catchment along the Macquarie River and include most of the area of irrigated agriculture. This is a smaller area than the official Macquarie catchment area.

The Macquarie Marshes Water Management Plan (DLWC & NPWS 1996) uses flood patterns and vegetation types to define the marshes and included areas inundated by flows from the Macquarie River and its streams and anabranches, specifically the Macquarie River, Marebone Break, Bulgeraraga Creek, Buckiinguy Creek, Monkeygar Creek, the Old Macquarie River, the Bora Channel, the Ginghet, Mullins Swamp, the Gum Cowal–Terrigal Creek to its confluence with Marthaguy Creek, Long Plain Cowal and Dusty Swamp (DLWC & NPWS 1996). The water management plan gives a figure of approximately 150,000 hectares for the study area, consisting of 72,000 hectares of semi-permanent wetland, 59,000 hectares of ephemeral wetland and 23,000 hectares of dryland vegetation within the boundary (Wilson 1992).

The ecological condition of the marshes has declined since the Ramsar listing in 1986, and since 2000 the decline has been accelerating (Bacon 1996, 2004; Summerell 2004). Similarly, much of the semi-permanent wetland identified in the 1996 management plan is in poor condition, or no longer present (Bowen & Simpson 2010). The specific decline in condition at the Macquarie Marshes Ramsar site was acknowledged in July 2009 when the Australian Government submitted a notification of likely change in ecological character at the site in accordance with Article 3.2 of the Ramsar Convention. In order to stabilise the condition of the marshes under both existing and predicted climatic conditions, their existing condition must be used as the base to work from. This will need a precise and systematic approach to managing water, including improved delivery, measurement and reporting on managing environmental and extractive water. This plan, by identifying ecological values and assets and the water needs of those assets, will guide priority setting for managing water in the marshes. The plan will also provide the broader catchment scale context for the development of the Macquarie Marshes Ramsar site 3.2 Notification Response Strategy. When completed, the response strategy will set out actions aimed at responding to the change in ecological at the Ramsar site.

2 The ecological assets and values of the marshes

The ecological assets and values of the marshes are defined in this plan as the ecological components, processes, functions and sites of significance known to contribute to the essential character of the Macquarie Marshes. The assets selected serve as indicators for the health of the whole ecosystem. When semi-permanent wetlands and waterbirds are flourishing, it is because ecological functions and processes are in place. The animals, plants and wetland ecosystems noted here also hold important Aboriginal cultural values.

The ecological assets defined in the plan are as follows:

1. Waterbirds and waterbird habitat: the marshes are renowned for large-scale waterbird breeding with many tens of thousands of birds breeding throughout the whole system.
2. Semi-permanent wetland vegetation: this vegetation is typified by river red gum forest and woodland and by common reed and water couch grasslands.
3. Species and communities of special significance: these species and communities include threatened species; endangered ecological communities and species of conservation concern, including the aquatic ecological community; silver perch; coolibah, black box and myall woodlands; woodland birds and red-bellied black snakes.

Assets are described in each of these three categories. The marshes are then described in terms of the assets and values on the basis of their water supply and their geomorphological and management boundaries – the North Marsh, South Marsh and East Marsh, as shown in the maps in Figure 1.3.

Water is sometimes defined as an asset as well as the driver and supporter of other assets (Torrible et al 2008). In this plan water is treated separately as the unifying element of the Macquarie River's ecological and social systems. Water supports, organises and drives the functions and processes of the marshes, as well as the Macquarie Valley's agricultural and social systems. The frequency, duration, extent of inundation and quality of the water determine the character of the marshes (Poff et al 1997; Puckridge et al 1998).

Wetland processes and functions are not described specifically in this plan. Ecological processes are dynamic forces within ecosystems. They include all the changes or reactions that occur between organisms, and within and between populations and communities, including interactions with the non-living environment that shape ecosystems. They may be physical, chemical or biological (Ramsar Convention 1996; Australian Heritage Commission 2002). Ecological functions are activities or actions that occur naturally in wetlands as a product of the interactions between ecosystem structure and processes. Functions include flood control, connections between river channels and floodplains, nutrient, sediment and contaminant retention and dispersal, erosion control, habitat provision, food web support, water quality maintenance and improvement, erosion control and stabilisation of local climatic conditions, particularly rainfall and temperature (Ramsar Convention 1996).

Wetland functions and processes and their interactions are poorly understood. Expanding our understanding from knowledge of structure to knowledge of function and processes is important work. Research into carbon metabolism and nutrients is underway in the marshes and will be finalised in late 2010. It will help determine indicators and thresholds for functions and processes.

2.1 Waterbirds and waterbird habitat

The Macquarie Marshes are recognised as a refuge for waterbirds during dry times and for supporting some of Australia's largest recorded waterbird breeding colonies (MMIC 1951; Marchant & Higgins 1990; Kingsford & Auld 2005). Seventy-six waterbird species have been recorded in the marshes, and 44 of these species have been recorded breeding (Kingsford & Auld 2003). Included are species listed as being threatened both in NSW and nationally, and the only NSW breeding record for the pied heron.

The ecological requirements of breeding waterbirds in the marshes are known at a structural level. Information exists about the wetland vegetation and the materials required for most species' nesting sites. The flow size, timing and duration are known for different sized breeding events. Food required by breeding waterbirds is known, and there is some information about what happens to both adult and young birds after breeding (Kingsford & Auld 2005).

Of the waterbirds that breed in the marshes, colonial nesting species are prominent, and have been the most studied. Sixteen species have been recorded breeding, with the great egret, intermediate egret, little egret, nankeen night heron, glossy ibis, Australian white ibis, straw-necked ibis, little pied cormorant and little black cormorant occurring in the largest numbers (Kingsford & Thomas 1995; Kingsford & Auld 2005; Jones 2009).

Between 1986 and 2001, colonially nesting species bred in 10 years at 14 sites throughout the marshes (Kingsford & Auld 2003). By 2008 several of the known breeding locations were considered to be in poor condition due to both lack of water and grazing pressure. Since 2001, only one breeding event of colonially nesting waterbirds has occurred in the marshes. In 2008, a relatively small flood supported a successful nesting of about 2000 pairs of egrets in river red gum forest on the Bora Channel. This nesting was unpredicted because flows were lower than the threshold previously considered necessary to stimulate breeding, and it was the first record of colonially nesting waterbirds breeding at only one location in the marshes (Jones 2009). Environmental water was delivered to the site of this colony to ensure water levels were maintained at a sufficient level to sustain the breeding event.

The Macquarie Marshes were long known for providing waterbird habitat that served as a refuge during dry times (MMIC 1951). Waterbird habitat components include preferred locations and vegetation for shelter and nest sites, the water needed to flood breeding sites and feeding areas, and the availability of preferred food items. Most sites are located in semi-permanent wetland vegetation types, requiring regular, frequent and prolonged flooding (Kingsford & Auld 2005). Managed environmental flows will be critical for their maintenance and, in some cases, their restoration.



Photo 1 An intermediate egret steps onto a nest in a river red gum in the Bora Creek colony of the northern nature reserve (W. Johnson).

Large-scale waterbird breeding events in the marshes – more than 40,000 nests – indicate the whole ecological system is functioning. Numerous management issues are affecting the ecological system's ability to support large waterbird breeding events. Most of these issues are related to the flow regime, but others include the effects of grazing, clearing, fire, pests and a limited understanding of the complexity of a system such as the marshes.

The minimum requirement for colonially nesting waterbirds to breed successfully is flooding of a sufficient volume and duration for colony sites and feeding areas to be inundated for a minimum of four to five months between August and March (DECCW unpublished reports). These flows are also critical both for maintaining wetland vegetation and for completing the life cycles of aquatic invertebrates (Jenkins & Wolfenden 2006). Although smaller flows do not generally support successful colonially nesting waterbird breeding, they do enable other flood-dependent waterbird species to breed (Marchant & Higgins 1990; Jones 2009).

2.2 Semi-permanent wetland vegetation

Semi-permanent wetland vegetation in the marshes requires regular, frequent and prolonged flooding. Some species and communities have specific legislative protection, and some plants – such as river red gum, river cooba, cumbungi and nardoo – have iconic Aboriginal cultural values. The extent and condition of semi-permanent wetland vegetation in the Macquarie Marshes have been declining since the 1930s (Paijmans 1981; Brander 1987; Goodrick et al 1991; Bowen & Simpson 2010) with many communities recently being colonised by chenopod shrubs *Sclerolaena muricate* and *Salsola kali* (black roly poly and soft roly poly or buck bush).

2.2.1 River red gum forest and woodland

River red gum forests and woodlands are widespread in Australia and occur most commonly in narrow bands fringing watercourses. About 50 per cent of their pre-European extent remains in western NSW (Benson 2006). They support critical ecological functions and provide waterbird nesting sites and habitat for many animals, including woodland birds.

River red gum forest and woodland is a distinctive part of the character of the marshes. The river red gum forest community has a denser canopy and occurs mostly in the channel country of the North Marsh. It usually has a wetland understorey that includes aquatic species, reed, rushes and sedges; it is described as inland riverine forest (Paijmans 1981; Keith 2004). The river red gum woodland community is less dense in canopy and occurs between the main channels in less frequently flooded areas. It has mostly grass and forb species in the understorey (Paijmans 1981). About 40,000 hectares of river red gum forest and woodland were mapped in the marshes in 1991 (Wilson 1992). Some areas were under stress at the time, mainly due to lack of flooding (Bacon 1996).

Although the extent of river red gum forest and woodland has remained relatively constant since 1991 (38,428 hectares in 2008), the condition of large areas has changed due to insufficient flooding. Most areas of river red gum woodland now have an understorey dominated by the chenopod shrubs (Bowen & Simpson 2010). By 2004, up to 30 per cent of trees that had been listed as stressed in 1996 had died (Bacon 1996, 2004).

The general water requirements of river red gum forest and woodland are that they be inundated in winter, spring or summer every one to three years (Robertson et al 2001) and that inundation lasts for a minimum of four to seven months but for no longer than 24 months. The key requirement is cycles of flooding and drying that enable soil aeration and water penetration into the root zone.



Photo 2 River red gum woodland in Bora Creek, northern marsh nature reserve, including aquatic plants in the foreground and water couch, cumbungi and common reed in the background (W. Johnson).



Photo 3 River red gum in the northern marsh nature reserve (W. Johnson).

2.2.2 Common reed tall grassland

Extensive stands of common reed (reedbeds) are a distinctive part of the Macquarie Marshes' character. The area of common reed mapped in 1991 was 4780 hectares (Wilson 1992). By 2008 this area had declined to 2202 hectares (Bowen & Simpson 2010). Common reed tolerates a range of flood frequencies, from permanent to infrequent inundation. To maintain vigour, surface flooding is required every one to two years (Roberts & Marston 2000). Expansion and regeneration for common reed is more effective from rhizomes than from seed (Weisner et al 1993; Roberts & Marston 2000). Germination and seedling requirements for common reed in Australia are mostly unknown but seed germination is better in moist rather than waterlogged conditions. If large stands are lost they could be difficult to restore due to the relatively low success of recruitment from seed. In the marshes, common reed is a habitat for many waterbirds and provides nest platforms for large breeding colonies of ibis as well as for Australasian bitterns.

2.2.3 Water couch grassland

Extensive water couch grasslands have been mapped in the marshes (Paijmans 1981). Wilson (1992) mapped 5500 hectares. These marsh grasslands have declined in area and condition, such that some have been colonised by roly poly and buck bush or are now mapped as 'mixed marsh'. The area of water couch mapped in the marshes in 2008 covered 420 hectares with only 53 hectares (12 per cent) of this being in good condition. The remaining 367 hectares was invaded by chenopod shrubs (Bowen & Simpson 2010). Water couch is a prolific seeder but the success of seed germination is limited and it can regenerate more successfully from fragments or buried nodes (Middleton 1999). If this is the case, loss of water couch from large areas might lead to its failure to recover quickly, because its regeneration depends on the presence of mature, healthy plants that have trailing stems. Water couch marsh grassland is considered by Benson to be an endangered community (Benson 2006).

To maintain vigour, water couch generally needs flooding in spring or summer at least once a year (Bennett & Green 1993). Flooding can be continuous for four to six months or longer, or can come in two or three separate, shorter events (Blanch et al 1999). Water couch can recover from a one- to three-year dry spell but cannot tolerate extended or frequently repeated dry periods. Spring and summer flooding is important (Roberts & Marston 2000).

When water couch is water stressed – that is, when it is dry – it does not tolerate grazing well. When it is underwater, it does not tolerate persistent grazing. However, according to recent research, under suitable flow conditions, grazing can be a contributing factor in maintaining water couch's dominance in grassy wetland communities (Wilson et al 2008).

In the summer and autumn of 2007 and 2008, widespread rain and some flows into the marsh that maintained inundation for more than three months in the summer and autumn of 2007 and 2008 supported a rejuvenation of water couch grassland in Willancorah Swamp, River Paddock in the North Marsh, and parts of the Gum Cowl–Terrigal Creek system (R. Jones pers. comm.).

2.2.4 Lignum shrubland

Lignum occurs throughout the marshes as an understorey plant but exists as a shrubland in only a few areas. Lignum provides valuable habitat for waterbird breeding, especially for ibis. Approximately 2800 hectares of lignum shrubland were mapped in 1991 (Wilson 1992). About 1000 hectares of lignum shrubland were cleared between 1991 and 2008, with about 300 hectares remaining in the marsh in 2008 (Bowen & Simpson 2010). Lignum shrubland is considered by Benson to be vulnerable (Benson 2006).

Lignum shrubland occurs in areas flooded at frequencies of once in two to ten years for durations of three to 12 months. The optimal flood times for growth and recruitment are spring and summer so as to maintain soil moisture (Young et al 2003). Lignum responds rapidly to flooding by producing an abundance of shoots, leaves, flowers and seeds. Seeds ripen quickly, disperse on floodwaters and germinate under moist soil conditions. To maximise seed germination, seeds settle in moist, but not flooded, soil within approximately eight weeks of flower development (Chong & Walker 2005).



Photo 4 (Top to bottom): Common reed, river red gum forest and woodland, lignum shrubland, and coolibah woodland in the northern marsh nature reserve (W. Johnson).

2.2.5 River cooba

Little is known about the ecology of river cooba. In the marshes it is found in the Marebone area, parts of the North Marsh and along the Gum Cowal–Terrigal Creek, often in association with river red gum or lignum. It provides valuable nesting habitat, especially for colonially nesting species (Kingsford & Johnson 1998; Kingsford & Auld 2005). Most of the remaining river cooba community is in poor condition. In 2008, 2614 hectares of river cooba was mapped in the Macquarie Marshes and many areas were invaded by chenopod shrubs (Bowen & Simpson, 2010).

2.3 Species and communities of special significance

This category contains threatened species, endangered ecological communities and species of conservation concern, including the aquatic ecological community; silver perch; coolibah, black box and weeping myall woodlands; woodland birds; and red-bellied black snakes.

2.3.1 The aquatic ecological community

The aquatic ecological community of the Macquarie Marshes, which is part of the natural drainage system of the lowland catchment of the Darling River, is listed under the *NSW Fisheries Management Act 1994* as an endangered ecological community (NSW Government 2005). This community includes all the area's native fish and aquatic invertebrates as well as the natural rivers, creeks, lagoons, billabongs, wetlands, lakes, tributaries and anabranches in which they live. The need exists both ecologically and legislatively to protect and restore the community.

Under the *NSW Fisheries Management Act 1994*, the key threatening processes or issues listed that affect the Macquarie Marshes aquatic ecological community are in-stream structures and other factors that alter natural flow, degrade native riparian vegetation and favour exotic species.



Photo 5 Wavy marshwort (W. Johnson).

2.3.2 Silver perch

Silver perch is listed as a vulnerable species in NSW under the *NSW Fisheries Management Act 1994*. This species inhabits warm, sluggish, standing waters with cover provided by woody debris and reeds as well as fast-flowing, turbid waters (Koehn & O'Connor 1990). Little is known about silver perch's ecological requirements in the wild, although some information is available from breeding in captivity. Recruitment of silver perch seems to be localised and opportunistic (Morris et al 2001). Although spawning can occur during non-flood conditions, spawning activity and recruitment success can be significantly increased during floods and higher flows. The larvae and juveniles use floodplain habitats. The adults and juveniles feed on small aquatic insects, molluscs, earthworms and green algae, and the larvae feed on zooplankton (Merrick 1996). In a formal survey undertaken in 2008, silver perch was recorded in the marshes for the first time since 1989 (S. Davis pers. comm.).

All native fish species in the Macquarie Marshes and lower Macquarie River typically recruit during spring and early summer. During this critical time, appropriate flows are needed for spawning so that eggs can be protected and larval and juvenile fish survival can be promoted. For most species, warmer temperatures are important during this period. It is vital that flow conditions be suitable during these critical larvae rearing stages and that the summer irrigation flows which follow be reduced so that larvae and prey are not washed out from nursery habitats (Humphries et al 2002). If late winter and spring floods were restored, conditions would be optimal for adult fish to feed and grow before they spawned (Humphries et al 2002) and floodplain habitats would have a rich supply of food for larval and juvenile fish (Gehrke et al 1995).

Many changes to the condition of the river have contributed to the degradation of native fish habitat. River regulation has changed the flow conditions that many native fish depend on. Changing flow patterns and degraded riparian zones increase bank erosion, turbidity and sedimentation within channels, filling pools and smothering habitats that include macrophytes, woody debris and gravel substrates (MDBC 2003). Constant low flows reduce ecosystem productivity by removing the boom (wet) and bust (dry) cues that trigger and sustain aquatic cycles (Poff et al 1997; Ward 1998). Other threats include increased contaminant runoff, competition with introduced species and structures in the river that act as barriers to movement (MDBC 2003).

Some structures are a direct threat to fish. Fish larvae are usually poor swimmers, and they travel with currents. Larval and juvenile fish are directly extracted from the river when water is pumped for irrigation and town water supply. Collaborative research is being undertaken between NSW DPI, the Australian Cotton CRC and Murrumbidgee Irrigation to investigate this (DPI 2005). Marebone Weir has an undershot design that is now known to cause high mortality among larval and juvenile fish; for example, 95 per cent of larval and juvenile golden perch (Baumgartner et al 2006; DPI 2007). Releases of cold, poor-quality water from the bottom of Burrendong Dam affect aquatic habitat adversely for many kilometres downstream. Habitat degradation has to be tackled at the whole-of-river scale and controlling introduced fish, especially carp, also has to be attempted at this scale (Humphries et al 2002).

Many parts of the marshes are potential habitat for fish, as evidenced by the number of mussel shells found in various areas. Freshwater mussels spend their early life as a small obligate parasite on the gills of fish (Baker et al 2003). Australian smelt, catfish and silver perch have been documented as being native fish hosts for mussel larvae. Provided that some mussel larvae parasitise on fish successfully, patterns of genetic distribution of mussels and fish hosts are likely to be closely linked (S. Davis pers. comm.).

Because the marshes are located in the lower end of the catchment, the fish communities are a blend of those found in adjacent main channel habitats; that is, directly upstream and downstream, but also in systems such as Marthaguy Creek. During flow events, fish are likely to move from these areas into the marshes. More specifically, the composition – the richness, relative abundance and biomass of pest species – of a fish community found at one of the marshes' specific sites or specific creeks is likely to be regulated due to a combination of local habitat characteristics; recent and historical flows; and the extent of longitudinal and lateral connectivity to habitats, including the floodplain (Jenkins et al 2004; Rayner et al 2009).



Photo 6 Silver perch (I&I NSW).

Reversing the decline of native fish communities in the Macquarie River and Macquarie Marshes will require finely calculated delivery of environmental flows, as well as the protection of riparian and instream habitat, particularly refuge areas (Rayner et al 2009). This will need a high level of cooperation between environmental flow managers, researchers and land managers.

2.3.3 Red-bellied black snake

The number of red-bellied black snakes in the Macquarie Marshes was once one of the highest in Australia, but over the past 20 years, both the number and the condition of the snakes have declined dramatically (Johnson 2005). Although the snakes are not listed as threatened, they are a significant feature of the Macquarie Marshes. Their diet includes fish, tadpoles, frogs, lizards, snakes, mammals and aquatic invertebrates. They feed both on land and underwater (Greer 2006).

The reason for the decline in the number and condition of red-bellied black snakes in the marshes is mostly unknown. However, frogs are a mainstay of this snake's diet (Cogger 1996) and declining frog populations are believed to be one of the major causes (Johnson 2005). The most important management issue for this species is to find out more about its needs.



Photo 7 A red-bellied black snake swimming through ribbon weed (Grenville Turner).

2.3.4 Frogs

There is little information about the current health and status of frog populations or about how flows might be managed to ensure the populations' survival. The most recent surveys of frogs in the marshes were undertaken in the early 1990s and in 2009 (Metcalf et al 1993; T. Rayner pers. comm.). The 2009 surveys found 8 of 14 frog species expected to occur in the marshes (J. Ocock pers. comm. 2010). Research is underway to determine the abundance, composition, richness and diversity of frog communities and the factors that influence populations, such as the amount of time since the most recent flood, inundation frequency, the dependencies of different frog species on environmental flows, habitat structure, water quality and the presence of chytridiomycosis.



Photo 8 A green tree frog (W. Johnson).

2.3.5 Coolibah, black box and myall woodlands

2.3.5.1 Coolibah woodland

Coolibah is found in association with river red gum in some of the wetter parts of the marshes, although it is more commonly found in areas that are less frequently flooded, where it forms coolibah and coolibah–black box woodlands. In the marshes, coolibah is found along a gradient of decreasing flood frequency and duration between river red gum and black box woodlands. This contrasts with the generally accepted view of the water requirements of coolibahs, which suggests black box requires wetter conditions than does coolibah (Roberts & Marston 2000).

Coolibah requires flooding for regeneration. Although its broad ecological requirements are not well known, according to experience in the marshes – especially in the northern nature reserve after the North Marsh Bypass Channel was constructed in the early 1970s and on Terrigal Creek between 1998 and 2000 – coolibahs will die if they are inundated for too long. It is recommended that inundation of coolibah woodland in the marshes last no longer than six to eight months.

Kidson found that since 1949 distribution of coolibah woodland has declined by at least 12 per cent (Kidson et al 2000). In 1991, Wilson mapped 7800 hectares of coolibah woodland (Wilson 1992). Bowen and Simpson found the area of coolibah woodland has changed little since then but the condition of these woodlands has changed, with most now mapped as coolibah woodland–chenopod shrubland (Bowen & Simpson 2010). Coolibah woodland is part of the coolibah–black box woodland endangered ecological community listed under the NSW *Threatened Species Conservation Act 1995*. Coolibah open woodland is considered by Benson to be an endangered community (Benson 2006).

The Wailwan people considered coolibah woodlands to be especially important because the floodplain trees were the source of materials for implements, such as coolamons, and for shelter. The remaining scarred trees are especially important because few of the wooden implements have survived (Biosis Research 2008).

2.3.5.2 Black box woodland

In the marshes, black box is found at the drier end of a gradient of decreasing flood frequency and duration from river red gum to black box woodlands, where it forms black box and coolibah–black box woodlands. Both these communities are part of the coolibah–black box woodland endangered ecological community that is listed under the NSW *Threatened*



Photo 9 Coolibah and river red gum woodland in the northern nature reserve (W. Johnson).

Species Conservation Act 1995. Since 1949, distribution of black box woodland has declined by at least 38 per cent (Kidson 2000) due mostly to clearing. Wilson (1992) mapped 16,600 hectares of black box. Bowen and Simpson (2010) found that the area of black box woodlands have remained fairly constant since then, however, the condition of black box woodlands has changed, and most is now mapped as black box woodland–chenopod shrubland. Black box requires summer flooding for regeneration. It occurs most commonly in the ephemeral wetland vegetation zone of the marshes.

