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Health of the River Murray

Menindee Lakes, the Lower Darling River and Darling Anabranch)

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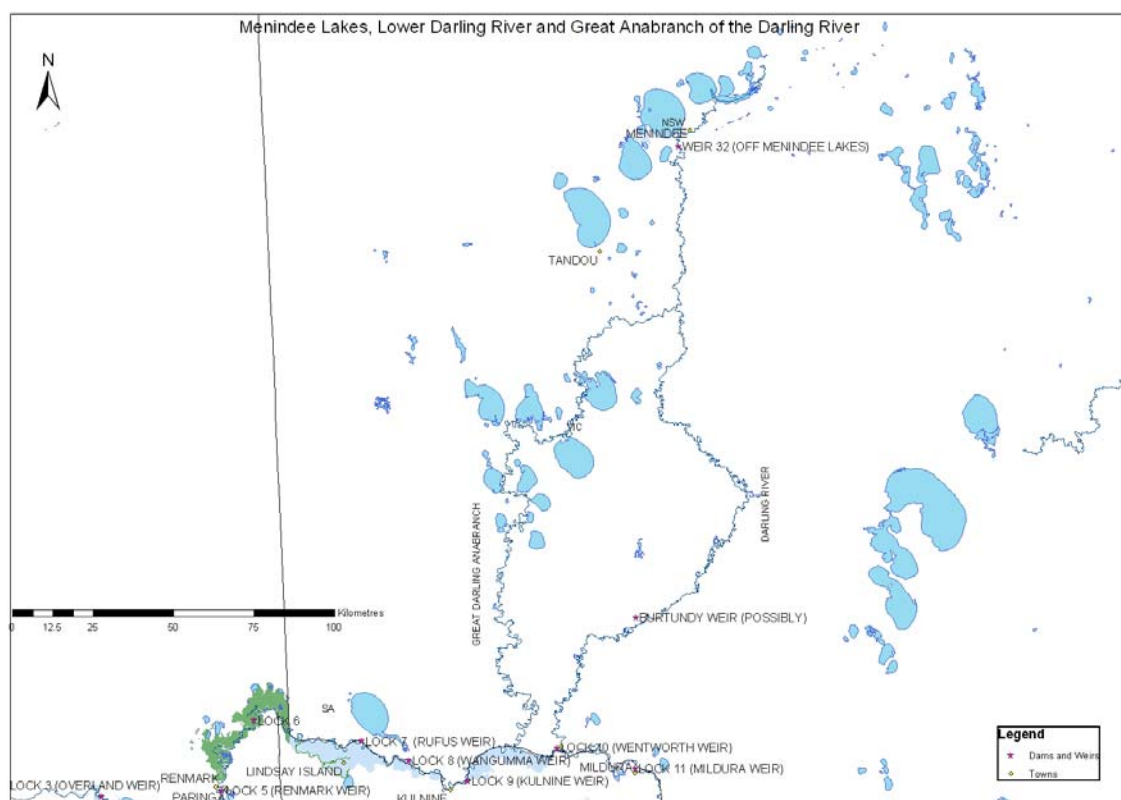
Introductory Note

Please note: The contents of this publication do not purport to represent the position of the Murray-Darling Basin Commission. The intention of this paper is to inform discussion for the improvement of the management of the Basin's natural resources.

Environmental assets within the river zone

The lower Darling River system is located at the downstream end of the River Murray system in NSW and is marked by Wentworth to the south and Menindee to the north. It encompasses the Menindee Lakes system, the Darling River below Menindee and the Great Anabranch of the Darling River (referred to hereafter as the Darling Anabranch) and associated lakes. These are iconic riverine and lake systems within the Murray-Darling Basin. In addition, a vital tributary and operating system feeds the lower River Murray. The climate of the area is semi-arid with an annual average rainfall of 200 mm at Menindee (Auld and Denham 2001) and a high potential annual evaporation of 2,335 mm (Westbrooke et al. 2001). It is hot in summer (5–46°C) and mild to cold in winter (-5–26°C).