2.3.5.3 Myall woodland

Myall, or weeping myall, woodland is listed as an endangered ecological community under the NSW *Threatened Species Conservation Act 1995*. Only 14 per cent of its original area remains in NSW (Benson 2006). Bowen and Simpson (2010) found there was 7997 hectares of weeping myall woodland in the marshes in 2008. Despite its endangered status, little is known about myall's ecological requirements. In the marshes, it occurs on the outer floodplain, on the edge of ephemeral wetland vegetation and is inundated in large floods. About 680 hectares of myall woodland was cleared in the Macquarie Marshes between 1991 and 2008.



Photo 10 Myall woodland inundated in a large flood on the property Stanley, East Marsh (W. Johnson).

2.3.6 Woodland birds

In south-eastern Australia, many woodland bird species that were once common are now declining. Of 20 woodland bird species whose numbers have declined significantly since the 1980s (Reid 1999), 18 are found in the marshes. Four species – the brown tree creeper, diamond firetail, hooded robin and grey-crowned babbler – are listed as vulnerable under the *NSW Threatened Species Conservation Act 1995*.

In the NSW central Murray catchment, woodland bird abundance and species richness were highest in woodlands with an area greater than 100 hectares that were located less than a kilometre from other patches of woodland that had high habitat complexity – canopy cover, shrubs, groundcover, litter and logs – and good tree health (Oliver & Parker 2006). When compared with woodlands and forests of white cypress pine, black box, yellow box, grey box, buloke and myall (boree) and with tree planting sites, river red gum woodlands and forests had the highest total bird abundance and species richness.



Photo 11 Diamond firetail (Nevil Lazarus).

The main reasons for a decline in woodland bird species are loss of habitat, fragmentation of woodland vegetation and simplification or degradation of the remaining woodland vegetation. In south-eastern Australia, large intact woodlands containing native shrubs and groundcover plants are now extremely rare, especially on fertile soils. The Macquarie Marshes are an important area where woodlands remain on fertile soils. In the marshes, river red gum woodlands and forests and coolibah and black box woodlands are important and extensive plant communities. More information is needed about the relationship between these plant communities and woodland birds.

2.4 Locations in the marshes, based on landform and water management boundaries

The values and assets identified are found throughout the marshes. In the following section, the North Marsh, South Marsh and East Marsh are described on the basis of their water source and location, as shown in Figure 1.3. This section includes descriptions of past and present condition, and change in condition.

2.4.1 The North Marsh

The North Marsh includes the Bora Channel, the Gingham, the River Paddock, Pillicawarrina, the Zoo Paddock, Loudon's Lagoon, Hunt's Woodland, the confluence of Monkeygar and Bulgeraga creeks, and the Macquarie Channel. It supports river red gum forest and woodland, extensive marshy grasslands of common reed and water couch, lignum shrubland, river cooba and cumbungi. The North Marsh contains relatively deep and protected open water lagoons. It provides habitat for important breeding colony sites and feeding habitat for colonially nesting species – egret, heron, cormorant, spoonbill, ibis and darter – and many other waterbird species. It provides habitat for threatened species – brolga, magpie goose, Australian painted snipe, Australasian bittern and blue-billed duck – and species included in migratory bird agreements between Australia and Japan, China and the Republic of Korea (JAMBA, CAMBA and ROKAMBA, respectively). The North Marsh includes the northern part of the Macquarie Marshes Nature Reserve portion of the Ramsar site.

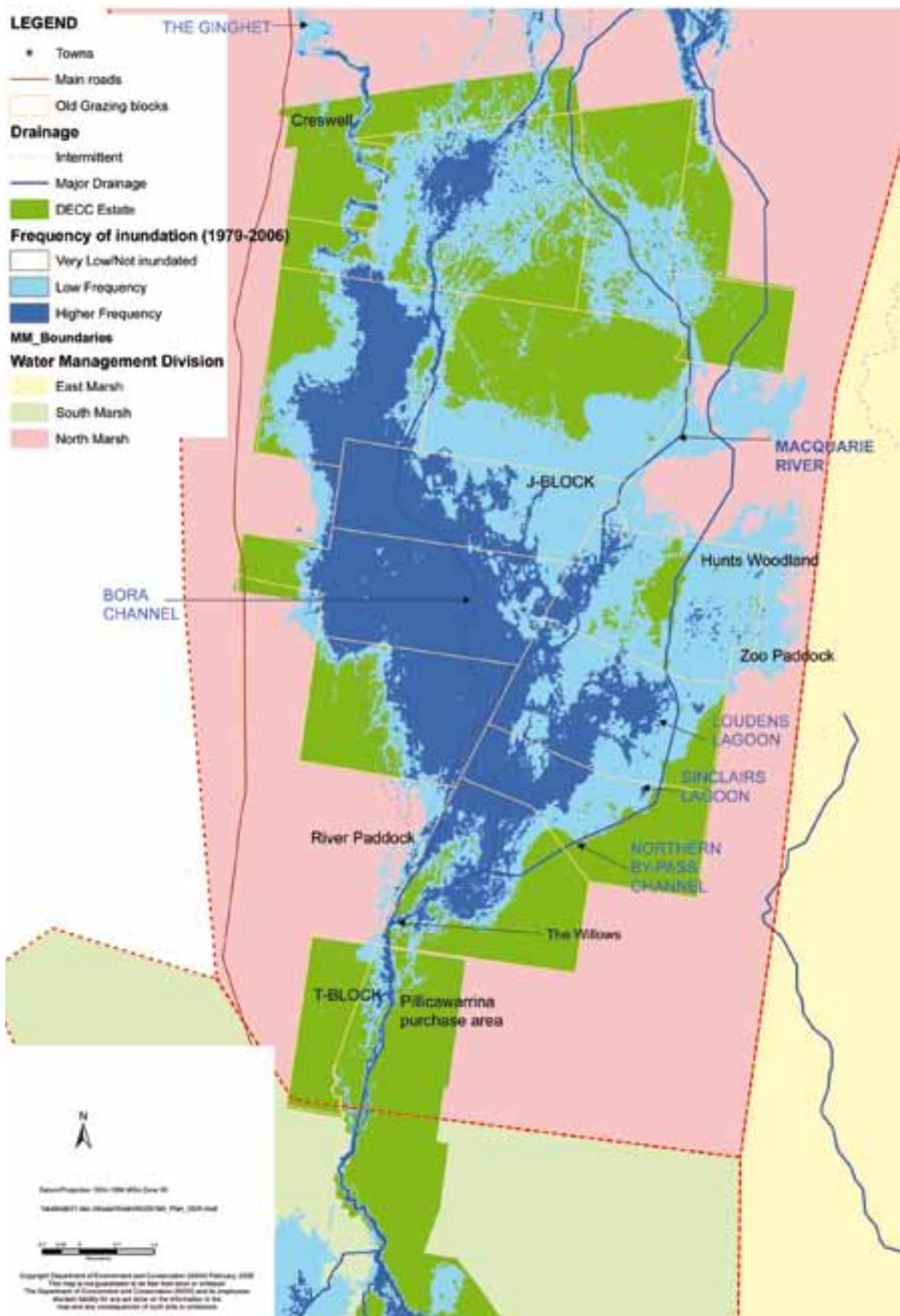


Figure 2.1 Localities within the North Marsh.



Photo 12 River red gum forest in the northern nature reserve (W. Johnson).

Colonially nesting waterbirds have been recorded breeding in eight locations in the North Marsh (Kingsford & Auld 2003). In 2000, when the most recent large flood and breeding event occurred, colonially nesting waterbirds used six locations. They did not use two known sites: Hunt's Woodland, a river red gum breeding site last used in 1990 and Louden's Lagoon, a common reed and marsh club-rush site last used in 1998 (Jones unpublished reports). Bowen and Simpson (2010) found that the river red gums in Hunts Woodland are showing signs of stress and demographic decline and that the understorey has been colonised by chenopod shrubs, (*S. muricata* and *S. kali*). It has been mapped as 'intermediate' condition (10–40 per cent dead trees). The vegetation in Louden's Lagoon is in poor condition probably due to lack of water and the presence of pigs and kangaroos (DNR 2007; Bowen & Simpson 2010). In 2008, an egret colony of 2000 pairs nested successfully in river red gum forest on the Bora Channel (R. Jones pers. comm.).

The North Marsh supports the most extensive area of river red gum forest and woodland in the Macquarie Marshes. Bowen and Simpson (2010) found that since 1991 the overall area of river red gum woodland has remained relatively stable, although the condition of red gum woodlands has declined in both overstorey condition – tree health (Bacon 1996; Nairn 2008), and understorey composition – species richness and type (Bowen & Simpson 2010). The river red gum woodland understorey is now dominated by chenopod shrub species that are more indicative of dryland communities. The area of river red gum forest that has a wetland understorey declined by 20 per cent in the period 1991–2008 (from 1860 hectares to 1486 hectares) (Bowen & Simpson 2010).

In the northern nature reserve in 2008, Bowen and Simpson (2010) found that 23 per cent of the 6130 hectares of river red gum communities were in 'good' condition (< 10 per cent dead canopy). All of this was river red gum forest occurring along the Bora channel. Of the remainder, 57 per cent was classed as 'poor' condition (80–100 per cent dead canopy), 19 per cent 'intermediate' (10–40 per cent dead canopy) and 1 per cent 'intermediate/poor' (40–80 per cent dead canopy).

In the northern nature reserve the majority of river red gum communities on the interflaves between the channels no longer receive adequate flooding and are composed of older trees which are stressed, dead or dying. There are often thickets of juvenile trees which are dead or dying, and the understorey is dominated by invasive chenopod shrubs or supported nothing at all in 2008 (Bowen & Simpson 2010).

Nairn (2008) surveyed tree health and population structure and found that 73 per cent of the sites surveyed in the northern nature reserve were under extreme water stress and that only 8 per cent of the sites had a profile that indicated 'fair' regenerative potential – none were found to be 'good'.

North of the nature reserve is a large area of river red gum forest and woodland (about 4000 hectares). The forest community is confined to narrow bands along channels and has an understorey of aquatic and semi-aquatic species when wet. River red gum woodland occurs between the main channels and was found to be stressed and dying, having a chenopod understorey (roly poly) that increases in density with distance from channels and on higher ground (Bowen & Simpson 2010). Of these river red gum communities, none is in good condition and 80 per cent are in intermediate condition (10–40 per cent dead canopy) (Bowen & Simpson 2010). The intermediate condition river red gums occur along the Bora and Ginghet in areas which receive some flooding.



Photo 13 Dead river red gum woodland in the northern nature reserve (W. Johnson).



Photo 14 *Foreground: dead river red gum woodland; top centre: dry reedbeds; top right background: healthy river red gum forest and woodland, in the northern nature reserve (Grenville Turner).*

The death of river red gums in the woodlands of the North Marsh has been attributed to lack of flooding (Bacon 2004). River red gums in the marshes need floods every one to two years, and Bacon found that trees receiving a flood in 2000 but not in 2003 were either under severe stress or dead. It is likely that in 2009 as much as 75 per cent of the woodlands had not been receiving the inundation frequency they needed in order to survive in the long term.

In the northern nature reserve there has been a 41 per cent reduction in the area of common reed, cumbungi and water couch marsh. In 1991 a total of 3314 hectares were mapped, of which 1946 hectares remained in 2008. Much of this area is in poor condition, and the area is continuing to contract. The area of common reed has declined by 17 per cent (2147 hectares were mapped in 1991, 1774 hectares remain in 2008), cumbungi has declined by 100 per cent (259 hectares were mapped in 1991, 0 hectares were mapped in 2008) and the area of water couch marsh has declined by 95 per cent (908 hectares were mapped in 1991, 49 hectares in 2008) (Wilson 1992; Bowen & Simpson 2009). Areas mapped as these communities in 1991 are now invaded by chenopod shrubs (*S. kali* and *S. muricata*) (328 hectares), or mapped as mixed marsh (123 hectares) (Bowen & Simpson 2010).

Widespread rain and some flows into the marsh maintained inundation for more than three months in the summer and autumn of 2007–2008, and supported an apparent rejuvenation of water couch grassland in the River Paddock. Even so, parts of the water couch grassland in the River Paddock are infested with black roly poly and soft roly poly (buck bush) (Bowen & Simpson 2010).

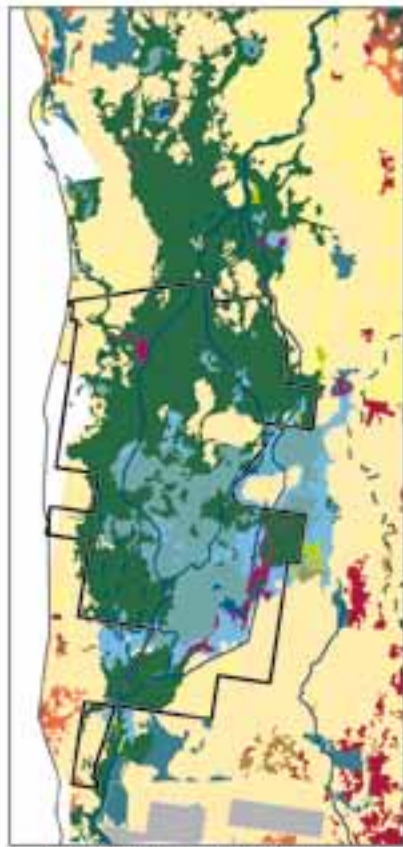
In 1986 and 1987, marsh club-rush was recorded in the North Marsh in Louden's Lagoon, where it provided nesting material for an ibis colony. Several stands have been recorded on the Bora Channel (R. Jones pers. comm.). Marsh club-rush sedgeland is considered by Benson to be critically endangered (Benson 2006) and is nominated as an endangered ecological community under the *Threatened Species Conservation Act 1995*.

Lignum occurs in many areas of the marshes as an understorey plant and occurs as shrublands in some areas of the North Marsh. According to the area of lignum shrubland mapped by Paijmans in 1981 and Wilson in 1991, there has been little change in the extent of lignum shrubland in the North Marsh other than in about 200 hectares near the confluence of Monkeygar and Bulgeraga creeks. Lignum shrubland in the Zoo Paddock, which is a critical nesting habitat for straw-necked ibis, is now in poor condition and is invaded by chenopod shrubs. Bowen and Simpson (2010) found that lignum shrubland had declined by 41 per cent from 17 to 10 hectares in the northern nature reserve and that 97 per cent of the 216 hectares of lignum mapped in the Pillicawarrina area had been cleared in the period 1991–2008.

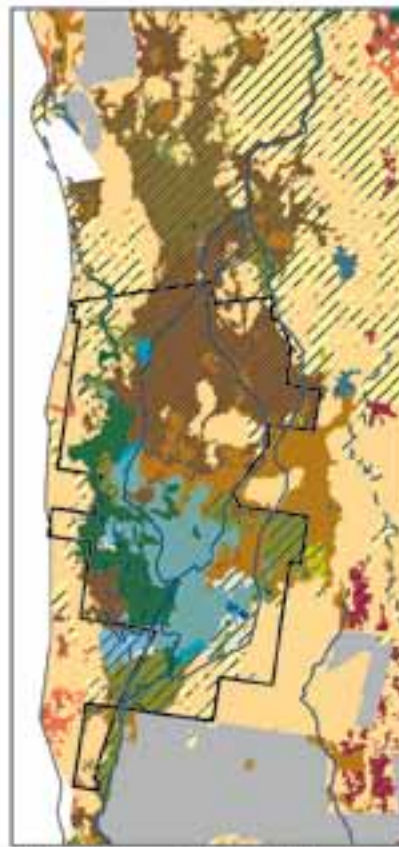
Declining condition of wetland vegetation is the most significant ecological issue for the North Marsh, as shown in the maps in Figure 2.2. The 'hatching' pattern in the vegetation maps represents areas in which chenopods such as black roly poly and soft roly poly (buck bush) have colonised wetland areas in the North Marsh.



Photo 15 A narrow band of healthy river red gum forest and woodland located on the western side of the northern nature reserve, including the extent of green vegetation as an indication of the effect and boundary of inundation (W. Johnson).



1991 Vegetation map (Wilson 1992)



2008 Vegetation map (Bowen & Simpson 2009)

LEGEND

1991 vegetation communities

- black box
- common reed
- coolabah
- cultivated
- cumbungi
- grassland/cleared land
- dryland complex
- lignum
- mixed marsh / grassland
- myall
- open water
- poplar box
- river cooba
- river red gum
- stressed/dead trees
- water couch
- wilga

Additional vegetation communities in 2008

hatching indicates understorey colonised by chenopods or chenopods occurring as a secondary species

- black box_chenopod
- chenopod shrubland
- chenopod shrubland/grassland/cleared land
- chenopod shrubland/mixed marsh
- coolabah_chenopod
- lignum/chenopod shrubland
- mixed marsh
- mixed marsh/chenopod shrubland
- myall_chenopod
- river cooba_chenopod
- water couch/chenopod shrubland

River red gum condition 2008

hatching indicates understorey colonised by chenopods

- good (<=10% dead canopy)
- intermediate (10-40% dead canopy)
- intermediate/poor (40-80% dead canopy)
- poor (>80% dead canopy)

- roads
- major drainage
- intermittent drainage
- DECCW estate



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Figure 2.2 Changes in vegetation communities in the northern nature reserve and surrounding areas between 1991 and 2008 (Bowen & Simpson 2010).

2.4.2 The South Marsh

The South Marsh includes Mole Marsh, Willancorah Swamp, Monkey Swamp, the southern nature reserve, Buckiinguy Swamp and the Marebone area. It supports river red gum woodland, river cooba, water couch marsh and common reed, and contains large, relatively deep and protected open-water lagoons.

These communities provide important breeding and feeding habitat for colonially-nesting species, especially ibis and spoonbill. They support threatened species including the brolga, magpie goose, Australian painted snipe, Australasian bittern and blue-billed duck, as well as species included in the migratory bird agreements between Australia and Japan, China and the Republic of Korea (JAMBA, CAMBA and ROKAMBA, respectively). Willancorah Swamp provides important habitat for magpie geese.

The Macquarie River, Bulgeraga Creek and Monkeygar Creek provide important riparian habitats between Marebone Weir and the North Marsh, although the Old Macquarie River on the western side of the southern nature reserve is in very poor condition because of reduced flows. Bulgeraga Creek provides especially important fish habitat in the marshes. The lagoons in Buckiinguy Swamp and the eastern side of the southern nature reserve provide important wader habitat. The South Marsh includes the southern Macquarie Marshes Nature Reserve part of the Ramsar site.

Three breeding locations for colonially nesting waterbirds have been recorded in the South Marsh. Two of these locations have not been used since the 1960s. The only site used in the 2000 flood was Willancorah Swamp (R. Jones pers. comm.).

Evidence of change includes a significant reduction of common reed (reedbeds). Extensive stands of common reed are a distinctive part of the character of the Macquarie Marshes. Common reed provides habitat for many waterbirds and nest platforms for large breeding colonies of ibis. In 1981, Paijmans mapped about 2000 hectares of reedbeds in the South Marsh. In 1991 Wilson mapped a similar area (Wilson 1992). By 2006, areas of the South Marsh that had previously been mapped as having extensive reedbeds were supporting only a few clumps of reed remaining near channels (DNR 2007; Figure 2.3).

In the southern nature reserve, Bowen and Simpson found there has been a 96 per cent reduction in the area of semi-permanent wetland communities. The area went from 1446 hectares in 1991 to 63 hectares of intermediate condition wetland in 2008, which by then comprised 56 hectares of common reed/chenopod shrubland and 7 hectares of mixed marsh/chenopod shrubland. According to the same study, the area of common reed at Willancorah Swamp has been reduced by 40 per cent – from 571 hectares to 326 hectares. The remaining wetland in 2008 consisted of water couch/chenopod shrubland (100 hectares) and mixed marsh/chenopod shrubland (372 hectares) in poor condition. The area of mixed marsh and reed vegetation at Mole Marsh had been reduced by 98 per cent – from 1458 hectares to 17 hectares (Bowen & Simpson 2010; figures 2.3, 2.4, 2.5).

Although cumbungi was widespread in the marshes, it formed large stands or rushlands in only a few areas. In 1981, Paijmans mapped about 500 hectares of cumbungi rushland at several locations in the South Marsh, including the Mole Marsh, Willancorah Swamp, Monkey Swamp and Buckiinguy Swamp. He noted that at the Mole Marsh and Buckiinguy Swamp it seemed to be dying. In 1991, cumbungi rushland was mapped along Monkey Creek and in Buckiinguy Swamp only. In 2006, cumbungi was found in only one location in the South Marsh, at Buckiinguy Lagoon (DNR 2007).

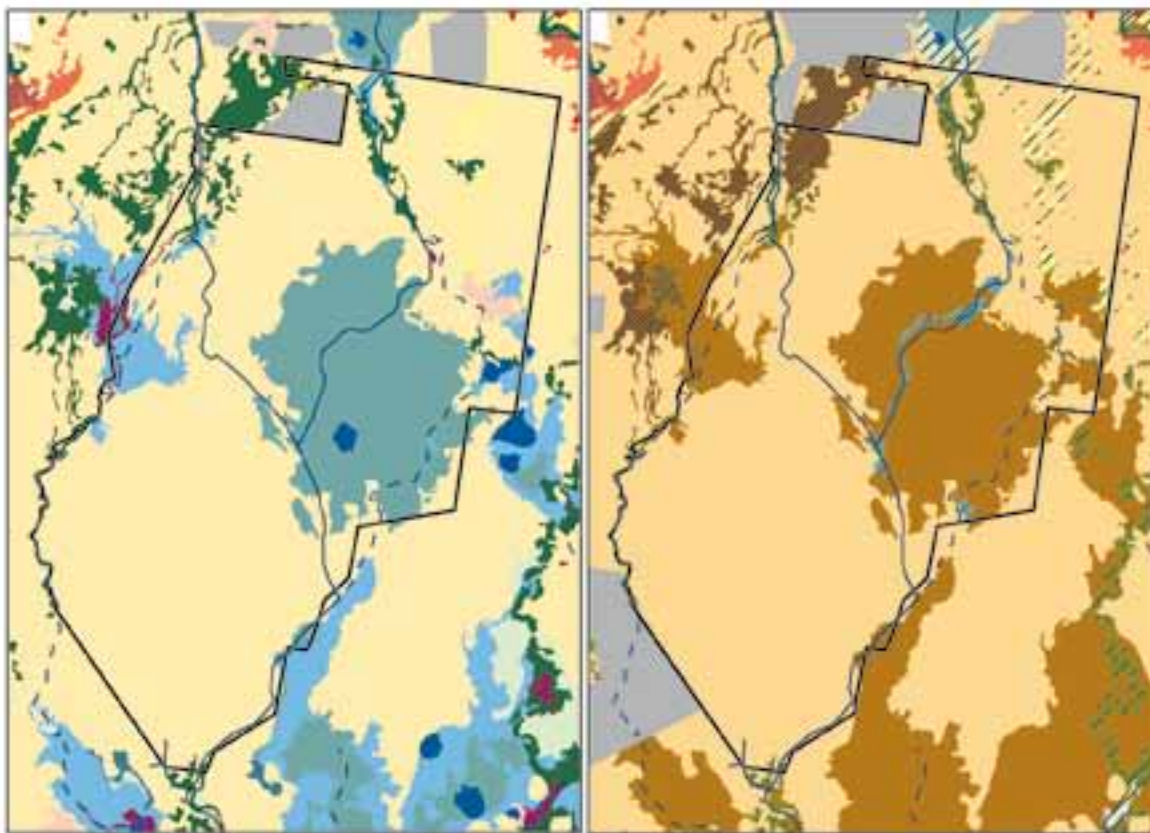
Water couch forms extensive grasslands in the South Marsh and is an important understorey plant in woodland areas. In 1981, Paijmans mapped about 300 hectares of water couch in the Mole Marsh, 300 hectares in Willancorah Swamp, 2000 hectares in Monkey Swamp and Monkey Creek, and 200 hectares at Buckiinguy Swamp and Buckiinguy Lagoon. In 2006, the only water couch marsh remaining in the South Marsh was at Willancorah Swamp and Buckiinguy Lagoon, and the area of water couch in each area had been much reduced (DNR 2007). In 2008, in the southern nature reserve, no water couch grassland remained – a loss of 220 hectares from 1991–2008 (Bowen & Simpson 2010). The area of water couch grassland at Willancorah Swamp has been reduced by 65 per cent. As a result of widespread rain and some flows into the marsh, inundation was maintained for more than three months in the summer and autumn of 2007 and 2008 and supported a rejuvenation of water couch grassland in Willancorah Swamp.