In particular, the lower Darling River system is characterised by clusters of large floodplain lakes, 103 to 15,900 ha in size, located at Menindee and along the Darling Anabranch. Billabongs, channel complexes, backwaters, riverine benches, saline lakes, lignum swamps, deep riverine pools and extensive floodplain are also features of the region. The Darling Anabranch is also special being the ancient bed of the Darling River that continued to flow when the river changed its path 11,000 years ago. Located at the downstream end of the expansive Barwon and Darling River systems, the lower Darling River system has a unique hydrological signature marked by periods of dryness in the first half of last century followed by clusters of large floods in the 1950s and 1970s and moderate floods in the 1980s and 1990s.



The wetlands of the lower Darling River system provide significant waterbird habitat in the Murray-Darling Basin. In particular, the lakes of the Menindee system as they dry and flood again support tens of thousands of birds (Kingsford et al. 2002). The Menindee Lakes system is also regarded as important fish habitat within the basin. River red gum (*Eucalyptus camaldulensis*) lines the northern anabranch channel and

the Darling River and associated benches. It spreads across the floodplain and borders the numerous billabongs that connect to the river during small floods. Black box (*Eucalyptus cunninghamii*) and lignum (*Muehlenbeckia florulenta*) occurs throughout the system, and prior to regulation lignum covered much of the 16,535 ha bed of Menindee Lake (Kingsford et al. 2002). Records from early explorers in the 1800s reveal that many Australian mammals (i.e. Western quoll, mulgara, numbat and stick nest rats) lived in the unique and well-watered region where the Darling Anabranch and Darling River connect to the River Murray.

In the late 1990s, the River Murray Scientific Panel on Environmental Flows assessed the condition of the environmental assets (geomorphological, hydrological and ecological) of lower Darling River and the Darling Anabranch (Thoms et al. 2000). Their assessment, based on knowledge of panel members, local authorities, ecological theory, concepts of large rivers and a joint site inspection, is the key reference used here to describe the current condition of the ecological assets in the lower Darling River system.

Riverine and wetland environment

The Darling River below Menindee flows in a south easterly arc for 200 km before joining the River Murray at Wentworth, NSW. The river channel is young, forming only 11,000 years ago, and as a consequence, is relatively narrow with small meanders, and downstream of Pooncarie is quite straight (Thoms et al. 2000). It is characterised by numerous billabongs both adjacent to and adjoining the river and some extensive low-lying areas that support dense stands of lignum (particularly around Pooncarie) (King and Green 1993). An association of river red gum and black box is the dominant riparian vegetation along the river (King and Green 1993). Several lakes — Yartla (890 ha), Cuthero (203 ha) and Porters Lakes, occur between Menindee and Pooncarie. The river channel features horizontal benches formed by deposition of sediments that are typical of semi-arid rivers (Thoms et al. 2000).

The Darling River spills into the Darling Anabranch along the main channel, a shallow inlet that passes through a series of lagoons, about 55 km south of Menindee. In moderate floods, water also flowed from the Darling River into Tandou Creek where it flowed to the anabranch via Redbank Creek or Coonahugga Creek. There is an expansive area of floodplain with river red gum woodland and black box along these creeks, between Menindee and the Darling Anabranch. However, there is little information published on the plants and animals of this region. The anabranch channel is extremely sinuous with large meanders, due to being the ancient river channel (Thoms et al. 2000).

A series of 16 lakes (120 to 11,000 ha) occur along the Darling Anabranch. The lakes connect to the Darling River during small, medium and large floods, providing important habitat for waterbirds and fish. River red gum floodplain dominates the frequently flooded northern part of the Darling Anabranch. Lakes in this section flood 1 in 3 years (Irish 1993). The southern half of the Darling Anabranch floods less often with lakes in this section flooding 1 in 10 years (Irish 1993). The Darling Anabranch receives backwater flows where it joins the River Murray, 15 km west of Wentworth, and is dominated by river red gum. In between, black box woodland is the dominant vegetation.

The Menindee Lakes system is one of the more important and extensive wetland systems on the Darling River (Kingsford et al. 2002). Menindee Lakes are a cluster of

19 lakes, ranging in size from 103 to 15,900 ha (Kingsford et al. 2002). Before the Menindee Lakes Scheme was constructed in the 1960s they connected directly to the Darling River via short creeks (less than 20 km), and ranged in flood frequency from 1 in 2 years to 1 in 20 years (Kingsford et al. 2002). Other small lakes and wetlands also occur in the area.

The lake systems at Menindee and on the Darling Anabranch cover 45,000 and 47,000 hectares respectively and are both listed in the Directory of Important Wetlands in Australia (Environment Australia 2001). The lakes are typical freshwater inland lakes in the Murray-Darling Basin with low-lying elliptical or kidney-shaped basins and white sandy beaches and a lunette on the eastern margin, which is largest on the downwind north east side. A red soil ridge, sometimes steep, eroding and cliff-like, forms the western edges of lakes. Other nearby lakes, such as some in the Willandra system, are considered extinct, as they have been dry for 18,000 years. However, the lakes in the lower Darling River system still flood periodically, and are significant as ancient but living lake systems in a sea of fossil lakes.

Hydrological signature

The river and wetland systems in the lower Darling River system rely on flows from the 2,740 km Darling River (also known as the Barwon-Darling), the longest river in Australia (Crabb 1997). For most of its length, elevation changes by only 122 metres, falling only 12.7 cm km⁻¹ above Menindee and 4–6 cm km⁻¹ below Menindee (Withers 1996). The river originates west of the Great Dividing Range in the north of the Murray-Darling Basin, receiving water from 10 major tributaries draining an area of 650,000 km² of southern Queensland and northern New South Wales (Thoms and Sheldon 2000). Most floods in the lower Darling River system occurred in winter and spring after winter rainfall in central and northeastern NSW. Floods also occur in autumn after summer monsoon rainfall in the tributaries that drain southern Queensland.

The hydrological signature, or pattern of flows, floods and drying events, is influenced by the semi-arid climate and sporadic rainfall across most of the catchment. As a result, the historical flood pattern is highly variable, especially in comparison to the upper reaches of the River Murray. Rivers that flow through such regions are termed dryland rivers. In the lower Darling River system, the first half of last century was very dry with only a few small floods (1917, 1921, 1931 and 1941) (Jenkins 1999). In contrast, significant floods followed in the 1950s, 1970s, 1983 and 1990. The largest flood recorded in the lower Darling River system was in 1890. Two in every 3 years there was a small flood in the upper reaches that flowed into the Menindee Lakes, northern anabranch lakes and Darling River billabongs (Irish 1993; Kingsford et al. 2002). One in 10 years there were moderate floods that spilled onto the floodplain and filled the southern most lakes and wetlands for months to years (Irish 1993). Floods in the lower Darling River system tended to occur in clusters with a second or even third flood much more likely to occur in the years following a major flood (Irish 1993).

Most summers the Darling River would typically dry back to a series of deep waterholes (Withers 1996). The Darling River at Menindee ceased to flow 48 times between 1885 and 1960, and the river did not flow for 364 days in the 1902–3 drought (Lloyd 1992). Similarly, the lakes at Menindee and on the Darling Anabranch would dry for many years between floods. From 1890 to 1961 water flowed the full length of the anabranch to the River Murray nine times (Withers 1996).

Waterbirds

The main lakes at Menindee, Lake Cawndilla and Menindee Lake, support up to hundreds of thousands of waterbirds, including migratory shorebirds, as they dry out and when they flood again (Kingsford et al. 2002). In January 1996 when Menindee and Cawndilla Lakes were almost dry, waterbird numbers were at 221,781 including 34 species and 40,000 small wading birds (Kingsford et al. 2002). In the 1960s when Menindee Lake was covered in lignum, black swans nested in their thousands and again in the late 1970s (J. Eveleigh personal communication in Kingsford et al. 2002). Hundreds of Australian pelican bred on the southern end of Cawndilla Lake in 1952 (J. Eveleigh personal communication in Kingsford et al. 2002).