The change in the southern nature reserve since 1991 is described as catastrophic (Bowen & Simpson 2010), with the loss of 96 per cent of semi-permanent wetland vegetation, a decline in the condition of river red gum, coolibah and black box communities and a 100 per cent loss of grassland communities. Eighty per cent of the southern nature reserve is now covered by chenopod shrubland. Extensive areas of Monkey Swamp and Buckiinguy Swamp are now covered by black and soft roly poly shrubland and are in very poor condition (Bowen & Simpson 2010).

Changes to vegetation in the southern nature reserve, Monkey Swamp, Buckiinguy Swamp, Willancorah Swamp and Mole Marsh are shown in the maps in figures 2.3 2.4 and 2.5. As is the case in other areas of the marshes, much of the area identified in the early 1990s as wetland or grassland has since been colonised by chenopods. This change has been due not only to lack of water but river regulation and major geomorphological changes in this part of the system.

The South Marsh is upstream of the North Marsh and therefore acts as a natural sediment filter for the lower Macquarie River. As a result, sediment accumulation is greater in and around the main distributary channels in the southern part of the system, causing channels in the South Marsh to evolve and shift across the floodplain more rapidly than those further downstream. In particular, the main channel running into the southern section of the nature reserve in the South Marsh – Monkeygar Creek – has become enlarged and incised since the 1960s, and excessively so since the 1990s. Another channel known as the Breakaway also formed through erosion in the early 1990s. Despite attempts at erosion control using rock-rubble structures since 2002, the Breakaway continues to allow water entering the nature reserve to flow through without flooding parts of the floodplain that were inundated at times before this channel formed.

As a result of the overall increase in the size of the channels in the South Marsh, larger inflows are needed to cause overbank flooding throughout the entire southern section of the nature reserve. It is believed that the great and apparently rapid increase in channel depth and width in the South Marsh, particularly that related to bed lowering and bank undercutting, has been exacerbated by the predominantly regulated flow conditions in the system since the late 1960s. It is unknown what effect grazing by native animals and domestic livestock has had on channels in the nature reserve, but bank erosion is typically exacerbated by animals gathering at water access points.



1991 Vegetation map (Wilson 1992)

2008 Vegetation map (Bowen & Simpson 2009)

LEGEND

1991 vegetation communities

- black box
- common reed
- coolabah
- cultivated
- cumbungi
- grassland/cleared land
- dryland complex
- lignum
- mixed marsh / grassland
- myall
- open water
- poplar box
- river cooba
- river red gum
- stressed/dead trees
- water couch
- wilga

Additional vegetation communities in 2008

hatching indicates understorey colonised by chenopods or chenopods occurring as a secondary species

- black box_chenopod
- chenopod shrubland
- chenopod shrubland/grassland/cleared land
- chenopod shrubland/mixed marsh
- common reed/chenopod shrubland
- coolabah_chenopod
- mixed marsh/chenopod shrubland
- myall_chenopod
- river cooba_chenopod
- water couch/chenopod shrubland

- major drainage
- intermittent drainage
- DECCW estate

River red gum condition 2008

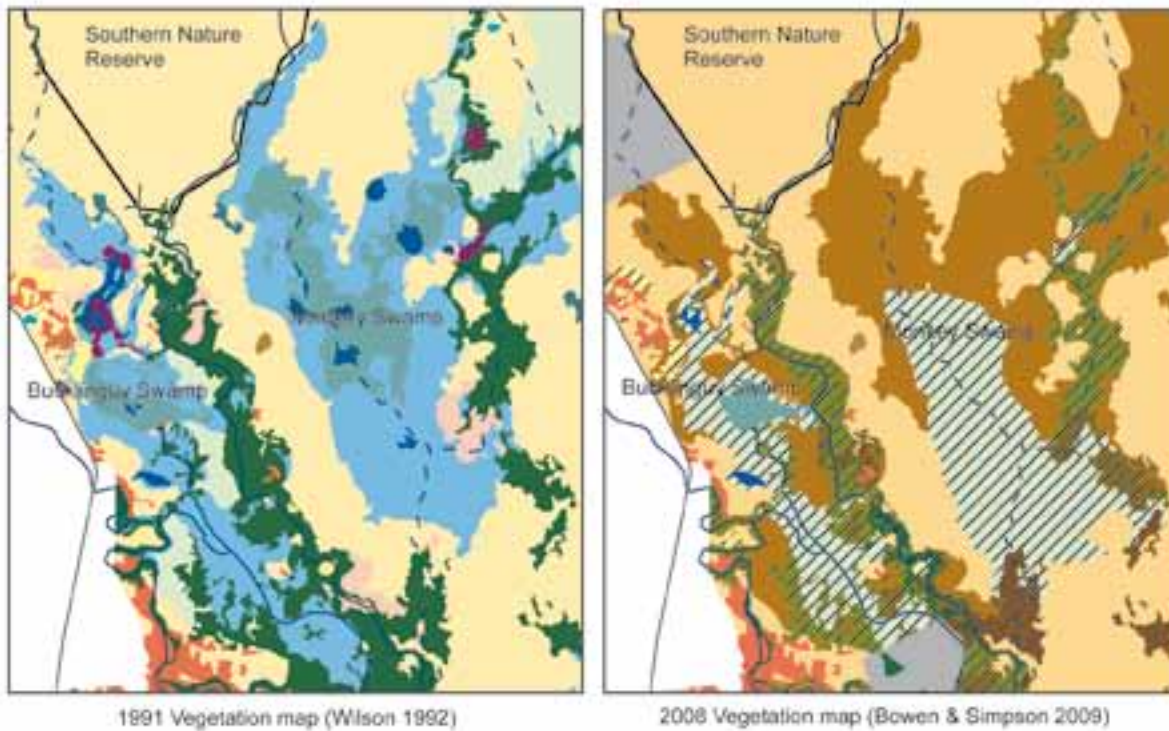
hatching indicates understorey colonised by chenopods

- good (<10% dead canopy)
- intermediate (10-40% dead canopy)
- intermediate/poor (40-80% dead canopy)
- poor (>80% dead canopy)



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Figure 2.3 Changes in vegetation communities in the southern nature reserve and surrounding areas between 1991 and 2008 (Bowen & Simpson 2010).



LEGEND

1991 vegetation communities

- black box
- common reed
- coolabah
- cultivated
- cumbungi
- grassland/cleared land
- dryland complex
- signum
- mixed marsh / grassland
- myall
- open water
- poplar box
- river cooba
- river red gum
- stressed/dead trees
- water couch
- wilga

Additional vegetation communities in 2008

hatching indicates understorey colonised by chenopods or chenopods occurring as a secondary species

- black box_chenopod
- chenopod shrubland
- chenopod shrubland/grassland/cleared land
- chenopod shrubland/mixed marsh
- coolabah_chenopod
- mixed marsh/chenopod shrubland
- myall_chenopod
- river cooba_chenopod
- water couch/chenopod shrubland

River red gum condition 2008

hatching indicates understorey colonised by chenopods

- good (<10% dead canopy)
- intermediate (10-40% dead canopy)
- intermediates/poor (40-80% dead canopy)
- poor (>80% dead canopy)

- roads
- major drainage
- intermittent drainage
- DECCW estate



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Figure 2.4 Changes in vegetation communities in Buckingham Swamp and Monkey Swamp in the South Marsh between 1991 and 2008 (Bowen & Simpson 2010).

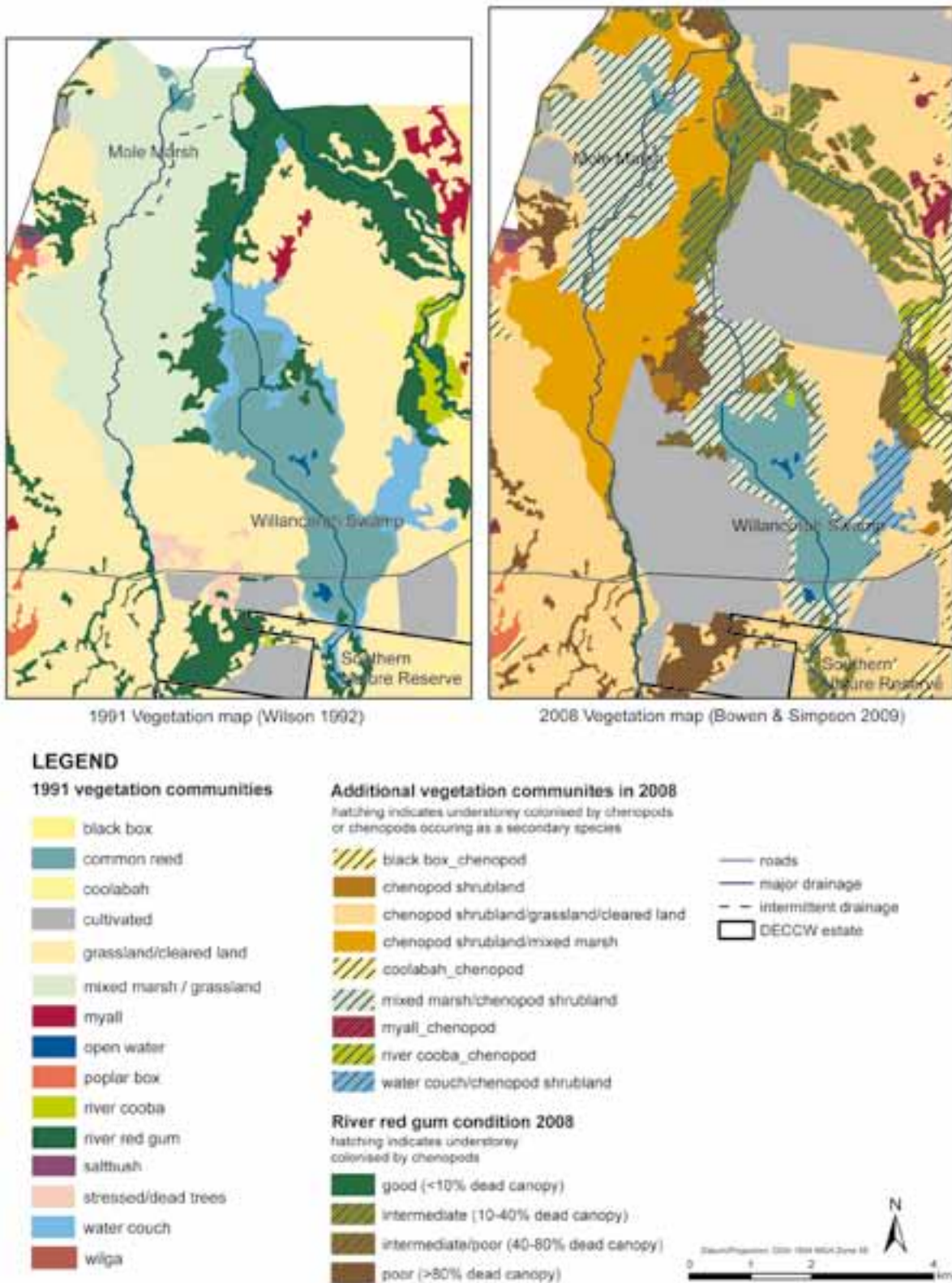


Figure 2.5 Changes in vegetation communities in Mole Marsh and Willancorah Swamp in the South Marsh between 1991 and 2008 (Bowen & Simpson 2010).

The North Marsh is currently shielded to a great extent from these severe sedimentation and erosion problems thanks to its position downstream of South Marsh. However, some indications of the adverse effects of these geomorphic processes is evident in discrete areas of the North Marsh, where sediments have begun to infill and block marsh channels, and where small erosion points have started to form in places where water can run from high points to low points on the floodplain or in channels. These recent observations in the North Marsh may be related to the increasingly poor infiltration role played by the much diminished and structurally altered South Marsh (Ralph 2008; T. Ralph pers. comm.).

Many areas of the South Marsh no longer support wetland vegetation. The remaining wetlands in this system are critical to the integrity of the system as a whole, including Back Swamp and the Jungle in the Marebone area. Most of the remaining wetlands in the South Marsh – including Mole Marsh, Willancorah, Buckiinguy Swamp, Monkey Swamp and wetlands on Mundooie – are there only because of banks and regulators designed to control erosion and stabilise these systems. Substantial structural work, including maintenance and modification of existing structures to control erosion, manage or respond to deposition, improve the capacity to distribute water, and restore fish passage, will be necessary for maintaining wetland values of the South Marsh. The swamps and marshes within the South Marsh depend on several streams, and are connected closely with one another. A strategic approach to restoration and maintenance work in the South Marsh and the marshes as a whole is essential.

2.4.3 The East Marsh

The East Marsh includes Gum Cowal–Terrigal Creek, Long Plain Cowal and Dusty Swamp. It supports river red gum forest and woodland, river cooba, water couch marsh and lignum shrubland. It has relatively deep and protected open water lagoons and supports important breeding colony sites and feeding habitat for colonially nesting species, including egret, heron, cormorant, spoonbill, ibis and darter. It supports threatened species including brolga, magpie goose, Australian painted snipe, Australasian bittern and blue-billed duck as well as species that are included in the migratory bird agreements between Australia and Japan, China and the Republic of Korea (JAMBA, CAMBA and ROKAMBA, respectively). The only recorded breeding of pied herons outside northern Australia occurred during the most recent major breeding event in 2000 (Jones unpublished reports). The East Marsh includes the Wilgara portion of the Macquarie Marshes Ramsar site.

According to vegetation mapping of the Wilgara portion of the Ramsar site, some change occurred in the extent of the vegetation communities between 1991 and 2008 and the condition of some vegetation types has declined (Bowen & Simpson 2010; Figure 2.6). Water couch marsh now has dryland chenopod shrubs occurring as a secondary species in the community. Widespread rain and some flows into the marsh maintained inundation for more than three months in the summer and autumn of 2007–2008 and supported a rejuvenation of water couch grassland in the Gum Cowal–Terrigal system in the East Marsh.

According to recent surveys of tree health in the river red gum community of Wilgara, condition ranged from 'fair' to 'stressed' and all trees were considered to be 'vulnerable' in terms of their regenerative potential. The largest – and probably therefore the oldest – trees tended to be relatively healthy; however, signs of stress were evident in some large trees and most of the younger ones. The understorey at these sites included water couch and lignum, indicating that Wilgara has not progressed as far towards the dryland state noted in some other parts of the marshes (L. Nairn pers. comm). The river red gum woodlands of the Wilgara portion of the Ramsar site were in 'intermediate' (10–40 per cent dead canopy) condition (Bowen & Simpson 2010). River cooba, a tree most often found in association with river red gum and lignum and often used by nesting waterbirds, including pied heron, is stressed and

dying in parts of East Marsh. The reason for this has not been investigated but likely causes include lack of water, grazing of seedlings and old age accompanied by little or no recruitment. The areas of the Gum Cowl–Terrigal system that were mapped as mixed marsh and water couch in 1991 (Wilson 1992) have now been mostly replaced by chenopod shrubland of black and soft roly poly (buck bush) (Bowen & Simpson 2010).

Long Plain Cowl and Dusty Swamp are inundated only in medium to large floods and under existing conditions providing such floods is beyond the scope of most managed environmental flows. They support river red gum woodland along channel margins, lignum shrubland, river cooba, coolibah, black box and myall woodlands, grassland and chenopods.

When inundated, they support mixed semi-aquatic species. These areas provide important habitat for colonially nesting and other waterbird species, waders, and threatened species including brolga, magpie goose and Australasian bittern. In 1991 the Long Plain Cowl supported approximately 365 hectares of lignum shrubland, 1278 hectares of mixed marsh/grassland and 3961 hectares of river red gum in a mosaic of river red gum, river cooba, coolibah woodlands and myall woodland (Wilson 1992). In 2008, chenopod shrubland had replaced all areas of lignum and mixed marsh, and invasive chenopod shrubs had colonised understorey of the river red gum woodlands, river cooba shrublands and coolibah and myall woodlands (Bowen & Simpson 2010).

Because the Wilgara Wetland has Ramsar status, legal as well as ecological reasons exist for ensuring maintenance of the site's wetland value. According to the results of recent work, the condition of river red gum woodlands located on the property Wilgara is better than that of river red gum woodlands located in many other parts of the marshes (Nairn 2008 and pers. comm.; Bowen & Simpson 2010).



Photo 16 Intermediate egret chicks in a nest in river red gum located in the Wilgara colony of Gum Cowl–Terrigal Creek (W. Johnson).



Photo 17 Coolibah woodland in Long Plain Cowl (W. Johnson).



1991 Vegetation map (Wilson 1992)



2008 Vegetation map (Bowen & Simpson 2009)

LEGEND

1991 vegetation communities

- black box
- common reed
- coolabah
- cultivated
- cypress
- grassland/cleared land
- dryland complex
- lignum
- mixed marsh / grassland
- myall
- open water
- poplar box
- river cooba
- river red gum
- stressed/dead trees
- water couch
- wilga

Additional vegetation communities in 2008

hatching indicates understorey colonised by chenopods or chenopods occurring as a secondary species

- black box_chenopod
- chenopod shrubland
- chenopod shrubland/grassland/cleared land
- chenopod shrubland/mixed marsh
- coolabah_chenopod
- lignum/chenopod shrubland
- myall_chenopod
- river cooba_chenopod
- water couch/chenopod shrubland

River red gum condition 2008

hatching indicates understorey colonised by chenopods

- good (<10% dead canopy)
- intermediate (10-40% dead canopy)
- intermediate/poor (40-80% dead canopy)
- poor (>80% dead canopy)

- major drainage
- intermittent
- Wilgara Ramsar site



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Figure 2.6 Changes in vegetation communities around the Gum Cowl–Terrigal Creek and the Wilgara portion of the Ramsar site in the East Marsh between 1991 and 2008 (Bowen & Simpson 2010).

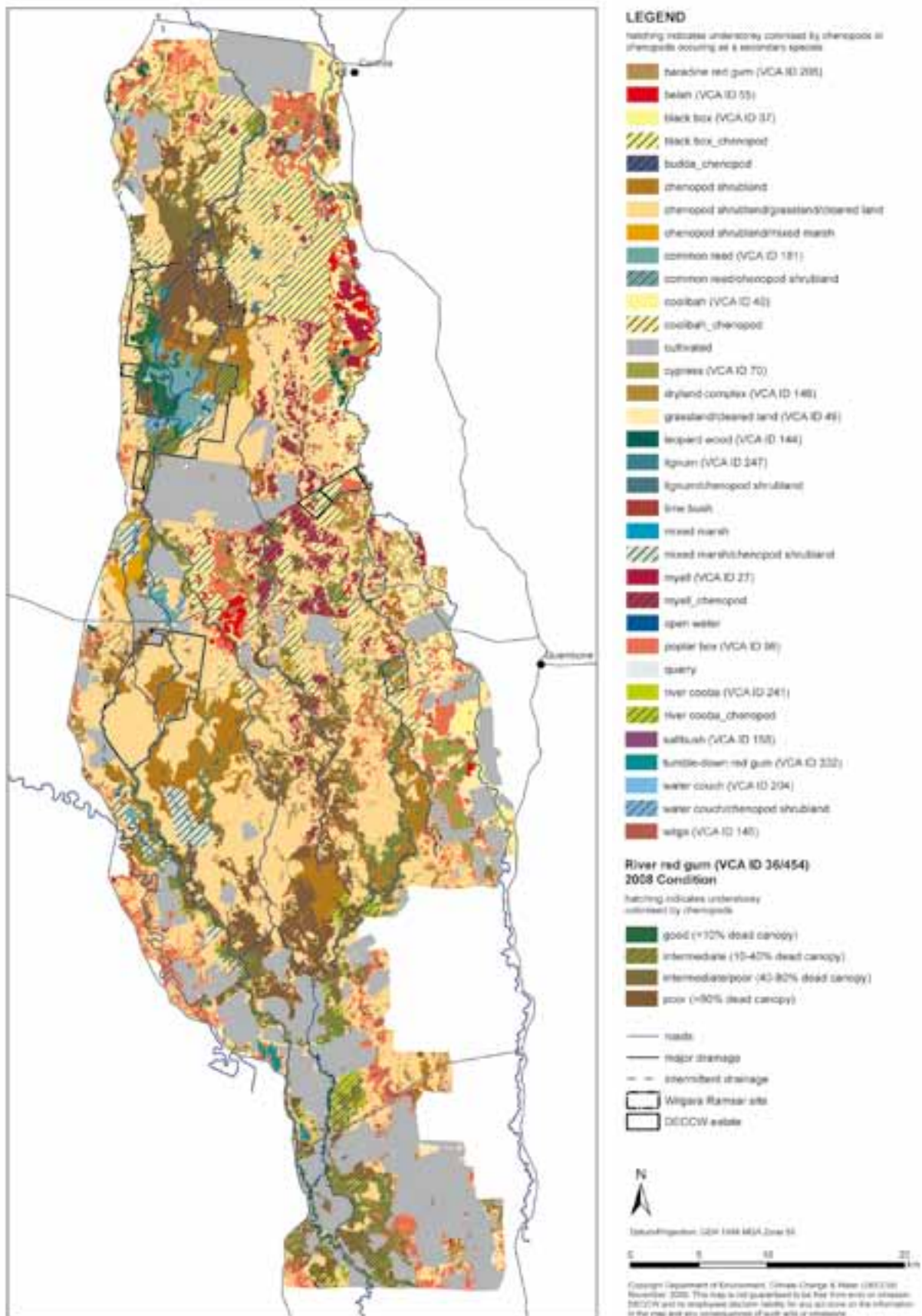


Figure 2.7 Vegetation communities in the Macquarie Marshes 2008 (Bowen & Simpson 2010).

2.5 Ecological objectives, priorities and targets

The desired ecological outcomes from managing the marshes are restoration and maintenance of critical ecological processes and functions, especially habitats.

The primary objective for the Macquarie Marshes for the duration of this plan is to support the ecological functions and processes necessary to sustain the diversity of type, and extent, of the ecological assets described within the plan. As further progress is made in recovering water for the environment, and depending on the climatic conditions experienced, enhanced ecological function and condition should begin to restore resilience to the marshes ecosystem. Objectives and priorities for restoring former wetlands areas that no longer support wetland values may then be possible.

The AEMP clarifies the broad management context within which water and land management decisions will be made. It also includes information that will inform actions in the context of the actual climatic circumstances and the environmental condition of the ecological assets at the time. Determining priorities for delivering environmental water will involve an annual planning process; the Macquarie–Cudgegong Environmental Flow Reference Group will be integral to this process. The Central West CMA will inform and facilitate land management investment and actions through its catchment action plan. Implementing the Macquarie Marshes Nature Reserve plan of management and on-ground actions within the Macquarie Marshes Ramsar site will be informed by the contents and objectives of this plan. I&I NSW (Fisheries) will lead the restoration of fish habitat.

The general water requirements of the ecological components contributing to the character and values of the marshes are already known. It is possible to give a reasonable assessment of the volume of water needed to maintain wetland functions and processes that support the assets identified in this plan, for a given area (tables 8.1, 8.2 and 8.3). It is also possible to assess the area and location of marsh that can be maintained with an available volume of water. Water availability and its implications for the marshes are discussed in the following sections of the plan.

3 Water

3.1 Flow regime

Flow regime organises, drives and defines the ecological systems of rivers and wetlands (Poff et al 1997; Puckridge et al 1998). A river's natural flow regime is driven by climate and runoff from the upstream catchment. The main components of flow regime are size, frequency, duration, timing and rate of change of flows (Poff et al 1997; Puckridge et al 1998). In the Macquarie Marshes, extent and duration of surface flows are crucial drivers of presence, type and vigour of wetland vegetation. The nature of flows depends on water from the river (the current flow), water stored in the soil (a result of recent years' flow history) and local rainfall. River regulation changes the hydrology, geomorphology and ecology of rivers by changing the size, duration, frequency and timing of flows. It often causes water quality to decline. These changes have a profound effect on riverine and wetland ecosystems (Johnson 2005).

According to several studies using both measured and modelled flow data, changes to flow regime in the Macquarie River have occurred, particularly since the construction of Burrendong Dam in 1967. They include:

- a significant reduction in moderate to high flows in the Macquarie River and end-of-system flows (CSIRO 2008)
- an increase in the average period between large flows and a reduction in the average volume of these events (CSIRO 2008)
- a reduction in the number of small flows likely to cause flooding passing the Oxley gauge (greater than 1000 megalitres per day) since construction of Burrendong Dam (Jenkins et al 2006)
- establishment of permanent low flows in previously intermittent streams (Grimes 2001)
- a significant reduction in frequency of floods in the marshes and the area inundated (Thomas et al in press).

3.2 Inundation mapping

The extent of inundation in the marshes, calculated using water and vegetation signatures, has been mapped for October each year from 1979 (the first year for which Landsat imagery is available) to 2006 using Landsat MSS and TM data (Thomas et al in press). Twenty-eight individual maps have been combined to produce an index of inundation frequency for different parts of the marshes, as shown in the map in Figure 3.1. The response of vegetation to recent inundation is included in the index because when only surface-water distribution is mapped, the effects of flow history are underestimated. There is a good relationship between the index of water distribution given for October each year and flows in the marshes during the six months before the date of the satellite image capture (Thomas et al in press).

The frequency and duration of inundation are indicators of the location of different wetland vegetation types (Figure 2.7). In the maps in figures 3.1, 3.2 and 3.3, areas of higher inundation frequency are coloured blue, mauve and pink, and represent areas that either sustain or have sustained semi-permanent wetland vegetation. This vegetation includes river red gum forest and woodland, water couch and common reed grasslands, cumbungi and lignum. Areas of lower inundation frequency are coloured pink, orange or yellow and represent larger floods that support ephemeral wetland vegetation. Coolibah, black box and myall woodland are more likely to occur in these areas.

In the three maps in Figure 3.2, inundation frequency is shown for three periods: 1979–87, 1988–97 and 1998–2006. During these periods, the area in the marshes that received high inundation frequency declined. This decline is closely related to water availability and flow

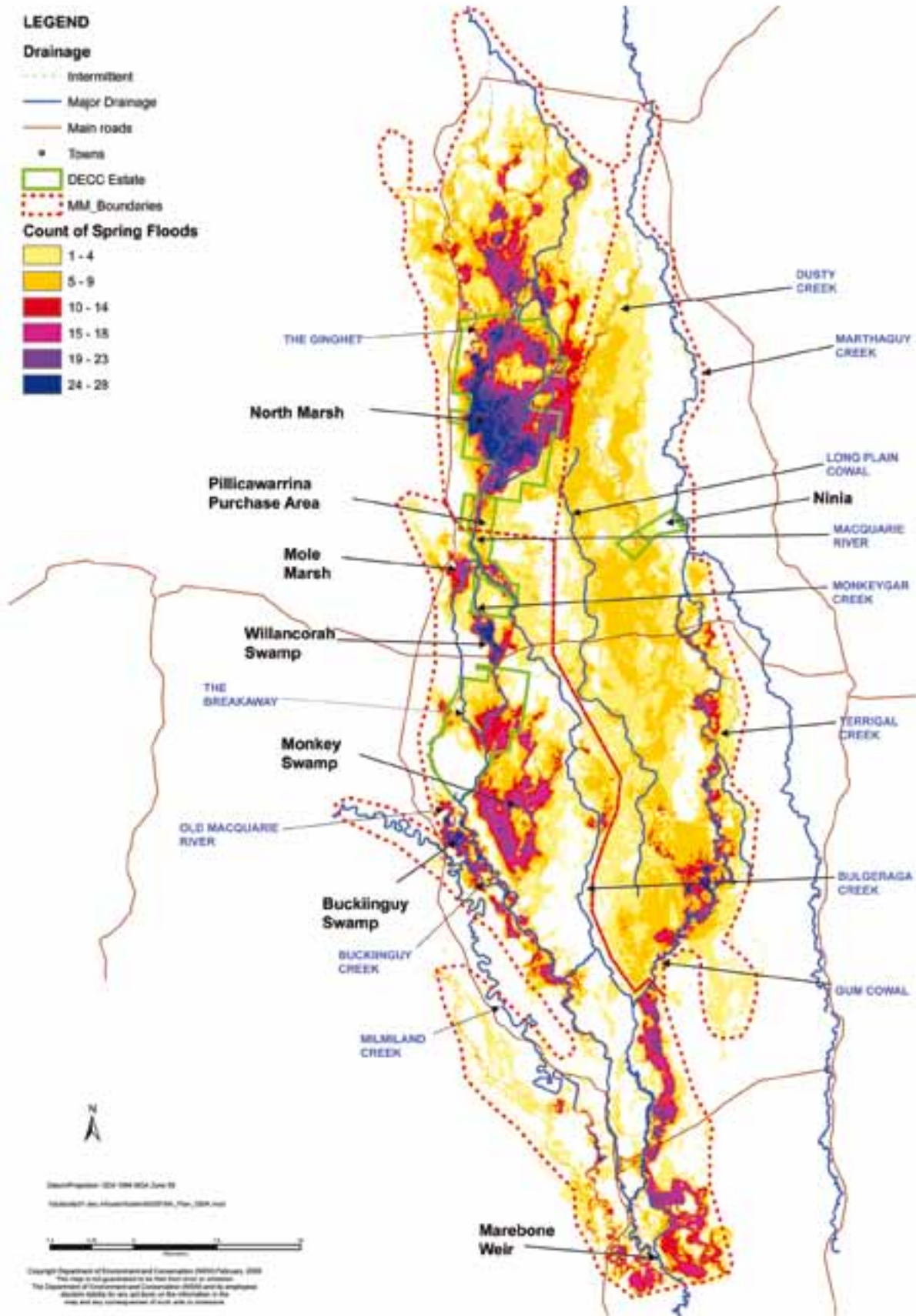


Figure 3.1 An index for the extent and frequency of inundation in the Macquarie Marshes from 1979–2006.

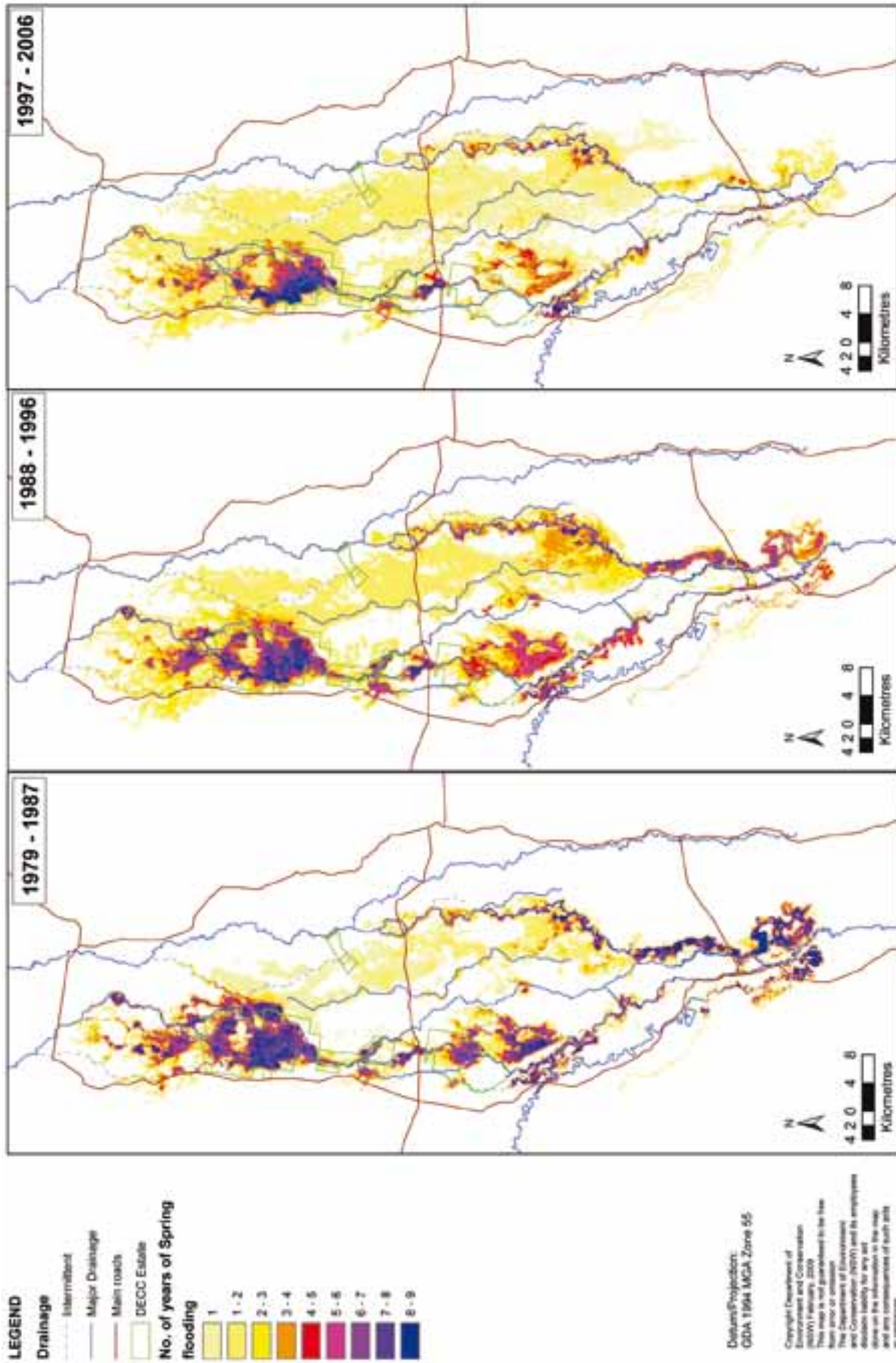


Figure 3.2 Changes in frequency and extent of Macquarie Marshes inundation. The area of low frequency inundation (yellow) increased in 1988–97 and again in 1998–2006 because of large floods that occurred in 1989, 1990, 1998 and 2000.

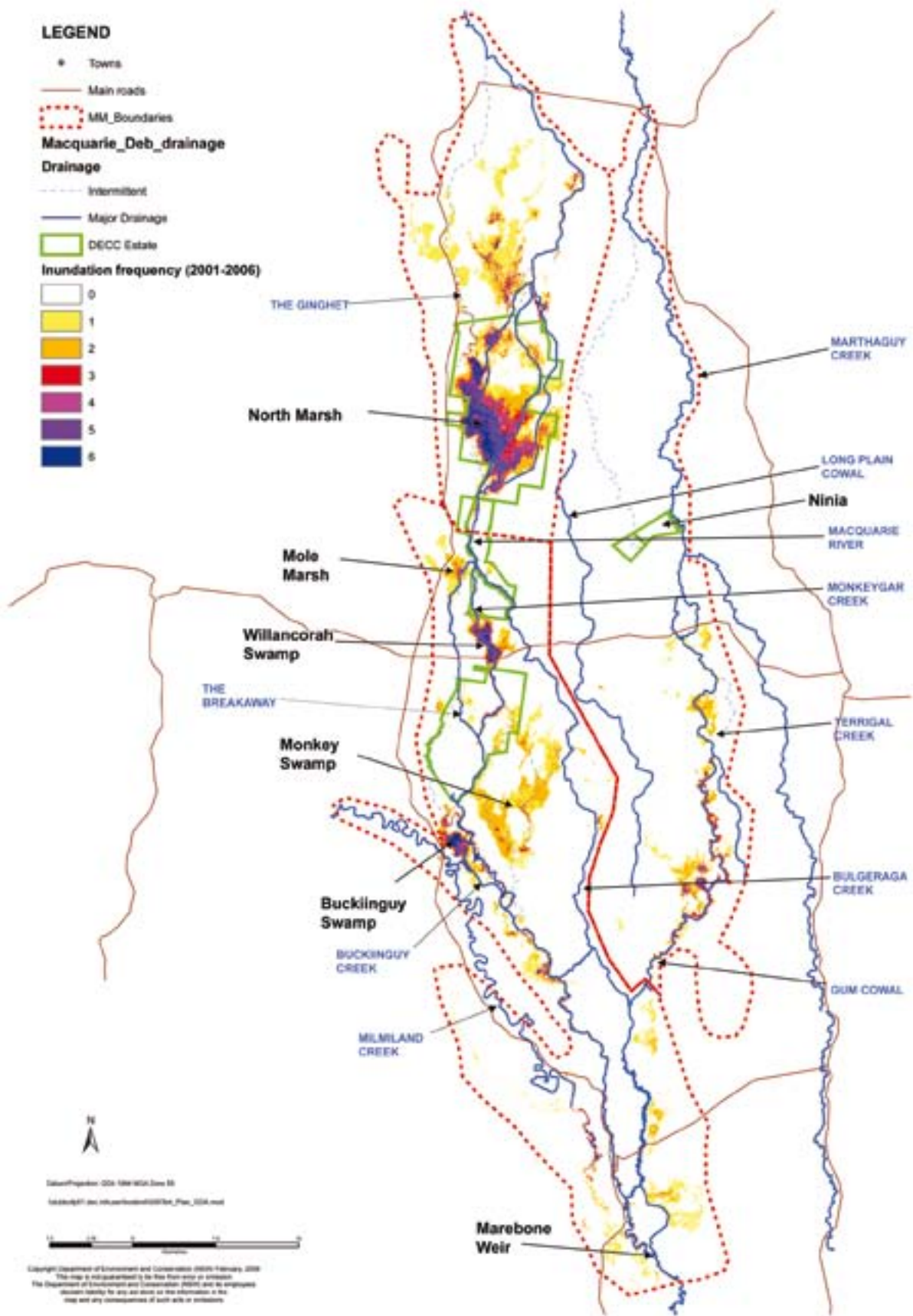


Figure 3.3 Extent and frequency of Macquarie Marshes inundation from 2001–06. Note the lack of large floods (yellow) and the small area of high inundation frequency (blue, mauve or pink).

size and is reflected in declining general security water allocations. Average allocations for comparable periods are:

- 1980–81 to 1987–88: 90 per cent
- 1988–89 to 1997–98: 83 per cent
- 1998–99 to 2006–07: 46.7 per cent.

There has been a decline in the area of the marshes that receives the flood frequency and duration necessary to maintain the values of identified semi-permanent wetland assets. In the maps, this area is represented in blue and mauve. The years from 1998–2007 (which had an average allocation of 47 per cent) began with three very wet years. Since 2001, conditions have been much drier and the average allocation between 2002–03 and 2008–09 was 12.7 per cent (figures 3.5, 3.6). It has been since 2001 that the decline of the marshes has been especially rapid.

3.3 Water allocation and availability

Until 1979, most irrigation in the Macquarie Valley was based on an individual entitlement to irrigate 162 hectares of land, although the volume of water that could be applied to the land was not specified (Sinclair Knight & Partners 1984). Entitlements to a set volume of water were introduced in 1979 (WRC 1979).

The Water Sharing Plan for the Macquarie–Cudgong Regulated Water Source 2003 now provides the framework for water allocation in the regulated rivers of the Macquarie Valley. Under this water sharing plan, the total share component of access licences plus the environmental water allowance are now about 899,453 megalitres. This consists of 14,265 megalitres for domestic and stock access licences; 22,681 megalitres for local water utility access licences; 19,419 megalitres for regulated river (high security) access licences; 632,428 megalitres for regulated river (general security) access licences; 50,000 megalitres for regulated river (supplementary water) access' licences and 160,000 megalitres for the environment (NSW Government 2003). The accounting rules for the environmental water allowance are the same as for general security entitlement (NSW Government 2003; column graph in Figure 3.4). In 2007, an additional 660 megalitres was granted to Nyngan's town water supply. These volumes do not include extraction from groundwater, from the unregulated tributaries of the Macquarie River or access to be licensed under the NSW Floodplain Harvesting Policy.

The water sharing plan also allows access licences to be purchased and dedicated to environmental purposes. As at 30 April 2010, 46,275 megalitres of general security and 1,442 megalitres of supplementary access water entitlements had been purchased by the NSW Government to manage as environmental water. At 30 April 2010 the Commonwealth Environmental Water holder held 55,873 megalitres of general security and 1,888 megalitres of supplementary access water entitlements in the Macquarie-Cudgong.

The available water determination and allocation of shares to general security access licences determines the amount of water available from regulated flows for the irrigation industry and the environment.

Measurements of water availability and use are often given as averages. For example, the average surface water availability in the Water Sharing Plan for the Macquarie–Cudgong Regulated Rivers Water Source 2003 is 1,448,000 megalitres per year, and average total diversions are 391,900 megalitres per year (NSW Government 2003). The long-term average annual flow to the Macquarie Marshes is 440,000 megalitres per year (Macquarie–Cudgong RMC 2001). However, long-term averages, especially in a highly variable system such as the

Allocation of water in the Macquarie Valley

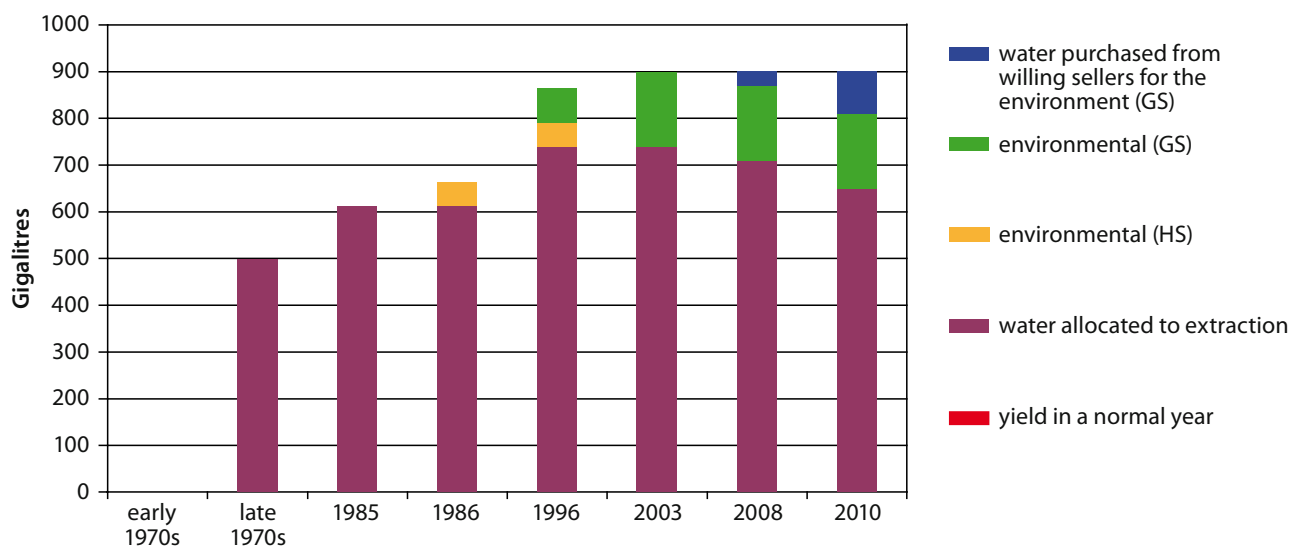


Figure 3.4 Distribution of the share components of access licences in the Macquarie River Regulated Water Source (NSW Government 2003).

Note: 'Total annual regulated yield of the Macquarie River in a normal year' was first calculated during the early 1970s by the Water Conservation and Irrigation Commission as being 406,000 megalitres (Sinclair Knight & Partners 1984) and was subsequently increased to 475,000 megalitres in 1979 by the Water Resources Commission. By that time, the estimated total requirement downstream of Burrendong Dam was 497,500 megalitres (WRC 1979, 1981, 1985).

Macquarie, can be misleading when managing at the shorter time scales relevant to agricultural and ecological systems.

The variability of the Macquarie River is demonstrated by the three measures of water distribution mentioned above:

1. Total system flows, calculated as surface water flow into storages and from tributaries downstream of Burrendong Dam.
2. Extractive use of licensed surface water shares in the regulated river.
3. Flows to the marshes at Marebone Weir, as shown in the column graph in Figure 3.5. A large proportion of total flow occurs in a relatively small number of years, and many years have extremely low flows. It is when low flows occur for several years in a row that the risk of managing according to long-term averages becomes evident.

Since 2001, the Macquarie's flows have been low by historical standards and surface runoff has been similar to that of the 1930s (State Water unpublished data). For the semi-permanent wetlands of the marshes, the sustained lack of flows has been especially damaging. However, between 1930 and 1950 at least seven moderate to large floods were recorded in the area now included in the northern nature reserve: in 1934, 1937, 1940, 1941, 1943 and 1948. More than half the area now included in the Macquarie Marshes Nature Reserve was classified as 'flooded channel country', 'swampy plain' or 'usually inundated' (Department of Lands 1941; circa 1950). The system is now under the additional pressure of Burrendong Dam harvesting flows from the largest and historically most reliable water supply in the catchment. Also, the river now supports a large irrigation industry as well as many other industries and larger urban populations. For the irrigation industry, which between 1980 and 2001 had an average of 88 per cent allocation to general security shares, a sudden shift to seven years of low flows and an average allocation of less than 13 per cent is equally serious.

Use of water in the Macquarie Valley

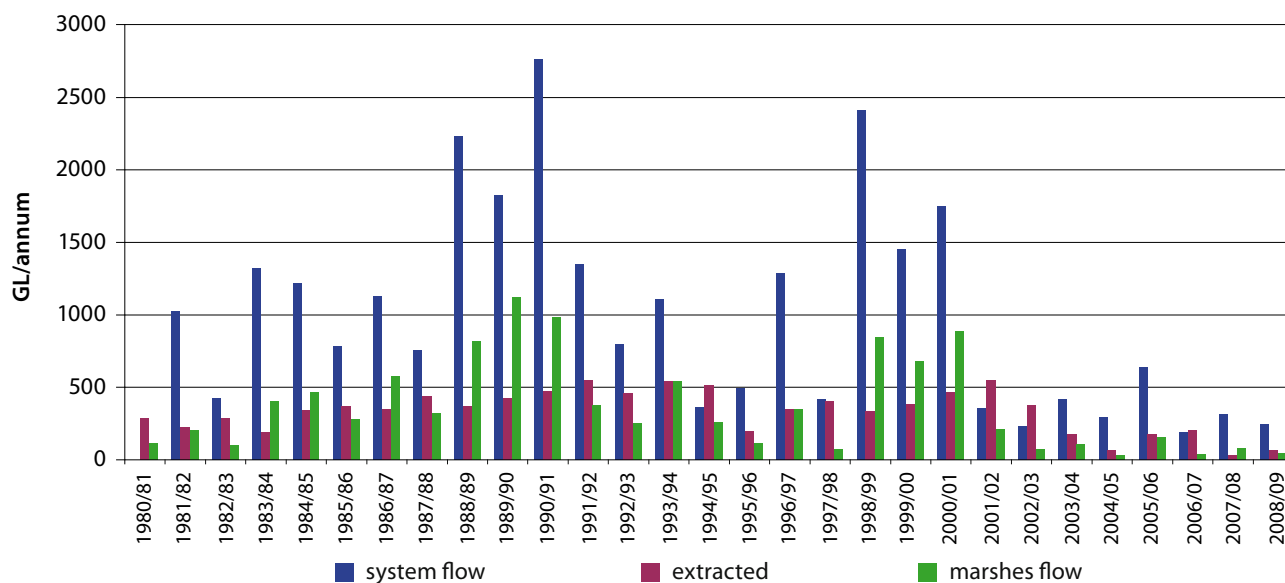


Figure 3.5 Assessed and estimated water distribution and use in the Macquarie Valley, 1980–2008 (State Water).