Records from the NPWS Wildlife Atlas for the Darling Anabranch and Lower Darling River revealed 74 waterbird species of which 34 were small wading species (Jenkins 1999). Freckled ducks (*Stictonetta Naevosa*) and blue-billed ducks (*Oxyura Australia*), recorded in lower Darling River system, are listed as vulnerable under the NSW Threatened Species and Conservation Act 1995. In total, the wetlands of the lower Darling River system support 24 species of waterbirds considered rare or endangered. Eleven of these rely on temporary rather than permanent wetland habitat (i.e. freckled duck and migratory waders (King and Green 1993). During field surveys in 1992 while western NSW was in drought, waterbirds concentrated on the deeper anabranch lakes, Nearie and Little Lakes suggesting their value as drought refuge in the southern basin (King and Green 1993). Although not surveyed during the annual survey of eastern Australia, the Darling Anabranch and lakes were predicted to support more than 10,000 waterbirds when flooded (Kingsford et al. 1997).

There seems to be no contemporary evidence of major waterbird breeding colonies (thousands) in other parts of the lower Darling River system, south of Menindee. Though this may partly reflect incomplete survey effort, it possibly represents the true situation. Perhaps the southern habitat is inadequate to support major colonies like those that exist elsewhere (ie. Macquarie Marshes). Nests have been observed in blackbox trees/woodland/fringe around Popio Lake, and surveys during floods and for nesting sites are needed to determine the value of the Darling River and Darling Anabranch for waterbird breeding.

Fish

The lower Darling River system offers fish a diversity of habitats and a potential waterway to move from the Murray to the Menindee Lakes and Barwon-Darling River system. Habitats include deep waterholes along the Darling River, expansive lakes, lignum swamps and a mix of slower water interspersed with shallow fast flowing runs (Jenkins 1999). Despite the significance of the habitats, fish have not been widely surveyed in the lower Darling River system with only three surveys being undertaken (Llewellyn 1983; Harris and Gehrke 1997; Scholz et al. 1999).

In 1996 and 1997, two sites in the lower Darling River system (Pooncarie and Wentworth) were surveyed for fish in winter and summer as part of the NSW Rivers Survey. Between 100 to 1000 bony bream (*Nematalosa erebi*) and 11 to 100 golden perch (*Macquaria ambigua*) were captured at both sites each time. Murray cod were captured in moderate abundances (11–100) at the Wentworth site and the crimson spotted rainbowfish (*Melanotaenia fluviatilis*) (1–10). Australian smelt (*Retropinna semoni*) and gudgeon (*Hypseleotris* spp.) were captured at Wentworth (11–100) and at Pooncarie (1–10).

In 1997 and 1998, three sites in each of six Menindee Lakes were surveyed four times (Scholz et al. 1999). The surveys detected 10 fish species, including fly specked hardyhead (*Craterocephalus stercusmuscarum*) and crimson spotted rainbowfish (*Melanotaenia fluviatilis*) as well as the more common species (above) from the Darling River surveys. Five species, bony herring, carp, carp gudgeons, golden perch and smelt were collected on all trips and from all lakes (Scholz et al. 1999). Although not detected in the recent surveys, the Menindee Lakes supports Murray cod and also silver perch (*Bidyanus bidyanus*) and fly specked hardyhead (*Craterocephalus stercusmuscarum*), both listed as vulnerable under the Fisheries Management Act 1994 in NSW. Seven of the 19 species of native fish recorded in the Darling River are on the threatened list.

In 1988, common species in the Darling Anabranch were golden perch, bony bream and European carp (*Cyprinus carpio*), while silver perch and floodplain mussels (*Velesunio ambiguus*) were seen occasionally (Lloyd 1992). Murray cod, freshwater catfish (*Tandanus tandanus*), goldfish (*Carassius auratus*) and redfin (*Perca fluviatilis*) were rarely seen (Lloyd 1992). Typically, Murray cod and catfish were seen after floods (Lloyd 1992).