Note: Extractive use includes licensed surface water extraction from the regulated river. It does not include extractions from unregulated tributaries, groundwater extractions from aquifers linked directly to the river, or floodplain harvesting. Total system flows are greater than the combined total of extractions and flows to the marshes because of operational losses and extensive floodplain and distributary system flows during high flows.

3.4 Climate variability and climate change, and the Macquarie Valley

According to modelling by the CSIRO, the recent climate average (1997–2006) was similar to the long-term average conditions (CSIRO 2008). Also, future runoff in the Macquarie Valley is more likely to decrease than increase in response to climate change. CSIRO has considered climate scenarios for 2030 ranging from extreme wet to extreme dry, and a mid-range ‘best estimate’ are as follows:

- extreme wet: 25 per cent *increase* in surface water availability, 12 per cent increase in total diversions, and 41 per cent increase in end of system flows
- extreme dry: 25 per cent *decrease* in surface water availability, 16 per cent decrease in total diversions, and 28 per cent decrease in end of system flows
- best estimate: 8 per cent *decrease* in surface water availability, 4 per cent decrease in total diversions, and 9 per cent decrease in end of system flows

Water-resource development has already increased the average period between important inundation events for the Macquarie Marshes (200 gegalitres past Oxley between 1 June and 30 November), from 2.2 years to 4.7 years, and has reduced the average volume of these events from 328 gegalitres to 278 gegalitres per event (CSIRO 2008). Under the best estimate for climate in 2030, the average period between important inundation events in the Macquarie Marshes would increase by a further 10 per cent from the current level. The number of flood events would be 5 per cent smaller, and average annual flood volume would be reduced by 16 per cent. The scale of waterbird breeding events is expected to be reduced.

According to the 'extreme dry' estimate for climate in 2030, the average period between events would be increased by 24 per cent and the average annual flood volume would be reduced by 38 per cent. The changes that have already been experienced have had serious consequences for all aspects of wetland ecology. Under projected drier conditions, these consequences are expected to increase (CSIRO 2008).

3.4.1 Future water availability

Wetter or drier climatic conditions do not have the same relative effect on the availability of environmental water that they have on extractive water. Under wet conditions, the environment receives proportionally more of the available surface water than it does under dry conditions. Under dry conditions, the environment receives proportionally less water – a smaller proportion of a smaller total volume (CSIRO 2008) – due to reduced unregulated flows from tributaries and fewer dam spills (both of which benefit the environment). For the purposes of this plan, allocations to general security are used as a surrogate for general surface water availability. This probably underestimates the effects of a drying climate on the environment due to the greater proportional impact on the environment during dry periods described above.

In Figure 3.6, the annual allocation to general security since 1980 is shown, with averages calculated for decades as well as for the periods that correspond to the inundation maps at Figure 3.2. The graph also includes the average allocation since 2002–03, the beginning of the current dry period in terms of water allocations. Examining water availability for periods of a decade or less makes sense at both social and ecological scales: a period of water shortage such as the one experienced since 2002 is damaging for both river-dependent ecosystems and the irrigation industry.

Macquarie Valley General Security allocation history

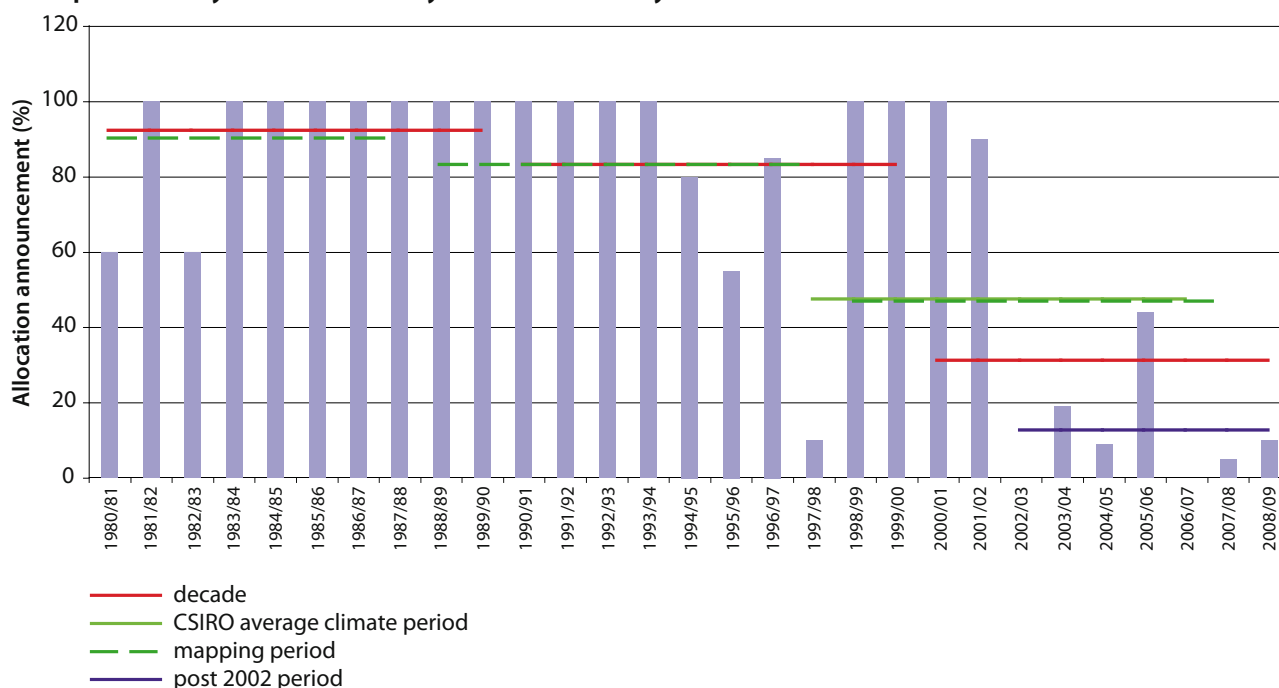


Figure 3.6 Allocations to general security shares expressed by decade, by inundation mapping periods and since 2002.

Climate change predictions for the Macquarie Valley

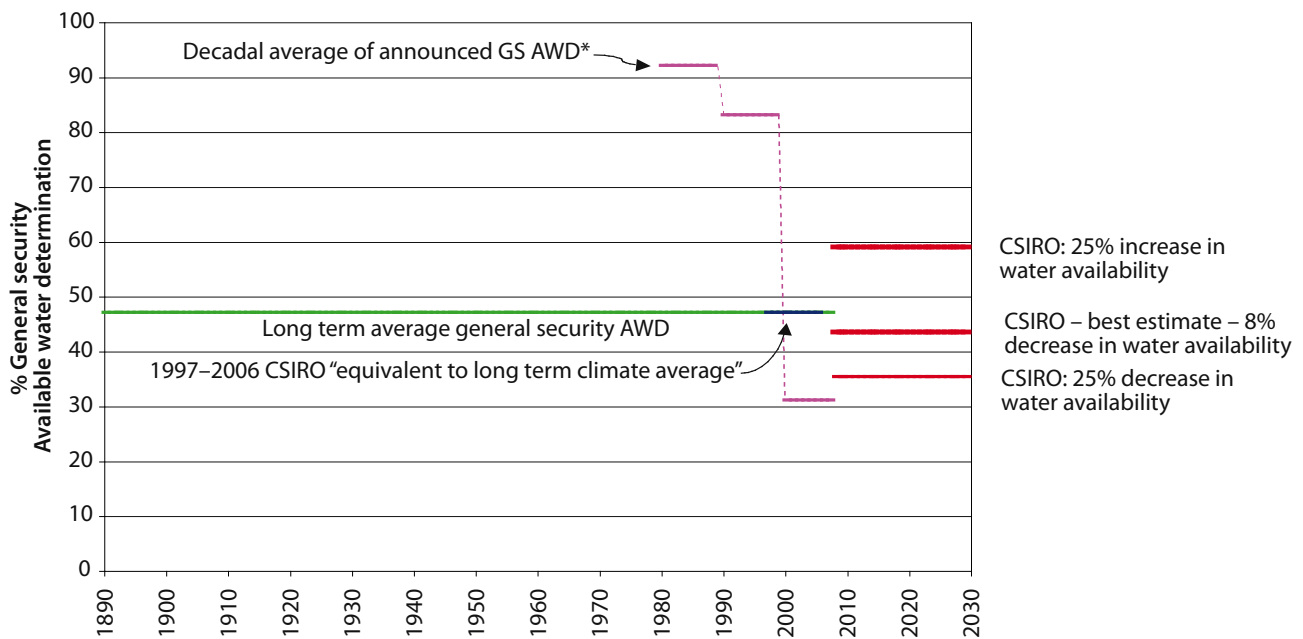


Figure 3.7 A comparison between the CSIRO forecasts for 2030 with surface water availability (represented by general security shares) in the Macquarie Valley since 1980. The variability experienced since 1980 exceeds the forecasts for 2030, on both the high side and the low side.

* GS AWDs = general security available water determinations

It is unlikely that rainfall conditions will return to the ones experienced during the 1970s, 1980s and 1990s (CSIRO 2008). Planning and management for the future of the Macquarie Marshes should take into account a range of possibilities, from a return to somewhat wetter conditions (which are nevertheless likely to be drier than the period from 1980–2000) to a continuation of existing or drier conditions. The scenarios provided by the CSIRO, represented in Figure 3.7, can inform water planning.

3.5 Water requirements of ecological assets

Scientific and technical studies now underway will help develop a better idea of the area of semi-permanent wetland that needs to be protected to maintain critical ecological functions and habitats in the marshes. Already, studies of vegetation extent, type and condition as well as waterbirds, native fish, microinvertebrates, soil nutrients, organic matter, flood patterns and groundwater levels show a declining trend and a major shift in the state of the system (Kingsford & Auld 2005; Jenkins et al 2004, 2009; Bacon 2004; Bowen & Simpson 2010; DECCW unpublished data). Large areas of semi-permanent wetland vegetation are being colonised, or have already been replaced, by dryland species (Bowen & Simpson 2010). This change in vegetation type indicates that most of the ecosystems of the marshes need more water, more regularly, than they have received since 2001.

Microinvertebrates underpin the food web, and their densities in recently inundated floodplain habitats in the marshes are among the highest in the world. They are eaten by all native fish species after hatching as well as by macroinvertebrates and some waterbirds, such as pink-eared ducks (Jenkins & Wolfenden 2006). Food availability both before and during nesting and egg laying is critical for successful waterbird breeding. The high densities of invertebrates and aquatic plants help to explain the ability of the marshes to support such large waterbird breeding events. Regular inundation is an important ecological requirement to maintain microinvertebrate diversity and density. Samples taken in 2005 demonstrate that the longer the period between flooding events, the greater the loss of organic matter and microinvertebrate diversity and density (Jenkins & Wolfenden 2006). Lack of regular inundation is a threat to maintenance of the high densities of microinvertebrates required to sustain large numbers of breeding waterbirds (Jenkins & Wolfenden 2006).

The locations and water requirements of the assets and values that contribute to the character of the marshes are known. The best knowledge available indicates that restoring and maintaining critical ecological functions and habitats of semi-permanent wetland assets identified in this plan will require inundation for a minimum of four months, and preferably six months, between July and April, at least seven and preferably eight years in 10 (Roberts & Marston 2000; Jenkins & Wolfenden 2006). Inundation every year would be beneficial for some parts of the system (Roberts & Marston 2000).

The volume of water from regulated sources needed to inundate a specific area of the marshes for a given time varies. It depends on many factors, including the location of the area receiving water, time of year, recent rainfall in the marshes, volume of unregulated flows, soil type, vegetation cover and flow history. Estimates of required volumes are based on the assumption that some flows to the marshes will be available as relatively high flows, for several consecutive months, to ensure that water is distributed to designated areas and to provide the required duration of inundation.

The soils of the marshes are estimated to have the capacity to hold at least 10 megalitres per hectare and up to 15 megalitres per hectare (P. Bacon pers. comm.). Once the soil profile in the marshes becomes very dry, a large volume of water is needed to replenish it before surface flows can be maintained.

The wetter areas of the marshes need a lower volume per area to maintain an appropriate wetland condition than the increasingly large, and increasingly dry, areas beyond them. For example, in 2008, an environmental flow release targeted a small area in the wetter part of the North Marsh, taking particular care to avoid spreading water over a large area of dry marsh and achieved a volume to area ratio of about 5 megalitres per hectare. The environmental release in 2005, made in combination with tributary flows, had generally higher inflow rates and targeted a larger area of dry marsh. Overall, this release achieved a volume to area ratio of about 9 megalitres per hectare. Figure 3.8 shows volume to area ratios up to 12 megalitres per hectare. During the 2009 environmental flow, almost 20 megalitres per hectare was required to inundate about 1000 hectares for three months. According to CSIRO forecasts, drying will probably increase (CSIRO 2008). It is likely that the drying will result in longer periods without water, drier conditions in the marshes and a higher volume-to-area ratio.

An important part of operational planning will be to obtain accurate information about the volumes required to provide suitable flow regimes in different parts of the marshes under a range of climatic conditions. Digital elevation and hydrodynamic models will assist environmental flow managers to narrow the range of volumes for any known set of antecedent conditions. These are currently being developed by DECCW.

Indicative inflow: inundation relationship

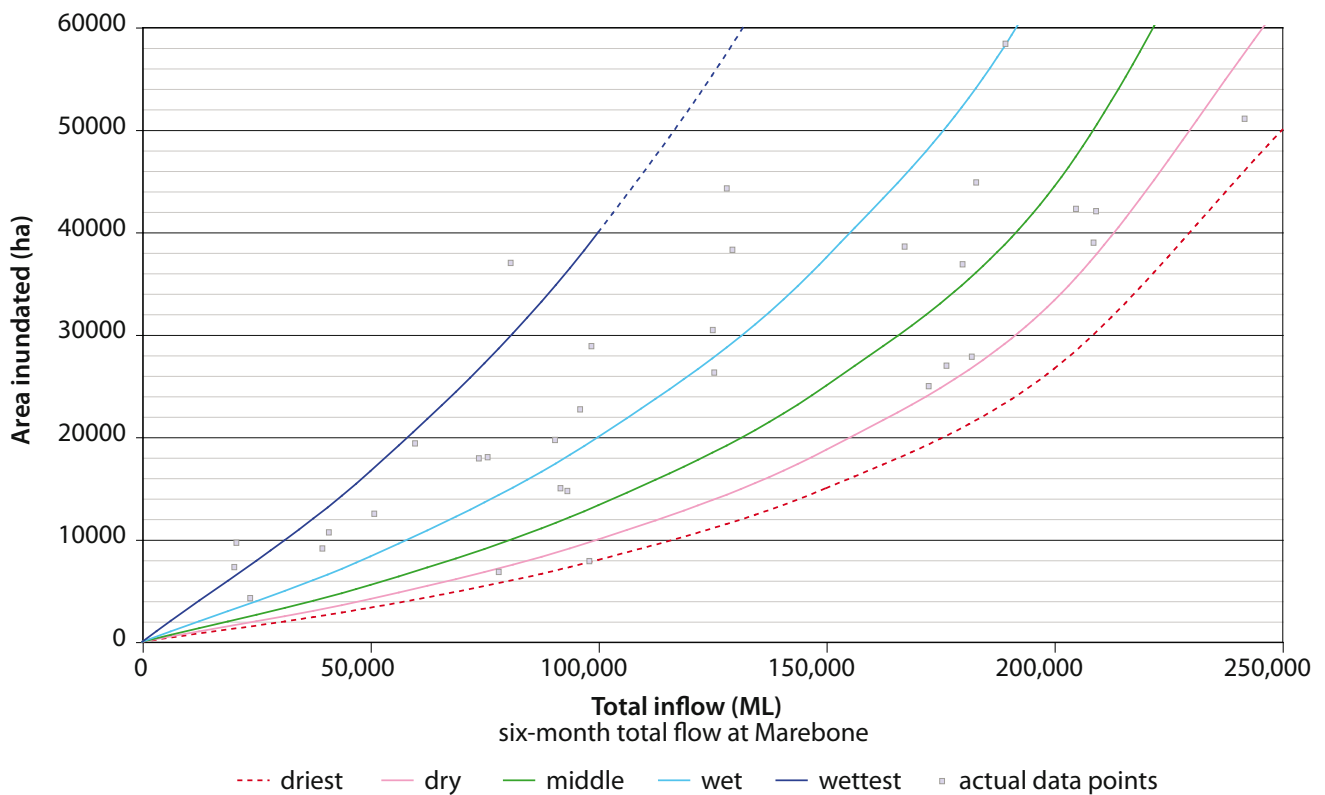


Figure 3.8 The relationship between inflows and area inundated. The volume is total flows for six months before the mapping of the inundated area.

3.6 Managing water in the marshes

One approach to managing water in the marshes is to identify an area to be maintained and calculate the volume needed to achieve it. Another approach is to calculate the amount of water likely to be available under different climate scenarios and identify how many hectares of wetland can be maintained for the given volume. In prioritising wetland areas for water delivery, consideration will be given to the ecological importance of each area and its importance for the character of the marshes, land management practices, legislative status, ease of water delivery and overall likelihood of achieving ecological outcomes and objectives.

3.6.1 Managing for an identified area of wetland (area based)

The area of semi-permanent wetland vegetation in the marshes in the early 1990s was mapped as about 72,000 hectares (Wilson 1992). The condition of most of this vegetation is declining (Nairn 2008; Bowen & Simpson 2010). It will be difficult to arrest this decline under the climatic conditions that have been experienced since 2000, or those predicted (CSIRO 2008). For example, restoring and maintaining functions and habitats in 30,000 hectares of semi-permanent wetland vegetation will require flows to the marshes of between 200,000–300,000 megalitres over six months, at least seven years out of 10. The marshes have not received this volume in a six-month period since early 2002.

3.6.2 Managing by availability of water (volume based)

The second approach is to calculate how many hectares of the identified assets and values of the marsh can be maintained to protect critical ecological functions and habitats, using a nominated amount of water. The amount of water available cannot be predicted accurately, although current trends and forecasts suggest that it will be less than the long-term average (CSIRO 2008).

The amount of water needed from regulated supply for the marshes will depend on climatic conditions. In the line graph in Figure 3.8, the broad relationship between inflows to the marshes and area inundated is shown. The wetter the climate, the less precise the relationship between inflows to the marshes and area inundated. During wet times, flows are higher; unregulated flows and rainfall in the wetlands provide more water; floods are longer and more extensive, and water flows through the marshes to the Barwon–Darling River. The relationship is more precise during drier climatic conditions, which are forecast for the Macquarie Valley. These are the conditions under which environmental flow management will be most significant.

3.7 Scenarios of water availability

Four scenarios of water availability have been selected to estimate the area of semi-permanent wetland that could be maintained under different conditions. The scenarios use allocation to general security and the environmental water allowance as an indicator of water availability, and are based on CSIRO’s Murray–Darling Sustainable Yields Project, long-term average conditions, and allocations to general security shares since 2002. The total regulated environmental share at the time of publication of the plan is 262,148 megalitres, consisting of 160,000 megalitres provided in the water sharing plan. As at 30 April 2010, 46,275 megalitres of general security entitlement has been purchased by the NSW Government, and 55,873 megalitres of general security entitlement is held by the Commonwealth Environmental Water Holder.

Table 3.1 The area of semi-permanent wetland estimated to be supported under various scenarios for water availability.

| Percentage allocated to general security shares | Megalitres per hectare | Regulated environmental share (ML)* | Number of hectares estimated to be maintained with no unregulated flow | Number of hectares estimated to be maintained with unregulated flow double (for scenario 1) or equal to the volume of regulated flow |
|---|------------------------|-------------------------------------|--|--|
| 60 | 7 | 157,289 | 22,470 | 44,940–67,410 |
| 40 | 8 | 104,859 | 13,107 | 26,215 |
| 25 | 9 | 65,537 | 7282 | 14,564 |
| 13 | 10 | 34,079 | 3408 | 6816 |

* assuming 262,148 ML total

The first three scenarios are for available water determinations allowing general security allocations of 60 per cent, 40 per cent and 25 per cent. The figure of 25 per cent strikes a middle line between the CSIRO driest case and allocations since 2001–02. This assumes that water availability will increase from recent low allocations. To account for the possibility that they will not, a fourth scenario – 13 per cent – using average general security allocations between 2001–02 and 2007–08 has been included. These scenarios assume a period of allocation at this level for 10 years, chosen as being a socially and ecologically relevant period. It is expected that some unregulated flows will also reach the marshes, although a great deal of uncertainty surrounds this figure. Estimates are provided for two unregulated flow scenarios: (1) volumes equal to the amount of regulated flow, and (2) no unregulated flow, as shown in Table 3.1.

3.7.1 Scenario 1: 60 per cent allocation to general security access licences and the environmental allowance

This percentage is near the upper estimate for water availability in the CSIRO forecasts. Under these conditions, the existing regulated environmental share of 262,148 megalitres will provide about 157,289 megalitres of available regulated water. Assuming that about 7 megalitres per hectare are needed under these conditions, and that no unregulated flows occur, it is possible that functions and habitats will be able to be maintained in an area of about 22,000 hectares of semi-permanent wetland vegetation. With the addition of twice the volume of unregulated flow, it is possible that functions and habitats will be able to be maintained in an area of about 67,000 hectares of semi-permanent wetland vegetation.

3.7.2 Scenario 2: 40 per cent allocation to general security access licences and the environmental allowance

Under these conditions, the existing regulated environmental share of 262,148 megalitres will provide about 104,859 megalitres of available regulated water. Assuming that about 8 megalitres per hectare are needed under these conditions, and that no unregulated flows occur, it is possible that functions and habitats will be able to be maintained in an area of about 13,000 hectares of semi-permanent wetland vegetation. With the addition of an equivalent volume of unregulated flow, it is possible that functions and habitats will be able to be maintained in an area of about 26,000 hectares of semi-permanent wetland vegetation.

3.7.3 Scenario 3: 25 per cent allocation to general security access licences and the environmental allowance

Under these conditions, the existing regulated environmental share of 262,148 megalitres will provide about 65,537 megalitres of available regulated water. Assuming that about 9 megalitres per hectare are needed under these conditions, and that no unregulated flows occur, it is possible that functions and habitats will be able to be maintained in an area of about 7000 hectares of semi-permanent wetland vegetation. With the addition of an equivalent volume of unregulated flow, it is possible that functions and habitats will be able to be maintained in an area of about 14,000 hectares of semi-permanent wetland vegetation.

3.7.4 Scenario 4: 13 per cent allocation to general security access licences and the environmental allowance (from 2001–02 to 2007–08)

If conditions continue as they have since 2001–02, with general security allocations of about 13 per cent, the current regulated environmental share of 262,148 megalitres will provide about 34,079 megalitres of environmental water. Assuming that about 10 megalitres per hectare are needed under these conditions, it is possible that functions and habitats will be able to be maintained in an area of about 3400 hectares of semi-permanent wetland vegetation. With the addition of an equivalent volume of unregulated flow it is possible that functions and habitats will be able to be maintained in an area of about 6800 hectares of semi-permanent wetland vegetation.

It is important to note that the four scenarios outlined above are indicative only, and are in the context of the regulated environmental water share at the time of writing of this plan. Additional water recovered under existing government initiatives will add to the environmental share, and increase the area able to be maintained under each scenario. The scenarios are also sensitive to the assumed volume of unregulated flow which may be much greater than the volume of regulated flow (and therefore greater than assumed in these scenarios), particularly in wetter years.

While the scenarios are indicative only, they demonstrate the necessity of prioritising assets for restoration, maintenance and protection. *Duration* and *frequency* are critical parts of the flow regime (Puckridge et al 1998). Long flows that are too infrequent are no more effective in maintaining important wetland values than frequent flows that are too short. Both duration and frequency can be important to ensure that seedbanks and eggbanks are maintained, which is critical to long term sustainability of wetland values.

Ephemeral wetland vegetation communities, except for areas on the fringes of semi-permanent wetlands, will rarely receive managed flows from allocated shares. In most cases, inundation of these communities will come from unregulated flows.

4 Water supply and management

4.1 Environmental water

The Macquarie–Cudgegong water sharing plan provides an environmental water allowance of 160,000 megalitres (NSW Government 2003). At the time of writing the plan, 102,148 megalitres of general security share and 3330 megalitres of supplementary share had been purchased and registered to the holdings of the NSW and Australian governments. Additional water may also be returned to the environment as a result of modernisation of the irrigation industry and river operations underway in some parts of the Macquarie Valley, although it is unclear how much water will be returned. The Basin Plan, in setting the new sustainable diversion limits for the basin and the Macquarie catchment, will influence the amount of water available for environmental purposes.

4.2 The available water determination

The process of allocating water for extraction and the environment is called the available water determination (AWD) and is undertaken by the NSW Office of Water (NOW) after a resource assessment. Under the process, the agency manages the system so that allocations of 100 per cent for domestic and stock, town water supplies and high-security shares are maintained throughout a repeat of the worst period of low inflows – ‘drought of record’ – in this water source. The ‘drought of record’ period is about two years in the Macquarie and seven years in the Cudgegong, based on 110 years of inflow records, from 1890–2000.

The available water resource is calculated by adding the volume of water stored in Burrendong and Windamere dams and the likely future minimum inflows, equal to the worst period of low inflows. From the available resources, NOW provides for essential requirements – which include basic rights; full allocations for stock and domestic, town water and high security shares; delivery and storage losses; and any water allocations remaining from previous available water determinations – before allocating to the environmental water allowance and general security shares.



Photo 18 Burrendong Dam, at less than 5 per cent capacity, in February 2007 (Grenville Turner).

This process differs from the available water determination that NOW undertakes in the Gwydir and Namoi valleys. There, the agency considers for allocation only water held in the dam at the time of the assessment, but is consistent with the resource assessment processes in southern NSW regulated rivers. Some anticipated future inflows are indirectly included in the assessment by discounting the budget for the essential requirements. This approach means that when inflows are less than or equal to the lowest on record (which has been the case in Burrendong Dam at times since 2002), essential requirements can be met, and often some general security water is available from new inflows. In 2007 the Macquarie–Cudgegong regulated rivers water sharing plan was suspended because insufficient reserves in storage meant that the ability to deliver full essential requirements was not assured. Access to the environmental and extractive carryover accounts was suspended, although later allowed as the resource availability improved, while high security users and town water supplies experienced restricted allocations.

Future reviews of the water sharing plan will need to consider the implications of the resource assessment method in dry-flow sequences not previously experienced and will need to be consistent with sustainable diversion limits to be established under the Basin Plan (Commonwealth *Water Act 2007*). The water sharing plan is to be reviewed in 2014.

4.3 Capacity of the Burrendong Dam outlet

Burrendong Dam has insufficient outlet valve capacity to meet high simultaneous demand for extractive and environmental water. The maximum rate of release from the dam is 8200 megalitres per day at full supply level, and peak summer extractive demand is typically between 4000 and 7000 megalitres per day. In the past, extractive requirements have been given priority for valve space (Keyte & Johnson 1997, 1998, 1999, 2000). Operational sharing of valve capacity might have to be specified in similar terms to channel capacity where this is constraining environmental or other operational releases, or the capacity of the valves might have to be increased.



Photo 19 A view downstream at the Burrendong Dam outlet (Grenville Turner).

4.4 Water quality, including cold water pollution

Although release of cold water low in oxygen from the bottom of Burrendong Dam does not affect the river's temperature as far downstream as the marshes, it has a significant effect on the aquatic ecological community for some distance downstream of Burrendong Dam. State Water is investigating options to manage this.

Water quality guidelines, objectives and targets are provided in the National Water Quality Management Strategy, the Natural Resources Commission Statewide Targets, and the Central West CMA's catchment action plan (CAP). Specific targets and objectives for the catchment within the CAP include having water temperature maintained or restored to within 2 degrees Celsius of median levels (ANZECC & ARMCANZ 2000), reducing the duration of blue-green algal blooms above high alert level, no detection of hazardous chemicals (ANZECC & ARMCANZ 2000) and reducing faecal coliforms to below primary contact levels at key sites located in the catchment (Central West CMA 2007). Meeting these targets is consistent with restoring critical ecological functions and habitats in the Macquarie Marshes.

4.5 The flood mitigation zone of Burrendong Dam

Burrendong Dam can store an additional 489,000 megalitres (42 per cent) of its capacity above the spillway. This is known as the flood mitigation zone (FMZ). The combined total of the conservation storage below the spillway (1,189,000 megalitres) and the FMZ storage is about 1,678,000 megalitres. The rules governing the FMZ are called *air space operations*. Using these rules, when the dam is between 100 and 120 per cent capacity, water releases are calculated to achieve a flow rate of 5000 megalitres per day at Warren. Between 120 and 130 per cent capacity, the target flow is 12,000 megalitres per day, and between 130 and 142 per cent capacity, the target flow is 18,000 megalitres per day, both at Gin Gin. If the dam is in the FMZ and is endangered as a result of more inflows that cannot be contained in the air space created by gate operation, then *flood operations* allow for the water to be released in a way that maintains the safety of the dam. The spillway's capacity is 1,200,000 megalitres per day.

Water stored in the FMZ cannot be allocated to extractive use, except for stock and domestic replenishment and opportunistic supplementary water extractions for irrigation. The water temporarily stored in the FMZ is for the environment. Historically, the storage has been returned to 100 per cent as soon as practicable and water from the FMZ has been released to the environment regardless of antecedent conditions, a practice that the agency developed during the 1980s after successive wet years. There is an opportunity to review management of the FMZ if increased flexibility of releases was considered to provide benefits to the environment.

4.6 The Marebone Choke

The Marebone Choke is a reference to impediments downstream of Marebone Weir that constrict flows in the river and on the floodplain. Prolonged flows of more than about 4000 megalitres per day at Marebone Weir cause flooding of Gradgery Lane (Johnson 2005). High priority is given to keeping environmental flow rates lower than would otherwise be the case in order to keep Gradgery Lane free of flooding, typically resulting in flows of less than 4000 megalitres per day at Marebone Weir. The range of flows that can be delivered to the Macquarie Marshes is thereby limited. The NSW Wetland Recovery Program has completed works to improve the hydraulic efficiency of the Macquarie River in the Marebone area by removing willows that block the channel. Gradgery Lane has also been upgraded under the program to allow regulated flows of up to 12,000 megalitres per day without impeding the

road. A floodplain management plan made under the *Water Management Act 2000* now governs the regulation of structures within an identified floodway, allowing their impact on flood flows to be addressed.

4.7 The effects of weirs and pumps on fish

Reasons for the decline in native fish in the Macquarie River, as in other highly regulated rivers, include flow regulation; habitat degradation; reduced water quality; pest species; over-fishing; disease; loss of genetic integrity through stocking; and structures such as dams, weirs, culverts and river crossings forming barriers that prevent fish moving throughout the river (MDBC 2003). Fish attempting to migrate upstream become easy prey for birds as they gather downstream of barriers.

Weirs can also cause physical injury to fish attempting to migrate downstream. The weirs are of two designs: (1) overshot, whereby the water passes over a crest, and (2) undershot, whereby the water passes under a gate (DPI 2007). Fish can be injured as they pass over the crest and fall to the bottom of the weir, and by turbulence and pressure changes as water passes under the gate. Marebone Weir has an undershot design that is known to cause high mortality among larval and juvenile fish; for example, 95 per cent among golden perch (Baumgartner et al 2006). A fishway is currently being constructed on the Marebone Weir to deal with this issue.

Most irrigation occurs during the warmer months and coincides with spawning and migration, and it is highly likely that fish are being extracted from the river through channels or pumps. Even if the fish are not injured, it is very unlikely that they will be able to return to the river (MDBC undated). The NSW DPI, the Australian Cotton CRC and Murrumbidgee Irrigation are undertaking collaborative research in order to investigate this (DPI 2005).



Photo 20 A view downstream at Marebone Weir. Left: irrigation supply channel; centre: the Macquarie River; right: Marebone Break (Grenville Turner).

4.8 Structures for managing water in the marshes

Structures including banks, weirs, regulators and diversion channels in the marshes from Marebone Weir to North Marsh are a subject of much discussion and some controversy (Hogendyk 2008; Steinfeld & Kingsford 2008). These works are used for flood protection, erosion control, wetland stabilisation, and to provide stock and domestic and irrigation water. During 2008 and 2009, the NSW Office of Water led a strategic compliance project to assess the role, effectiveness and status of the structures and determine their effect on flows destined for the marshes. During the project, 119 structures were investigated and regulatory action was taken on 28 of them. A number of the structures identified and investigated had been constructed by, or on the advice of, the former Department of Land and Water Conservation to prevent erosion (NSW Office of Water 2009).



Photo 21 Banks located in South Marsh (W. Johnson).



Photo 22 Irrigation development in the Marebone area, showing the Macquarie River in the middle distance (Grenville Turner).



Photo 23 Development in the marshes located in the Marebone area. An identified floodway in centre has been cleared, and natural drainage patterns remain evident (W. Johnson).

4.9 Measurement of water extraction

Measurement of water extractions, including the reliability of meters, has been a matter of concern since volumetric allocations were introduced (Minister for Water Resources 1986; DLWC 1995). Measurement of all water extractions, including regulated river allocations, groundwater use, unregulated flows and floodplain harvesting, must be as accurate and reliable as possible. The Australian Government has developed a draft national metering standard framework (NMSF), and aims to provide an acceptable level of confidence whereby non-urban metering throughout Australia has a 'maximum permissible error' limit, in the field, of plus or minus five per cent.

The Australian Government has made an in-principle agreement to allocate \$90 million to State Water under the Water for the Future program to replace existing customer-owned meters with State Water-owned meters, to be connected by telemetry. Water savings that the project may generate will accrue to a water access licence to be held by the Australian Government.

5 Land management

Within the context of sustainable development, the 'wise use' of wetlands encourages their beneficial use by people to provide services and benefits for present and future generations and maintain the wetlands' ecological character. However, some land management practices may not be sustainable and are causing damage to, or have the potential to cause damage to, the ecological value of the marshes. The causes of the damage can be diversion banks and channels, clearing, fire, cultivation, grazing and floodway obstruction.

5.1 Managing grazing

A grazing and landuse study of the Macquarie Marshes and Gwydir Wetlands investigated the ways grazing may be affecting the ecological processes in these systems. The study investigated vegetation composition, soil seed banks, soil chemistry, water quality and aquatic invertebrates (Wilson et al 2008).

Results indicated that the major driver of vegetation change is flow regime, and that grazing has a relatively small effect on wetland plant communities. Grazing by cattle appears to be important in maintaining the dominance of species such as water couch in grassy wetlands. The decline of water couch grassland in the nature reserve and its persistence on adjoining land grazed by domestic livestock lends support to this. By contrast, grazing disturbance appears to create openings for other species in marsh club-rush wetland, resulting in higher species diversity (Wilson et al 2008).



Photo 24 The boundary between the nature reserve and private land located in the North Marsh. Top left: river red gum, watered. Left foreground and centre: water couch, watered and grazed. Right foreground and centre: common reed, watered and ungrazed. Right background: chenopod shrubland, lack of water and ungrazed. Centre background and right centre: common reed, light brown and under stress from lack of water; ungrazed (W. Johnson).

There is evidence that river red gums germinate more successfully in grassy conditions but that tree establishment benefits from removal of grass by cattle grazing. Water couch tolerates neither sustained grazing when stressed from lack of water nor persistent grazing when underwater.

Common reed (reedbeds) can be damaged by grazing when it is dry or when new shoots are emerging. Lignum also seems to be damaged by sustained grazing when dry conditions are extended. Conditions of grazing leases that the Department of Lands issued for land that now lies within an area inside the nature reserve excluded livestock from *all reed regrowth until it has attained a height of not less than 3 feet* (Department of Lands no date).

Sustained, very dry conditions have led to increased grazing pressure from both domestic livestock and kangaroos. This is affecting lignum shrubland, common reed and water couch marsh in the North Marsh. A species-rich and abundant soil seed bank is vital if a wetland plant community is going to cope with variable environmental conditions and inundation patterns. It is important to balance the benefits to landholders of grazing cattle in the wetlands against the needs of plant species to reach maturity and set seed to allow species to maintain a long-term presence in the wetlands (Wilson et al 2008).

In consultation with marsh landholders, Industry and Investment NSW (I&I NSW) prepared guidelines for grazing (DPI 2009). Use of environmental water on wetland pasture, when grazed sensitively, can have both productive and ecological benefits.



Photo 25 Clearing and cultivation in the North Marsh. DECCW has since acquired this land on 'Pillcawarrina' for its estate. Foreground: the access road and bank. Left: the Macquarie River (W. Johnson).

5.2 Clearing

Clearing of floodplain and dryland vegetation communities has taken place in the marshes for many years, and the most affected species have been black box and coolibah woodland, river red gum woodland and lignum shrublands. Because the inundation frequency in the marshes has been reduced, pressure has been placed on the grazing industry, and landholders sometimes turn to cropping for an alternative income. The possibility of changing rainfall patterns (particularly higher summer rainfall) may make cropping more viable, and it is possible that clearing pressures will continue. DECCW and the CW CMA are undertaking regulatory activities, vegetation mapping, awareness campaigns and incentive programs.

5.3 Fire

For many years, it has been a normal part of grazing management to burn common reed, and this method is used by DECCW Parks and Wildlife Group (PWG) as a way to reduce fire hazard in the nature reserve (NPWS 1993). Fire is known to damage some wetland species and can kill river red gums. It is especially damaging when the marshes are dry, and any increased drying of the marshes will increase the threats from fire. PWG prepares fire management plans for the nature reserve and works closely with local bushfire brigades and the Rural Fire Service.



Photo 26 Fire in common reed in the northern nature reserve (W. Johnson).

5.4 Managing pests

Pest species in the marshes include pigs, foxes, feral fish and lippia. PWG, Livestock Health and Pest Authorities, and landholders have longstanding programs for controlling the numbers of pigs and foxes in the marshes. A carp-reduction strategy is being prepared for the Lower Macquarie region that will outline the current and future activities to stop the further spread of carp, control the size of the carp populations and increase the community's understanding and involvement in controlling carp.

Lippia, *Phyla canescens*, poses a considerable risk to the ecological and agricultural values of the marshes. Lippia was declared a target for biological control in November 2006 and in September 2009 was listed as a Class 4 Weed, requiring active management by councils for control. The Central West CMA is an active member of the National Lippia Working Group and has collaborated in the development of research work and the development of a best management guide for lippia.

The CMA's 'Warren to the Barwon' project is focusing on land management issues in floodplain and wetland areas along the Macquarie River and adjacent areas downstream of Warren. Trials of management practices to address issues of invasive plant species common to floodplains and wetlands of the area, such as lippia, black roly poly and bushy groundsell, are occurring.

5.5 Salinity

The Macquarie Marshes occupy a natural sump in the landscape where they have accumulated large amounts of salt over a long period of time. This salt is bound in saline clays and dissolved in saline groundwater in the quaternary aquifers and in the underlying regolith. Mapping of ground water shows a thin resistive layer only a few metres thick, with fresh pore water overlying this very large salt store throughout the marshes (BRS 2009).

Typically, the water table in these marshes rises and falls with floods and droughts (Brereton 1993). Salinity has been proposed as causing the loss of semi-permanent wetland in the North Marsh, particularly river red gum woodland and forest (Bacon 1996; Hogendyk 2007). The Australian Nuclear Science and Technology Organisation was commissioned to provide insight into groundwater–surface water interactions in the marshes and to identify sources of water used by riparian vegetation, to provide an improved understanding of wetland responses to water stresses (Hollis et al 2009). The report concluded that due to the high electrical conductivity (EC) values of the saline groundwater it is not likely to be a source of water for transpiration. The report goes on to say that:

The original hypothesis that trees may access groundwater during drought thereby lowering the water table would likely be untrue in those areas of the Macquarie Marshes where we have identified high salinity, shallow groundwater bodies – preliminary data suggest that in these areas, trees only access fresher soil waters from the unsaturated zone. When this source of water is less available (during periods of extended drought or when the extent of upstream diversions substantially reduces the frequency and degree of overbank flow) the trees become stressed. This is important to management considerations of which areas of the Macquarie Marshes to target with limited environmental flow allocations during periods of drought (Hollis et al 2009).

On-ground works that increase the permanence of water bodies within the marsh are also likely to have local impacts on groundwater. Maintaining the marshes over the long term depends on providing enough fresh water to maintain a thin layer of freshwater for plants to utilise (BRS 2009).

6 Aboriginal cultural values of the Macquarie Marshes

6.1 Introduction

The Macquarie Marshes are an iconic natural area with significant Aboriginal cultural values. The marshes lie within the traditional country of the Wailwan people and are the core of Wailwan Country. Aboriginal cultural values are related to both the long history of Aboriginal interaction with the marshes and the interests and aspirations of contemporary Aboriginal communities that have a custodial relationship with the area. Wailwan and other Aboriginal communities maintain a custodial relationship with the marshes – a connectedness to the landscape and a sense of responsibility to care for this important part of their Country.

Over the past two centuries, however, white settlement has made it increasingly difficult, and sometimes impossible, for Aboriginal people to exercise their custodial duties. Enhancing Aboriginal cultural values involves strengthening Aboriginal communities' relationships with the marshes.

Protecting the wetlands' cultural and natural values is aligned, although differences exist, including differences in emphasis for on-ground protection. For example, the elevated sandy ridges in the marshes are an important part of the Aboriginal cultural landscape, because they contain culturally important vegetation communities and important cultural heritage sites. These areas are a conservation priority.



Photo 27 A grinding stone from Macquarie Marshes. These were used for grinding seed from grasses which grow around the wetlands (Damian Lucas/DECCW).

6.2 The history of Aboriginal settlement and occupation of the marshes

6.2.1 Traditional settlement of the marshes

In traditional times, the Macquarie Marshes' wetlands and river channels were an important focus of settlement for Aboriginal people. The Wailwan people had a relatively small country compared to the larger Aboriginal nations that surrounded them – the richness of the marshes as a resource base may account for this difference. The marshes provided a range of favourable conditions for settlement in this dry area: rich and reliable wetlands, floodplains covered with riverine forests and grasslands, and elevated sandy ridges. Mt Foster and Mt Harris were two of the region's only quarries for obtaining stone for manufacturing axes and flaked implements. Given the richness of resources in the marshes, the Wailwan would have held an important place in the overall region, between the arid and river country to the north and west, and the slopes and ranges to the south and east.

The marshes were not only a resource base for Aboriginal people; the wetlands landscape was at the centre of Aboriginal culture and spirituality. Aboriginal people were connected to the natural world through totem and kinship relationships, which established relationships of mutual care and responsibility. The landscape, specific places and specific plants and animals were all animated through events in the Dreamtime. The creation spirits continued to inhabit the landscape and often rested in large waterholes or in the form of animals, such as Mullian the eagle hawk, one of the Wailwan's totems (Masman & Johnstone 2000). The landscape of the marshes was a 'nourishing terrain' for the Wailwan traditional owners and other groups who had relationships with this place (Rose 1996).

When the wetlands were flooded, they would have been a larder in the floodplain country. During flood times, waterbirds would have been greatly abundant and the people living on the wetlands would have used both the birds and the birds' eggs. When the wetlands were not in flood, the large river channels and semi-permanent areas of water would also have been a major feature of the cultural landscape, as the source of water and associated resources. Aboriginal people harvested food, tools, shelter and medicinal items from plant and animal resources. The plants and animals were also a cultural and material contribution to the social and ceremonial aspects of the region's Aboriginal life. Aboriginal people adapted and developed sophisticated technologies in order to live in the wetland environment, such as using fire to modify the landscape and setting fish traps (Sturt 1833; Mitchell et al 1999).

A key aspect of living on the wetlands would have been moving between the 'red country' (elevated ridges) and the 'black country' (the floodplain and wetlands). During floods, the black country was uninhabitable, but as the flood waters dried up, people would have focused on the main river channels and core wetland areas (Witter 2004). Today, elevated red ridges contain the physical remains of many campsites and hearths. The black soil floodplains, characterised by self-mulching alluvial soils and periodic floods, have poor conditions for preserving stone artefacts (Biosis 2008).

Core wetland areas provided the important and iconic wetland plants, including cumbungi (bulrush) and nardoo. The riverine forests, woodlands and grasslands would have contained another suite of important plants, including river cooba, river red gum, coolibah, Mitchell grass and native millet. Today, scarred trees, typically coolibah, located throughout the marshes indicate that the people used floodplain trees for implements – such as coolamons – and shelter. These scarred trees have added importance because few of the actual wooden implements have survived. A large number of surviving grinding stones and mullers indicate the importance of grasses and seeds in the marshes (Biosis 2008).

The elevated ridges also provided important resources, and some of the important species were wilga; bumble, or wild orange; belah; leopardwood; quinine bush; nepine; quandong; and western boobialla.

The marshes were a focus for large ceremonies. The Bora (initiation) ceremonies recorded at a Macquarie Marshes site in 1893 and 1898 (Mathews 1901; Miller 1999) were modern examples of long-running Bora ceremonies at the site. The ecologically rich and dependable wetland environment of the marshes would have provided the reliable setting and quality of resources necessary for Bora ceremonies (Bowdler 2005). After almost 200 years of white settlement, most of the country has been radically changed, explaining the Aboriginal concern for the remnants that have survived in a relative natural condition.

6.2.2 Post-contact history

Colonisation of the Macquarie Marshes from the 1820s onwards caused radical changes for Aboriginal people in the marshes, and more broadly across western NSW. Aboriginal people were usurped from their lands, and their social, cultural and spiritual ways of being were severely disrupted.

However, even though invasion occurred, Aboriginal people were not dispossessed (Goodall 1996, 2001; Hope 2004). In the colonial situation, Aboriginal people maintained a connection with the wetland area. Although physical 'openings' into the landscape were constrained, Aboriginal people used a range of strategies in order to maintain a connection with the Macquarie Marshes under greatly changed circumstances (Byrne & Nugent 2004).

Throughout the nineteenth century and into the early twentieth century, Aboriginal people were valued workers on the region's pastoral properties and worked on stations that included Pillicawarrina, Wallumgambone, Buckiinguy, Sandy Camp, Oxley and Buttabone. Aboriginal people lived in communal camps on pastoral stations, in camps located on riverbanks, and on reserves created by the Aboriginal Protection Board (Masman & Johnstone 2000).