Floodplain vegetation

The wetlands and floodplain woodlands in the lower Darling River system cover more than 300,000 ha. Of the 269,120 ha area surveyed on the Darling River floodplain and Darling Anabranch, but excluding the Menindee Lakes, there was 7360 ha of river red gum forest and an additional 8,200 ha of river red gum associated with black box, lignum, nitre goosefoot (*Chenopodium nitrariaceum*) or open water (King and Green 1993). The main vegetation type in the surveyed area is black box woodland (169,480 ha) with significant patches of lignum (1,360 ha) or lignum associations (15,630 ha) (King and Green 1993). Although black box woodlands are widespread through much of the alluvial country in southern Australia, the woodlands in the lower Darling River system are of scientific interest because they contain a single species of *Eucalyptus* trees, whereas most woodlands and forest contain two or more species (Fox 1991).

Current condition of environmental assets

Riverine and wetland features

Three low level weirs disrupt the lower Darling River, Weir 32 at Menindee, Pooncarie Weir and Burtundy Weir. The weirs, completed in 1958, 1968 and 1942 respectively, do not have provision for fish passage (Thoms et al. 2000). The horizontal benches are suffering erosion that is reducing their habitat values and the complexity of the in-channel environment (Thoms et al. 2000). The high-level benches now flood in 30% of years, compared to 60% of years naturally (Thoms et al. 2000). Similarly, the billabongs flood less frequently now, and are therefore infrequently available as aquatic habitat. At a discharge of 13,000 ML/d at Weir 32, 50% of billabongs in the lower Darling River are filled (Green et al. 1998). Prior to regulation, this flow occurred on average every 11 months, and currently occurs every 1.8 years (Green et al. 1998). More than half the billabongs in this reach hold water for durations longer than 7 months, with recorded durations up to 1–2 years (King and Green 1993; Green et al. 1998).

Seventeen weir pools, 17 bywashes and 10 block banks, most with regulators on the inlets to lakes, fragment the Darling Anabranch channel. The lake regulators prevent the stock and domestic flow going into the lakes, as the lake sill levels are close to the

level of the channel. The main channel into the Darling Anabranh commences to flow at 10,000 ML/d at Weir 32 and the lakes when flows in the channel reach 500 ML/d at the Wycot gauge (Withers 1994; Nias 2002). A flow of 1,000 ML/d at Wycot gauge is required before a significant volume of water flows into the lakes. In general, regulation in the Darling River has halved the frequency of floods (10,000 ML/day at Weir 32) to lakes and wetlands that naturally flooded every 1 in 2–3 years (Green et al. 1998). The Darling Anabranh channel is changing shape from a flat to incised cross-section. The pools behind structures on the anabranh have virtually no bed diversity, and because water is ponded they have high levels of sedimentation (Thoms et al. 2000).

The Menindee Lakes Scheme, completed in 1960, comprises 12 storage lakes, 4 weirs, 11 regulators, 7 block banks and about 15 km of constructed channels and levee banks (Kingsford et al. 2002). Its purpose was primarily to store water for the nearby township of Broken Hill and irrigation downstream. Consumptive use of water in the lakes are now predominantly for irrigation. A block bank and weir in the Darling River results in the storage of flows in Lake Wetherall and in Lakes Malta, Balaka, Bijijie and Tandure (Kingsford et al. 2002). About 32 km of levee on the western side of the floodplain ensures that most flows down the Darling River are captured (Kingsford et al. 2002). Water collected by Lake Wetherall is then stored in Lakes Pamamaroo, Menindee, Cawndilla and the smaller storage lakes (Kingsford et al. 2002). The stored water is released directly into the Darling River either through outlets on the main weir or Lakes Wetherall, Pamamaroo and Menindee (Kingsford et al. 2002). Water can also be released from Lake Cawndilla, via a constructed channel for downstream irrigation or supplying the Darling Anabranh (Kingsford et al. 2002). The regulation of flows in the Menindee Lakes system increased the time that 10 lakes were inundated (Malta, Balaka, Bijijie, Tandure, Pamamaroo, Menindee, Speculation, Dry-Eurobilli, Cawndilla and Spectacle), covering 39,244 ha (Kingsford et al. 2002). In the process of regulation, a series of temporary freshwater lakes were converted into permanent storages, while the building of levees and roads across the floodplain has changed the distribution of flooding patterns.