During the 1930s, scrutiny of Wailwan and other Aboriginal people living in the marshes radically increased. The Aboriginal Protection Board actively instituted a policy of concentrating Aboriginal people on a small number of board-run reserves (Goodall 1996; Hope 2004). In 1935, people from Quambone were forcibly moved to the reserve at Brewarrina, and people were also moved to Pilliga and other missions (Goodall 1996). A key point is that this active removal from Country occurred only relatively recently, and for older people, within the period of living memory.

In order to escape the board's control and seek education for their children, Aboriginal people moved from the marshes to informal camps outside towns, which were located throughout the region. By the 1960s, few Aboriginal families were permanently living on properties located in the marshes. However, from the base of surrounding towns, many Aboriginal people continued to work in the marshes as shearers, stock workers and fencers. The movement to centralised reserves and town camps affected identification of all traditional Aboriginal groups but had especially negative implications for smaller groups such as the Wailwan.

By the late 1960s, a pattern of limited physical access to the marshes had developed, and this pattern has continued to today. Significant Aboriginal communities live in the towns surrounding the marshes: Quambone, Coonamble, Warren, Narromine, Walgett and Brewarrina; however, few Aboriginal people actually reside in the marshes area.

In this situation, physical access to the marshes depends on maintaining good relations with private landholders, but because the amount of work on marsh properties decreased, these relationships were more difficult to maintain. Many Aboriginal people have reported that in trying to access favoured areas of the marshes, for fishing or simply for visiting places, they encountered fences and locked gates. Since the 1970s, Aboriginal people have experienced the ecological decline of the marshes as another form of loss, not by way of barriers to physical access but because Country itself is rapidly declining.

Restriction of physical access has led to loss of detailed knowledge of areas of Country. However, Aboriginal people have sustained detailed knowledge of the areas of Country that they continued to be able to access in the colonial situation. For example, Aboriginal people have sustained knowledge of land surrounding the reserves they lived on, places they could access through work, or public land such as riverbanks. In this situation of restricted access, land continued to be at the centre of culture, identity and spirituality for the region's Aboriginal people. Although detailed knowledge of Country has been lost, Aboriginal people continue to have broad knowledge of Country and a distinctive set of cultural and ecological goals for Country (Goodall 2001).

Since the 1970s, Aboriginal rights in relation to land have been re-asserted and Aboriginal people have become increasingly confident in seeking access to land, protection of cultural heritage sites and involvement in managing the environment. The practice of managing the environment has also slowly changed, whereby Aboriginal people's involvement in conserving and managing the environment has increased incrementally, slowly creating new 'openings' into the landscape of the marshes.

6.3 Values, interests and aspirations of contemporary Aboriginal communities

The interests and priorities noted below were documented in community consultation activities conducted in 2007 and 2008, including 'back to Country' events held at the Macquarie Marshes. This section also draws on interviews conducted with community members (Peckham & Molsher 2005; Dykes et al 2006; Waters Consulting 2008).

6.3.1 Wailwan traditional descendants: key priorities

As traditional owners of Country, the Wailwan people have a special role in planning for Country. Wailwan traditional descendants have identified the following six key priorities for the Macquarie Marshes:

1. Cultural flows to Country.
2. Access to Country in order to conduct cultural activities.
3. Inclusion in management of Country.
4. Training and working for Country.
5. Cultural continuity and heritage protection on Country.
6. Caring for Country: enacting cultural and ecological responsibility for Country.

As first people, the Wailwan have inherent rights in Country. Wailwan people, along with other Aboriginal people, have never given up sovereignty over or connection to their lands and water. They have a specific interest in re-engaging with Country in order to enhance their spiritual connection to Country, and to revive their cultural practice and expressions on Country.

The Wailwan have a holistic view of land management and aspire to be involved in all aspects of processes for cultural, environmental, economic and social management. They hold a vision for a healthy, living river system that has natural flows and cycles. They share this vision with other Aboriginal peoples of the Macquarie Valley and the Barwon–Darling River. Today, Wailwan descendants and other Aboriginal people aspire to be equal participants in protecting and regenerating the Macquarie Marshes' ecology and in protecting Aboriginal culture and heritage. Also, the members of the contemporary Wailwan community want to ensure a sustainable economic base for current Wailwan and future generations.

Although the Wailwan have a special position as descendants of the area's traditional people, other Aboriginal communities have important associations with the Macquarie Marshes.

Other Aboriginal groups that have a strong association with the marshes are:

- traditional owner groups from upstream and downstream of the marshes
- traditional owner groups who used to gather on Wailwan Country for ceremonial purposes
- Aboriginal people who have a historical connection with the marshes, especially through working in the pastoral and agricultural industry
- Aboriginal people who reside on Wailwan Country.

6.3.2 Values, interests and priorities: Wailwan and other Aboriginal people

During the community consultations conducted with community members from the Wailwan and other Aboriginal people, the following values, interests and priorities arose.



Photo 28 Ruby saltbush fruit, an important food plant, grows on the dry areas fringing the wetlands (Damian Lucas/DECCW).

6.3.2.1 Recognising custodianship

An overarching issue raised during the community consultations was the need to acknowledge and strengthen Aboriginal custodianship. Contemporary custodianship could be acknowledged by maintaining Aboriginal place names and renaming places so that they have Aboriginal place names, by welcoming people to Country at the beginning of events and by increasing Aboriginal people's participation in managing the environment.

6.3.2.2 Protecting Country

During the consultations, specific aspects of Country were considered to be especially important by members of the Aboriginal community and in need of conservation and protection. The priorities were as follows:

- to restore core wetlands
- to protect other areas and ecosystems, riverine forests, woodlands and grasslands, and elevated sandy ridges
- to institute a cultural allocation of water and take Aboriginal cultural values into account when managing environmental water
- to protect cultural heritage sites
- to take a holistic approach to managing Country
- to introduce additional land in conservation reserves.

6.3.2.3 Undertaking activities on Country

Aboriginal people described the activities they want to be able to undertake on Country:

- having access to Country in order to conduct cultural activities
- having work, training and economic opportunities on Country
- being involved in managing Country, especially in managing environmental water
- forming partnerships with the NPWS in managing conservation reserves
- establishing an Aboriginal cultural flow of water.

6.4 Identifying and protecting Aboriginal cultural values

6.4.1 Protecting Country

6.4.1.1 Aboriginal cultural values and ecological health

The Aboriginal cultural values of the wetlands are strongly associated with the wetlands' ecological health. Protecting the wetlands' natural values enhances their cultural values. However, there are differences of emphasis that exist. For example, Aboriginal communities have a strong interest in protecting wetland plants that have iconic cultural value, such as nardoo, cumbungi, river cooba, coolibah and river red gum. Also, Aboriginal people are strongly interested in being involved in managing and restoring their Country.

Along with the core wetland areas, other ecosystems and vegetation communities in the marshes are highly significant in relation to Aboriginal cultural values. Riverine forests, woodlands and grassland and the elevated ridge country ('red country', often associated with poplar box woodland) are the support systems for significant plants and animals that have cultural values and are important in the preservation of cultural heritage sites.

6.4.1.2 Aboriginal cultural values and management of environmental water: a cultural flow of water

Water is a key factor in sustaining wetland plants and animals that have cultural values and is important for sustaining the health of the cultural landscape in general. The Aboriginal community strongly aspires to having a dedicated cultural allocation of water for the Macquarie Marshes. Cultural flows are allocations of water that Aboriginal people control in order to improve the spiritual, cultural, environmental, social and economic conditions of Country (Morgan et al 2004). A cultural allocation of water is a way for Aboriginal community members to enact their custodial responsibilities for the Macquarie Marshes and to protect the health of the environment. The primary focus of these flows would be to provide water for important aspects of the cultural landscape – plants, animals, sites and the broader landscape – that depend on water. In practice, cultural flows could be used in conjunction with environmental flows.

Bringing about broader recognition of Aboriginal cultural values in managing environmental water involves other steps, including having Aboriginal representatives on committees that manage environmental flows and including Aboriginal cultural values as criteria in managing environmental water.

6.4.1.3 Aboriginal cultural heritage sites

The Macquarie Marshes contain a range of significant Aboriginal cultural heritage sites. More than 500 sites have been recorded in the wetland area (Biosis 2008). These places are important indicators of the long history of Aboriginal peoples' interaction with the Macquarie Marshes and show how Aboriginal people adapted to and used the wetlands' resources.

Cultural heritage sites in the Macquarie Marshes include:

- carved trees, and historically documented ceremonial and Dreaming sites and stone arrangements
- Aboriginal ancestral remains
- an assemblage of earth mounds that are the most northerly examples of a site type
- very large assemblages of grinding stones and scarred trees, which are evidence of how important plant foods and tree resources are in the wetland environment
- stone artefacts
- a range of places related to the region's post-contact (post 1788) history: sites of frontier violence, ceremonial sites, living places – missions, reserves and camps – and working places – pastoral properties (Biosis 2008).

According to predictive mapping of cultural heritage sites, important areas for potential sites include:

- within 250 metres of river channels and margins of inundation
- elevated sandy country within the marshes, which usually corresponds to box vegetation communities (Biosis 2008).

Cultural heritage sites are subject to a range of threats, which include land clearing, and tramping and erosion from livestock. In the marshes, cultural heritage sites occur across a range of tenures: private land, conservation reserves, travelling stock reserves and state forests.

6.4.2 Cultural activities on Country

6.4.2.1 Access to Country for cultural purposes

The ability to easily gain access to the wetlands for a range of cultural activities is a key interest for Aboriginal communities. Access to Country is a fundamental contributor to cultural renewal, creating opportunities for Aboriginal people to reconnect with their Country, conduct cultural practices and pass on their knowledge. Restoring access to Country addresses the long history of Aboriginal people's exclusion from the wetland area.

Activities that Aboriginal communities want to conduct on Country include:

- conducting family camps, back-to-Country camps and camps for conducting cultural practices
- undertaking education and cultural awareness activities
- collecting bush foods and wild resources – including sedges and reeds for weaving
- conducting men's and women's specific activities and specific activities for young people.

Public conservation reserves are a key focus for increased access to Country. Partnership arrangements with DECCW Parks and Wildlife Group are an important way to facilitate increased public access, as is expanding conservation reserves in the marshes. It is also important that Aboriginal communities have access to private land.



Photo 29 Fruit of the quandong tree, an important food plant that grows on the raised ridges surrounding Macquarie Marshes (Damian Lucas/DECCW).

Aboriginal cultural resources use is supported under the NSW Government's Aboriginal Cultural Resource Use Framework. The Central West CMA, as part of its cultural heritage activities, supports negotiated access to private lands located in the catchment. Furthermore, the NSW Government recognises that a key element in enhancing contemporary Aboriginal resilience is restoration of mechanisms for exercising connection with Country (DAA 2003; NSW Government 2006).

6.4.2.2 Working on Country: increasing employment, training and economic opportunities on the wetlands

Employment and training in conservation and management of natural resources are important ways for Aboriginal people to restore connections with Country (for the benefits of Working on Country programs in northern Australia, see Altman & Whitehead 2003, Garnett & Stilhole 2007). Opportunities for employment of Aboriginal people in the marshes could be created in a range of areas. This objective could be achieved by forming partnerships with the NPWS or undertaking activities for conserving and managing natural resources and the environment on private land in the marshes, supported by CMA projects. In the longer term, opportunities could be developed for Aboriginal-owned businesses or Aboriginal contractors to undertake contract work in conservation and management of natural resources.

6.4.3 Participation in managing the wetlands

It is important that environmental management agencies engage with Aboriginal communities early and on an ongoing basis so Aboriginal communities have the best opportunities to be involved in managing the Macquarie Marshes environment. Aboriginal communities would thereby be able to be involved in making decisions that affect them and to fully enact their custodial responsibilities to Country and its resources (DAA 2003; DECC 2006, 2007).

In the context of the marshes, which is a natural area with strong cultural values, it is important that Aboriginal communities participate in the overall environmental management of the marshes as well as in management of cultural heritage. Key forums for Aboriginal communities to participate in include the environmental flows reference group (EFRG) and management of the Macquarie Marshes Nature Reserve.

There are other important ways for Aboriginal people to be involved. Formation of an Aboriginal community reference group would be a key avenue for increasing Aboriginal people's engagement in managing the environment, especially in managing environmental water. The reference group would be a forum for Aboriginal communities to develop and advocate perspectives on managing the marshes environment. The Central West CMA and agencies could support the reference group by providing resources for the group to meet on Country a number of times a year.

Given that Aboriginal people's involvement in environmental management forums is relatively new, it is important that management agencies provide ongoing support and training for Aboriginal community representatives. In order to assist Aboriginal representatives on these forums, it is also important that cultural awareness training be available to non-Aboriginal committee members.

7 Integrating social and ecological systems

7.1 Adaptive management and adaptive governance

An aim of this plan is to guide adaptive management and adaptive governance of the Macquarie Marshes, to restore resilience and maintain critical ecological functions and habitats. Adaptive management provides structured links between science, policy and management, addressing two major concerns when managing social and ecological systems: (1) the need to have relevant knowledge of the systems and (2) ensuring that knowledge is included in decision making. Adaptive management uses available information to highlight management opportunities and choices, guide learning, and improve management (Holling 1978; Walters 1986, 1997).

An important definition of adaptive management is that it is *a structured process of 'learning by doing'* (Walters & Holling 1990; Walters 1997) that begins by applying existing knowledge, from different sources, to management. Management is adaptive when decision makers continuously monitor and integrate appropriate ecological, social and economic information into management and policy, and when uncertainty is acknowledged as always present (Berkes et al 2003; Johnson 2005).

Adaptive management includes social and technical processes. Objectives and actions must suit the time and place and must be at the right scale for it to be successful. Adaptive managers are aware that knowledge is always incomplete, that decisions are based on the values of the society they are made in, and that decision making is consequently a social and political responsibility (Johnson 2005; Resilience Alliance 2009). Adaptive governance goes beyond adaptive management to address the broad social contexts of management. It focuses on developing new institutional arrangements and organisational structures just as much as on scientific methods (Scholz & Stifftel 2005; Resilience Alliance 2009).

7.2 Resilience and adaptive capacity

Resilience is generally defined as the ability to recover from or adjust easily to misfortune or change. It applies to social and ecological systems and is a system's capacity to absorb disturbance and retain its basic structure and function. Resilience can also be defined as the distance from a threshold. A resilient ecosystem can withstand shocks or changed conditions and rebuild itself when necessary. Resilience in social systems includes the capacity of humans to anticipate and plan for the future (Walker & Salt 2006; Resilience Alliance 2009).

Adaptive capacity, or adaptability, is the ability to adapt to and shape change. It is the capacity of the parts of a system to influence resilience. In a social-ecological system, it is the capacity of humans to manage resilience. Systems that have a high adaptive capacity are able to adjust to changing conditions without undergoing significant declines in their crucial functions. A consequence of loss of resilience and therefore of adaptive capacity is loss of opportunity that limits choices for action during periods of change – an inability of parts of the system to do things differently, or to do different things (Resilience Alliance 2007, 2009).

7.3 Social systems

In this plan, social systems or social structures are defined as being the people, community groups or organisations that have some involvement in, interaction with or influence on, the Macquarie Marshes and its related ecological system. In this context, the term 'social' includes cultural, political and economic functions and structures. It also includes the organisational

arrangements, needs, values and interests of various individuals and groups within a specific, distinct area. Area can be defined in terms of geography, issue or problem, or subject of interest.

This plan acknowledges the strong cultural and historical links that groups and individuals have with the marshes. These groups and individuals include government agencies, non-government organisations, rural industry organisations, environmental groups, individual landholders, and people who have cultural and historical connections and interests.

So that either the effects can be reduced or some of the costs associated with change can be negated, the following principles are proposed for guiding integration of community priorities, values, needs and interests into management and planning:

- negotiations will be held before actions are taken
- negotiated actions to reduce the stress associated with change must be possible and practical in terms of cost, personnel and time
- actions should be monitored and reported against specific ecological objectives and management responses
- actions should be valued by the parties for whom they are intended
- actions can draw on the experiences and skills of individuals and groups in the community as well as existing infrastructure and resources.

7.4 Research, monitoring, evaluation and reporting

Knowledge comes from different sources. Managers and researchers in many different fields have learnt from experience in the marshes, responding to the behaviour and condition of the systems they manage and study (Fazey et al 2006). An important part of managing the marshes adaptively will be effective use of different sources and types of information, including the knowledge of landholders and Aboriginal people. Community ownership of scientific research will be more likely if people are involved in the conception and implementation, and at the completion of research. Information is sometimes not available, and sometimes it is simply the case that science cannot answer the questions that managers and policy makers ask. Strong links and effective communication between researchers, managers and policy makers must be developed and fostered. A research plan will be developed as part of the plan's implementation.

Monitoring, evaluation and reporting of the effectiveness of policies and management are essential for adaptive management. The NSW Wetlands MER Rapid Assessment technique is just one example of a system for reporting wetland condition quickly. However, on its own, it is not comprehensive enough for monitoring and evaluating the success of management in the Macquarie Marshes. Water delivery must be monitored to ensure that it reaches identified assets, and the distribution of water in the assets must be measured. The effectiveness of environmental flow management in meeting specific objectives is of special interest, particularly in relation to:

- changes in the extent of semi-permanent wetland vegetation
- the proportions of healthy and stressed semi-permanent wetland vegetation
- the diversity and density of aquatic invertebrates
- the diversity and density of waterbird species.

Scientific research and monitoring activities themselves should also be evaluated for their contribution to a broader understanding of wetland processes and functions and the uptake of information into management actions.

DECCW is working with the University of New South Wales to develop a strategic adaptive management and research framework for the Macquarie Marshes Nature Reserve. A goal of this project is to address the perennial difficulty of linking management, policy and science (Walters & Holling 1990; Rogers 1998; Johnson 2005). This process will be reviewed and evaluated with a view to applying it to the whole of the marshes.

7.5 Regulation, enforcement and compliance

The objectives of plans or activities aimed at protecting and maintaining complex social-ecological systems such as the Macquarie River and the Macquarie Marshes will be achieved only if the legislation, policy and guidelines are regulated and enforced consistently, credibly and effectively (Scholz & Stifftel 2005).

There is no shortage of responsibility or legislation for regulation and enforcement; I&I NSW, NOW, State Water, DECCW and the Australian Government have responsibilities and powers under legislation. However, programs for strengthening and improving coordination of the approaches to implementation will have to continue if the full benefits of the legislation are to be realised.

7.6 Cooperation and community participation in management

The centrepiece of community participation in managing the marshes is the Macquarie–Cudgegong Environmental Flows Reference Group. This group has been operating since 2002 and has become very skilled, including the critical skill of operating effectively as a group. Its membership has grown in recent years and now includes representatives of the regional Aboriginal community and a representative of the Australian Government as an observer.

Nevertheless, for community participation in managing the Macquarie Marshes to remain effective, the following five key challenges should be kept in mind.

1. Striving for genuine representation by:
 - (a) ensuring key people and groups are involved
 - (b) creating an explicit statement of roles, responsibilities and expectations and
 - (c) providing leadership and support so the stated roles can be undertaken effectively
2. Designing workable and useful processes.
3. Including scientific, expert and local knowledge in decision making.
4. Developing a common understanding of the system and the challenges that it faces.
5. Evaluating whether decisions are effective and whether they achieve management objectives (Scholz & Stifftel 2005).

Effective communication will be an essential part of undertaking the plan. Credible, trusted knowledge will not be developed without strong links and communication between relevant stakeholders.

8 Change and management in the Macquarie Marshes

Action is needed to arrest the decline of the marshes and ensure their ecological functions and processes are maintained. Most of the actions required for bringing about change are not new and many are already being implemented or planned under existing funding programs, policy or legislation.

DECCW and the Central West CMA will carry out an annual review of implementing the AEMP and ensure that other agencies, interest groups and individuals are involved both in the review and implementation of the AEMP. DEWHA, I&I NSW, NOW, State Water, Aboriginal communities and marshes landholders will be critical participants in this process.

8.1 Projects and actions identified in the plan

For the Macquarie Marshes to have a sustainable future, communities and government must establish a shared view of the condition and the trajectory of condition of the marshes, the causes, and useful management, research and policy responses. At the time of writing of the plan, agreement had been negotiated for many projects and actions. Most are uncontroversial, and some are already underway, as shown in tables 8.1-8.8 in section 8.4 of this plan. Examples include:

1. Modifying weirs and other barriers to improve conditions for native fish.
2. Increasing the release capacity of Burrendong Dam to increase the size range of managed flows.
3. Improving irrigation efficiency and purchasing water from willing sellers to return water to the environment.
4. Developing guidelines for grazing management to ensure the best outcomes from environmental water management.
5. Establishing processes for ensuring that community members participate effectively in river and wetland management.

For some issues, such as the regulation of floodplain harvesting, while policy directions have been generally agreed, specific actions to implement the policy are still to be developed or applied.

DECCW and the Central West CMA will review progress against the projects and actions in section 8.4 and the actions necessary for delivering them, in the context of the ongoing review and implementation of the AEMP.

8.2 Determining priorities for delivering water

Water from the Macquarie River drives the systems of the Macquarie Marshes and irrigated agriculture, and there is not enough to meet all existing needs. It is clear that much of the 72,000 hectares of semi-permanent wetland mapped in the marshes in the early 1990s no longer supports wetland vegetation and that most of the rest is in poor and declining condition.

The minimum duration and frequency of inundation identified as necessary to maintain the values of semi-permanent wetlands in the marshes is four months, in at least seven years out of ten, requiring about seven to 10 megalitres per hectare for the long term. Watering requirements for specific assets are defined in section 8.4. Delivering this duration and frequency of flooding to areas of wetland under both existing and forecast conditions of surface water availability will mean that a smaller area than has been historically mapped can

be sustained in good condition. The policy, management and research implication is that some areas of the marshes will need to be given priority for water.

Determining priorities for watering environmental assets is an ongoing task undertaken at a regional level through an annual planning cycle in the context of the climatic circumstances, water availability and environmental conditions as they evolve. The Environmental Flows Reference Group (EFRG) is a key forum for this process.

Priorities may also be determined on a longer term basis if it becomes apparent that all areas of the marshes cannot be sustained in the long term. This will depend on the success of water recovery programs, the sustainable diversion limit established under the Basin Plan and medium-term climatic circumstances that are experienced.

Priorities for delivering environmental water are determined by DECCW taking into account the advice of the EFRG.

Establishing priorities for environmental watering on an annual and medium-term basis will include:

1. Considering the ecological assets and values of the marshes and their water needs as identified in this plan.
2. An annual review of the progress with the implementation of this plan (DECCW and the Central West CMA).
3. Reaching agreement on the condition and trajectory of condition of the marshes and appropriate management responses (DECCW, CW CMA and EFRG).
4. Identifying flow paths and means of delivering water to identified areas (EFRG).
5. Determining priority areas for water delivery to sustain the assets, values and character of the marshes (DECCW, CW CMA, EFRG and affected stakeholders).

Other factors that will influence medium-term priorities identified in water-management planning will include:

1. The ecological, social and cultural assets and values that are threatened as a result of recent and forecast climatic conditions.
2. The capacity to support complexity and diversity within the marshes, as well as within specific assets or areas.
3. Legislative and policy responsibilities.
4. The nature of land- and water-management activities within or along flow paths to ecological assets, including the number and role of banks, channels, regulators and other structures; management practices; and any formal management agreements.
5. The likelihood that identified management activities will lead to achievement of land and water management objectives.
6. The capacity to deliver water to different areas, including existing or potential works for directing, holding or otherwise managing water.