Hydrological signature

Located at the terminal end of the Barwon and Darling catchment, the lower Darling River system is a barometer for flow modification upstream. Abstractions of water in the Barwon and Darling River systems, development of the Menindee Lakes Scheme and the annual stock and domestic flow along the Darling Anabranh have yielded a markedly different hydrological signature. Up to 81% of flows along the Barwon and Darling Rivers pass through nine headwater impoundments and 15 weirs (Thoms et al. 2000) and median annual runoff is reduced by 42% (Thoms and Sheldon 2000). Diversions above Menindee are equivalent to 60% of the natural flow at Menindee (Thoms et al. 2000).

The effect of the Menindee Lakes Scheme and its operations has resulted in high flows in summer instead of spring and autumn (Thoms et al. 2000). Winter flows are now relatively constant, with flows in the 200–500 ML/day range occurring 65% of the time (Thoms et al. 2000). The incidence of small floods (10,000 ML/day), also referred to as bankful flows, now occurs 10% of the time compared to 25% naturally (Thoms et al. 2000). There has been a reduction in flows by almost 50% by the combination of development in the Darling River catchment, water harvesting and high evaporation from the lakes (Thoms et al. 2000).

The Darling Anabranh is no longer an ephemeral channel, and now comprises a series of weir pools that store the annual stock and domestic allocation of 50,000 ML from Lake Cawndilla. The frequency of small floods that inundate the northern anabranh lakes and floodplain is reduced (Thoms et al. 2000).

The Menindee Lakes flood more frequently now than under natural conditions (1 in 2–3 years), and hold water for longer periods. The frequency of dry periods has declined dramatically. The Menindee Lakes also operate to reduce downstream flooding (Thoms et al. 2000). Local scale and upstream factors have changed the hydrology and reduced the value of most wetlands in the Menindee Lakes system. Of the 88,570 ha of wetland that make up the lakes and floodplain of Menindee Lakes, most (greater than 99 %) is degraded by too much flooding (39,244 ha) or too little flooding (45,298 ha) (Kingsford et al. 2002). Only small wetlands, filled by local rainfall, have natural hydrological patterns.

Fish

Only 14 fish species were caught during surveys of the lower Darling River (Harris and Gehrke 1997). Species richness at both sites was low with an average of only three species (Harris and Gehrke 1997). The proportion of fish caught with visible abnormalities at Pooncarie was 26–50% while 1–25% of fish caught at Wentworth showed abnormalities (Harris and Gehrke 1997).

In the 1997–98 survey in the Menindee Lakes, three species e.g. silver perch, catfish and Murray cod were expected to occur but were not present (Scholz et al. 1999). The absence of the first two species reflects their decline in the Murray-Darling Basin in recent decades, whereas anecdotal information suggests that Murray cod remain viable in the Darling system (Scholz et al. 1997).

Recent surveys in the southern Murray-Darling Basin have revealed that the purple spotted gudgeon and olive perchlet have become rare, while there are no records of tench or flathead gudgeons in the Menindee section of the lower Darling River (Scholz et al. 1999). The absence of the latter species is surprising given its occurrence in the northern tributaries of the Darling River and in the Murray River (Scholz et al. 1999).

Interviews with landholders on the southern Darling Anabranh revealed redfin were common in the 1950s, but declined after the regular releases started in 1961. Carp became established and reached high numbers in the 1960s and 70s. A professional angler reported that carp remained in the Darling Anabranh channel and native species were prevalent in the lakes (Lloyd 1992).