8.3 Delivering and managing water in the marshes

DECCW is responsible for managing environmental water allocations established under water sharing plans and water access licences held by the NSW Government for an environmental purpose. The EFRG established under the Water Sharing Plan for the regulated Macquarie and Cudgegong Rivers Water Source 2003 advises DECCW about managing this water and helps DECCW prepare an annual watering plan. NOW is responsible for developing and implementing water sharing plans and water licensing, including enforcement and compliance.

Under the *Commonwealth Water Act 2007*, the Australian Government has established a Commonwealth Environmental Water Holder (CEWH) to hold and manage water access licences for environmental purposes in accordance with the environmental watering plan which will be part of the Basin Plan to be prepared by the Murray–Darling Basin Authority (MDBA). The Basin Plan will also establish Sustainable Diversion Limits for water sources within the basin which are expected to be lower than existing diversion levels. The Commonwealth Environmental Water Holder is already a substantial and important holder of environmental water in the Macquarie Valley.

Governments, through the Murray–Darling Basin reform intergovernmental agreement, signed in 2008, have agreed to cooperate on environmental water management. In early 2009, DECC (now DECCW) and the CEWH signed a memorandum of understanding to ensure close cooperation on Commonwealth, state and territory environmental water planning and management.

Extensive public and private works have been built to manage water; to direct, control, harvest and store flows, and to control channel erosion, from Marebone Weir to the northern nature reserve (DNR 2006; Hogendyk 2008; Steinfeld & Kingsford 2008). Although many of these works are essential for managing the marshes, some are of either limited or of no benefit to the marshes and some may have to be modified or removed to protect assets. In some cases, new works will be needed.

An environmental allocation has existed in the Macquarie Valley since 1967 and has been actively delivered to the marshes since 1980. Many members of the Macquarie community have considerable expertise in managing environmental flows and will contribute to operational plans either at a site or on a broader wetland scale. Vegetation mapping and digital elevation and hydrodynamic models currently being developed will be especially useful when priorities for watering are being developed and annual watering plans are being prepared.

8.4 Tables of project and actions

The aim of this plan is to guide restoration of ecological structure and function of the Macquarie Marshes. In the plan, assets and their water needs are identified. It provides a broad context for a number of projects and actions that, when undertaken, will make an important contribution to a sustainable future for the Macquarie Marshes and the Macquarie River (see tables 8.1–8.9). This plan does not include directions for how the projects will be undertaken; it simply identifies them and explains why they are important. The projects and actions can be viewed as modules of the AEMP. Modules of particular importance, and necessary to achieve its objectives, include:

1. A review of the Macquarie Marshes Nature Reserve plan of management.
2. The Pillicawarrina restoration project.
3. An ecological character description of Ramsar site and review of the Ramsar information sheet.
4. Projects for managing water and land in the north, south and east marshes.
5. Guidelines for managing breeding of colonially nesting waterbirds.
6. Guidelines for grazing management.
7. A project for restoring fish habitat in the Macquarie River and Macquarie Marshes.
8. A strategic research plan for the Macquarie Marshes.
9. A monitoring and evaluation program for the Macquarie Marshes.
10. A strategic compliance project for the Macquarie Marshes.
11. A communication plan for the Macquarie Marshes.

Table 8.1 North Marsh wetland vegetation

Key to non-river red gum condition categories.

Good: species composition and structure representative of benchmark, 0–10% exotic (or invasive native) species.

Intermediate: 10–50% exotic (or invasive native) species in any stratum of community, reduced species and/or structural diversity from benchmark.

Poor: 50–100% exotic (or invasive native) species in any stratum of community, greatly reduced species and/or structural diversity from benchmark).

| Ecological characteristic and objective | Location | Approximate area, in hectares, in 2008 | Tenure | Current vegetation condition | Environmental water delivery potential under existing conditions | Existing wetland values |
|---|---|--|---|---|--|-------------------------|
| <p>River red gum forest and woodland</p> <p>Provide water to inundate for at least 4 months of the year, between July and April, at least 7 years out of 10. Ensure that grazing is managed appropriately.</p> | Bora Channel, Ginghet, Hunts Woodland, Macquarie Channel, Log Dam Channel | 6150 in nature reserve 6000 on private land | Nature reserve, Ramsar site and private | Good (<10% dead canopy) on south-western side of North Marsh. Intermediate (10–40% dead canopy) to poor (80–100% dead canopy) elsewhere, including many dead trees. | Some areas good, some moderate, some poor | Very high |
| <p>Lignum shrubland</p> <p>Provide water to inundate for at least 3 months of the year, between September and March, at least 5 years out of 10.</p> | Zoo Paddock, Ginghet, Pillicawarrina, H Block, Halls Block | 335 | Nature reserve, Ramsar site and private | Most is poor, some good | Some areas good, some moderate, some poor | Very high |
| <p>Common reed</p> <p>Provide water to inundate for at least 8 years out of 10. Timing is not critical.</p> | Northern nature reserve | 1820 as dominant species | Nature reserve and Ramsar site | Some good, some poor: stressed and dead | Some areas good, some moderate | Very high |

Table 8.1 (continued) North Marsh wetland vegetation

| Ecological characteristic and objective | Location | Approximate area, in hectares, in 2008 | Tenure | Current vegetation condition | Environmental water delivery potential under existing conditions | Existing wetland values |
|---|--|--|---|--|--|-------------------------|
| Water couch marsh Provide water to inundate for at least 6 months of the year, 8 years out of 10. | River Paddock | 250 | Private | Good to intermediate. Some areas of invasive chenopod shrubland | Good | Very high |
| | Macquarie Channel | 15 | Nature reserve and Ramsar site | Poor: stressed and declining in area | Moderate | Very high |
| | Bora | 25 | Nature reserve and Ramsar site | Good | Good | Very high |
| Mixed marsh Provide water to inundate for at least 8 years out of 10. Timing is not critical. | Macquarie Channel | 280 | Nature reserve and Ramsar site | Poor | Good | Very high |
| | Bora | 80 | Nature reserve and Ramsar site | Good to poor | Good | Very high |
| | Ginghet | 20 | Nature reserve and Ramsar site | Good to poor | Good | Very high |
| Coolibah | North Marsh/ Halls Block, areas to the west of the northern nature reserve | 4230 | Nature reserve, Ramsar site and private | Good to intermediate | Mostly low, some areas on margins of semi-permanent wetlands receive environmental flows | Very high |

Table 8.2 South Marsh wetland vegetation

Key to non-river red gum condition categories.

Good: species composition and structure representative of benchmark, 0–10% exotic (or invasive native) species.

Intermediate: 10–50% exotic (or invasive native) species in any stratum of community, reduced species and/or structural diversity from benchmark.

Poor: 50–100% exotic (or invasive native) species in any stratum of community, greatly reduced species and/or structural diversity from benchmark).

| Ecological characteristic and objective | Location | Approximate area, in hectares, in 2008 | Tenure | Current vegetation condition | Environmental water delivery potential under existing conditions | Existing wetland values |
|---|---|--|--------------------------------|--|--|-------------------------|
| Common reed Provide water to inundate at least 8 years out of 10. Timing is not critical. | Willancorah Swamp | 325 | Private | Good | Good | Very high |
| | Buckiinguy Swamp | 80 | Private | Some good, some intermediate | Good | Very high |
| | Mole Marsh | 20 | Private | Some good, some intermediate, some poor | Good | Very high |
| | Southern nature reserve | 55 | Nature reserve and Ramsar site | Poor: now mostly chenopod shrubland | Mostly poor | Very high |
| Water couch marsh Provide water to inundate for at least 6 months of the year, 8 years out of 10. | Buckiinguy Swamp | 5 | Private | Poor to moderate: now invaded by chenopods and lippia | Good | Very high |
| | Willancorah Swamp | 100 | Private | Intermediate | Good | Very high |
| River red gum forest and woodland Provide water to inundate for at least 4 months of the year, between July and February, at least 7 years out of 10. Ensure grazing is managed appropriately. Ensure clearing is halted. | Marebone, along Monkeygar Creek in southern nature reserve, Buckiinguy and Mole Marsh | 5765 | Private | Some good (0–10% dead canopy, along Macquarie River), intermediate (10–40% dead canopy) at Monkeygar, Buckiinguy and Mole Marsh, some poor (80–100% dead canopy), some cleared | Good in parts | High, moderate, and low |

Table 8.2 (continued) South Marsh wetland vegetation

| Ecological characteristic and objective | Location | Approximate area, in hectares, in 2008 | Tenure | Current vegetation condition | Environmental water delivery potential under existing conditions | Existing wetland values |
|--|---|--|---------|--|--|-------------------------|
| Mixed marsh, water couch Provide water to inundate for at least 6 months of the year, 8 years out of 10. | Mole Marsh | 1300 | Private | Intermediate to poor: now invaded by chenopods | Moderate | High |
| | Mixed marsh Provide water to inundate for at least 6 months of the year, 8 years out of 10. | Monkey Swamp | 990 | Private | Poor: now invaded by chenopods and lippia | Moderate |
| | Bucklinguy Swamp | 670 | Private | Intermediate to poor | Moderate | High |
| | Willancorah | 380 | Private | Intermediate to poor | Moderate | High |
| | Marebone area and Mundooie | 245 | Private | Intermediate to poor | Moderate | High |

Table 8.3 East Marsh wetland vegetation

Key to non-river red gum condition categories.

Good: species composition and structure representative of benchmark, 0–10% exotic (or invasive native) species.

Intermediate: 10–50% exotic (or invasive native) species in any stratum of community, reduced species and/or structural diversity from benchmark.

Poor: 50–100% exotic (or invasive native) species in any stratum of community, greatly reduced species and/or structural diversity from benchmark).

| Ecological characteristic and objective | Location | Approximate area, in hectares, in 2008 | Tenure | Current vegetation condition | Environmental water delivery potential under existing conditions | Existing wetland values |
|---|------------------------------------|--|---------------------------|--|--|-------------------------|
| River red gum forest and woodland Provide water to inundate for at least 4 months of the year, between July and February, at least 7 years out of 10. | Gum Cowl–Terrigal Creek. | 5700 | Private | Mostly intermediate (10–40% dead canopy). Some intermediate/poor (40–80% dead canopy) and some poor (80–100% dead canopy) | Good | Very high |
| | Wilgara portion of the Ramsar site | 167 | Private and Ramsar site | Intermediate (10–40% dead canopy) | Good | Very high |
| River red gum and coolibah woodland Provide water to inundate for at least 4 months of the year, between July and February, at least 5 years out of 10. | Long Plain Cowl | 3010 | Private | Mostly poor (80–100% dead canopy) or intermediate/poor (40–80% dead canopy). Some intermediate (10–40% dead canopy) and some good (>10% dead canopy) | Outside managed flows | Medium |
| | Dusty Swamp | 30 | Private | Intermediate (10–40% dead canopy). All have invasive chenopod shrubland in the understory | Outside managed flows | Medium |
| | Stanley | 330 | Nature Conservation Trust | Intermediate (10–40% dead canopy). All have invasive chenopod shrubland in the understory | Outside managed flows | Medium |

Table 8.3 (continued) East Marsh wetland vegetation

| Ecological characteristic and objective | Location | Approximate area, in hectares, in 2008 | Tenure | Current vegetation condition | Environmental water delivery potential under existing conditions | Existing wetland values |
|--|---|--|--------------------------|--|--|-------------------------|
| Lignum Provide water to inundate for at least 3 months of the year, between September and March, at least 5 years out of 10. | Gum Cowl-Terrigal, Wilgara | 70 | Private and Ramsar site | Intermediate, all have invasive chenopod shrubland | Moderate | Very high |
| Water couch marsh | Gum Cowl-Terrigal Creek, Wilgara portion of the Ramsar site | 30 | Private and Ramsar site | Intermediate | Good | Very high |
| Mixed marsh Provide water to inundate for at least 6 months of the year, 8 years out of 10. | Gum Cowl-Terrigal Creek, Wilgara portion of the Ramsar site | 25 | Private, and Ramsar site | Intermediate | Good | Very high |
| Coolibah woodland | Gum Cowl-Terrigal Creek, Wilgara portion of the Ramsar site | 800 | Private, and Ramsar site | Some good, some intermediate | Some outside managed flows. Some areas on edge of semi-permanent wetlands receive environmental flows | Very high |

Table 8.4 Management of water and land

| Issue | Management response or action | Responsibility | Mechanism | Timing |
|---|---|--|--|----------------------------|
| Existing flow regime, including flow size, frequency, duration and timing | Buy water for the environment | DECCW and DEWHA | RERP – Sub-program 1 – Acquisition and management of water for environmental Australian Government’s Water for the Future initiative: Restoring the Balance in the Murray-Darling Basin program | 2006–11 2008–18 |
| | Increase water efficiency through upgrading irrigation and water delivery systems and improved metering | State Water, DEWHA, irrigation industry and CW CMA | RERP Sub-program III – Ensuring better delivery of environmental water Australian Government’s Water for the Future initiative Irrigation metering and national metering standard framework (NMSF) | 2006–11 2008–18 2010 |
| | Consider the implications of the resource assessment method in dry flow sequences not previously experienced | NOW, State Water, DECCW and CW CMA | Review of the Water Sharing Plan for the Macquarie-Cudgegong Regulated Rivers Water Source 2003 (WSP) | 2014 |
| | Review the way the flood mitigation zone is managed | NOW, State Water, DECCW, local government and CW CMA | Review of the WSP | 2014 |
| | Establish the environmental benefits of increasing the outlet valve capacity at Burrendong Dam to allow for both extractive and environmental flows | State Water, NOW, I&I NSW Fisheries and DECCW | To be determined | |
| Planning | Clarify the role, effect and status of structures for managing water in the marshes | NOW, supported by DEWHA, I&I NSW, DECCW and CW CMA | Healthy Floodplain Project (funded under NSW Sustaining the Basin: Border Rivers–Gwydir Program) | 2008–14 |
| | Review the Macquarie Marshes Nature Reserve plan of management | DECCW (PWG) | Core business | Underway |
| | Update the Ramsar information sheet, and review the Ramsar sites’ boundaries | DECCW and private landholders | Ramsar program | 2010 |

Table 8.4 (continued) Management of water and land

| Issue | Management response or action | Responsibility | Mechanism | Timing |
|--|--|---|--|------------------------------------|
| Planning | Review the Macquarie Marshes Nature Reserve plan of management | DECCW (PWG) | Core business | Underway |
| The effects of grazing on wetland vegetation | An ecological character description of the Ramsar site and review of the Ramsar information sheet | DECCW and private landholders | Ramsar program | 2010 |
| | Improve understanding of how grazing affects wetland vegetation, and determine grazing strategies required for protecting and restoring wetland vegetation | Individual landholders and floodplain graziers, CW CMA, I&I NSW, DECCW and LPMA | Implement grazing in wetlands guidelines developed under NSW WRP | Ongoing |
| | Provide incentives to improve management of wetlands on private land | CW CMA and DECCW | CW CMA incentives programs REPP – Sub-program IV – Boosting the Benefits of Environmental Water on Private Land | Ongoing 2008–10 |
| Clearing | Implement the <i>Native Vegetation Act 2003</i> | DECCW and CW CMA | Legislative responsibility | Ongoing |
| Fire management | Improve understanding of the effects of fire on the marshes | DECCW | Macquarie Marshes Nature Reserve plan of management and fire management plan Additional research required | 2010 |
| Weed management | Minimise the effects of weeds on wetland values | DECCW, private landholders, LHPA, I&I NSW, CW CMA and LPMA | Implement Ippia BMP developed under NSW WRP Noogoora burr bio-control using <i>Epiblemma</i> species moth | Ongoing Established and ongoing |
| Carp control | Minimise the impacts of carp on wetland values | I&I NSW Fisheries | Development of a carp-reduction strategy | Underway |
| Pig control | Minimise the effect of pigs on wetland values | LHPA, DECCW and private landholders | DECCW core business on the nature reserve | Underway |
| Wetland restoration | Undertake the Pillicawarrina restoration project | DECCW (PWG) | Pillicawarrina project team comprising members from DECCW and UNSW | Underway |
| Water Management | Implement an integrated plan for supplying and managing water in relation to North Marsh, South Marsh and East Marsh | DECCW, State Water, NOW, I&I NSW Fisheries and private landholders | Inter-agency project teams | 2010 and ongoing |

Table 8.5 Restoration and protection of fish habitat and the aquatic ecological community

| Issue | Response or action for management | Responsibility | Mechanism | Timing |
|---|--|---|--|----------------|
| The effect of instream structures on native fish and the aquatic ecological community | Install fishways on all weirs and improve access through road culverts | I&J NSW Fisheries, State Water, local government and CW CMA | Marebone Weir fishway construction (funded under RERP Sub-program III) Investigation into requirements for fishways along Bulgeraga Creek (funded under RERP Sub-program III) Investigate installation of a fishway at Warren Investigate carp separation cages on Marebone, Warren and Gunningbar fishways | 2010 2010 |
| | Install screens on extraction points to prevent entrainment of fish | Local government and irrigation industry | Dubbo City Council has screens in place (otherwise unfunded) | Ongoing effort |
| | Identify and protect important refuge areas for fish in dry times | I&J NSW Fisheries, LPMA, UNSW, private landholders and CW CMA | Protection of riparian areas | Ongoing |
| Water quality | Apply the POEO Act | DECCW | Legislative responsibility | Ongoing |
| | Implement CW CMA CAP targets | CW CMA | Legislative responsibility | Ongoing |
| | Implement ANZECC 2000 guidelines | CW CMA and DECCW | Natural Resource Commission statewide targets Central West CMA catchment action plan | Ongoing |
| | Install mixing device to reduce cold-water pollution from Burrendong Dam | State Water | Assessment of performance of a suspended curtain (funded under RERP Sub-program III) | 2010 |

Table 8.6 Application of scientific knowledge to management and policy

| Issue | Response or action for management | Responsibility | Mechanism | Timing |
|--|--|--|---|---------|
| Improve links between management, policy and science | Prepare a strategic research program | DECCW and partners | DECCW Water for the Environment Branch, DECCW Rivers and Wetland Unit | 2010 |
| | Prepare a manual for managing waterbird breeding | DECCW | Underway (funded under NSW WRP) | 2010 |
| | Map vegetation area and condition | DECCW and UNSW | DECCW Rivers and Wetlands Unit SLATS program | Ongoing |
| | Monitor ecological character of Ramsar site | DECCW | DECCW Water for the Environment Branch Landholders | Ongoing |
| | Prepare a monitoring, evaluating and reporting plan, and a report on wetland condition | DECCW, NOW, State Water, I&I NSW Fisheries, CW CMA and private landholders | The development of a strategic adaptive management (SAM) framework is being investigated for the nature reserve and may provide a mechanism to evaluate existing programs against objectives and direct the monitoring activities | Ongoing |
| | Develop a hydrodynamic model of the marshes | DECCW | Component of Decision Support System (funded by RERP Sub-program II) | 2010 |
| | Improve technical and scientific support for managers and decision makers | DECCW | DECCW Rivers and Wetlands Unit Other researchers | Ongoing |
| | Regularly conduct planning meetings between managers, scientists and policy makers | DECCW to lead | Inclusion of all units in key processes and functions including environmental flow reviews, MM AEMP implementation, ecosystem response modelling conferences | Ongoing |
| | Investigate sedimentation rates in different parts of the marshes | DECCW | Pilot project underway in Buckingham Swamp (funded by RERP) | 2010 |

Table 8.7 Aboriginal cultural values

Short term: 2–3 years; medium term: 3–5 years

| Issue | Response or action for management | Responsibility | Mechanism | Timing |
|---|--|---------------------------------------|--|-------------------|
| Aboriginal cultural values and environmental water | Negotiate Aboriginal cultural values as criteria for managing environmental water | DECCW | EFRG Develop policies and guidelines on documenting places/sites with cultural values and methods for including these places/sites in the management of environmental flows. | Short term |
| | Negotiate an Aboriginal cultural flow | DECCW | Explore pathways for securing allocations of water and methods for managing these water allocations | Medium term |
| Aboriginal cultural heritage sites | Identify Aboriginal cultural heritage sites and take appropriate action to conserve them | DECCW, CW CMA and private landholders | NSW WRP (identification of sites), negotiated under CHD Aboriginal Heritage Conservation Program MMNR plan of management CW CMA Catchment Action Plan | Ongoing |
| Plants and animals that have Aboriginal cultural values | Identify and protect plants and animals that have Aboriginal cultural value | DECCW, CW CMA and private landholders | NSW WRP (identification of sites) Aboriginal Heritage Conservation Program MMNR plan of management CW CMA Catchment Action Plan Threatened Species Recovery Plans | Ongoing |
| Access to Country | Increase Aboriginal people's access to conservation reserves | DECCW (PWG) and LPMA | DECCW (PWG) Co-management Program MMNR plan of management | Short-medium term |
| | Increase negotiated access to private land in the marshes | CW CMA and private landholders | Catchment action plan: a guide to access agreements can be found at www.daa.nsw.gov.au/publications/DAA%20On%20Country.pdf | Short-medium term |

Table 8.7 (continued) Aboriginal cultural values

| Issue | Response or action for management | Responsibility | Mechanism | Timing |
|---|---|--|---|-------------|
| Working on Country | Increase employment, training and economic opportunities on the wetlands | DECCW (PWG) CW CMA | Caring for Our Country CW CMA Catchment Action Plan MMNR plan of management Aboriginal Land Management Framework Indigenous green teams Indigenous rangers | Medium term |
| Increased participation in managing the wetlands | Include Aboriginal representatives on the EFRG | DECCW | EFRG | In place |
| | Support formation of a reference group for both Aboriginal cultural heritage and land management in the marshes | Aboriginal community, DECCW, LPMA and CW CMA | To be determined | Medium term |
| Acknowledgement of Aboriginal connection to Country | Make a partnership arrangement with managers of conservation reserves | DECCW (PWG) | DECCW (PWG) Co-management Program MMNR plan of management review Emergent indigenous protected areas program | Medium term |
| | Include a welcome to Country and an acknowledgement of Country before major events occur in the marshes | DECCW and Aboriginal community | Event organisers to be advised of acknowledgement request; see guidelines at www.dpc.nsw.gov.au/publications/memos_and_circulars/circulars/2004/c2004-39 | In place |

Table 8.8 Adaptive governance: participatory processes and consultation

| Issue | Response or action for management | Responsibility | Mechanism | Timing |
|---|--|------------------------|--|---------------------------------------|
| Ensuring stakeholders are involved in managing the river and wetlands | Support the community's role in managing environmental flow | DECCW and CW CMA | Macquarie–Cudgegong Environmental Flows Reference Group, membership of which includes DECCW, CW CMA, NOW, State Water, I&J NSW Fisheries, DEWHA, the Aboriginal community and private landholders | Established and ongoing |
| | Ensure stakeholders participate in coordinating and reviewing the AEMP | DECCW and CW CMA | Undertake an annual review of the AEMP and identify priorities for watering assets in the marshes; the review to include DECCW, CW CMA, State Water, I&J NSW, DEWHA, EFRG and affected private landholders | Ongoing |
| | Develop a program for researching strategic adaptive management | DECCW, UNSW and CW CMA | Strategic Adaptive Management and Research Planning Group | Core of group established and ongoing |
| | Better understanding of legislation | DECCW, CW CMA | Central West CMA is running a <i>Native Vegetation Act 2003</i> information day in the marshes in 2010 | 2010 |
| | Develop a communication strategy | DECCW and CW CMA | Continue communication mechanisms established under NSW WRP and RERP | Ongoing |
| | Opportunities for the community to access the marshes | DECCW | Discovery tours run by Parks and Wildlife Group in good seasons; a marsh observation platform is located on the Gibson Way | Ongoing |

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