Waterbirds

There were large colonies of breeding waterbirds in the Menindee Lakes before regulation and immediately after regulation. HANZAB (Marchant and Higgins 1990) refers to '5000 nests and 20,000 pairs' of Great Cormorant *Phalacrocorax carbo* on 'Menindee Lakes' in 1974. The high numbers recorded in 1974 have not been observed recently, probably due to effects of regulation coupled with the lack of large flood events like that observed throughout much of Australia in 1974–76. Prior to regulation, the Menindee Lakes may have offered one of the largest areas of woodland and shrubland that was subject to periodic inundation, in the Darling system, making it very attractive to breeding waterbirds. Recently documented colonies of waterbirds in the lower Darling River system have mainly been relatively small colonies of cormorants/darters around Menindee.

In addition, the regulation of the Menindee Lakes has diminished the value of the system to waterbirds as foraging and breeding habitat (Kingsford et al. 2002). In a comparison of lakes that are permanently inundated (Menindee Lakes, Euston Lakes, Murray Tributary Lakes) versus unregulated lakes (Lower Cooper Creek Lakes, Paroo Overflow Lakes and Desert Upland Lakes) waterbird density and diversity was significantly reduced by regulation (Kingsford et al. 2002). Densities of waterbirds, across the 19 years of aerial surveys, were between 0.7 and 11 waterbirds/hectare on the regulated lakes. This was compared to 8–116 waterbirds/hectare on the unregulated lakes (Kingsford et al. 2002). However, when Lake Cawndilla and Menindee Lake dried in 1995 and subsequently flooded again, species richness and densities of waterbirds boomed (Kingsford et al. 2002).

There is little information on the current condition of waterbird communities on the Darling Anabranch and lower Darling River. However, elsewhere (i.e. Macquarie Marshes) reduced frequency of flooding has had detrimental effects on waterbird communities (Kingsford and Johnson 1998). Examination of the impacts of increased duration of dry periods, associated with declines to the frequency of small floods, on floodplain lakes associated with the lower Darling River, found declines in the diversity and density of microinvertebrates (Jenkins and Boulton 1998). Larval fish, waterbirds and larger invertebrates feed on these microscopic animals, and it is likely that impacts on them will cascade through the food web.

Floodplain and aquatic vegetation

There is little information about the condition of floodplain vegetation in the lower Darling River system. River red gum communities along the channel, benches and billabongs of the lower Darling River and in the northern Darling Anabranch are experiencing reduced frequency of flooding. This is likely to be reducing floodplain vegetation health and inputs of carbon into the river (Thoms et al. 2000). The constant flow levels and unseasonal flows have resulted in an apparent lack of macrophytes (Thoms et al. 2000).

The increased flooding of most major Menindee Lakes caused by regulation of the Menindee Lake Scheme destroyed about 13,800 ha of lignum and 8,700 ha of black box, growing on the lakebeds (Kingsford et al. 2002). A grassy understorey was absent close to Darling Anabranch weir pools and channels in areas near permanent water, but the floodplain may be in better condition (Thoms et al. 2000). There was little organic matter present; virtually no regeneration and the areas inspected appeared heavily grazed (Thoms et al. 2000). The invasive species of cumbungi, *Typha* occurs at weir pools on the Darling Anabranch (Thoms et al. 2000).

Algae

The Darling River is typically turbid with high total phosphorus and low nitrogen and the changed flow regime has increased the risk of algal blooms (Thoms et al. 2000). Algal cell counts can be high, especially during low or no flows, such as on the anabranch, where the critical value of 15,000 cells/mL was exceeded in 26% of samples over the summer-autumn of 1991 (Thoms et al. 2000).

Reasons why some environmental assets have declined in value

Barriers to fish passage

Within the lower Darling River system the Menindee Lakes Scheme, three weirs and constant low flows fragment the Darling River habitats, isolating fish from upstream

reaches (Thoms et al. 2000). The 17 smaller weirs along the Darling Anabranh also block fish passage. There is reduced access to flood runners and the floodplain due to reduced frequency of small to medium floods (Thoms et al. 2000). The weir at Menindee has allowed fish passage twice since construction in the 1960s, both times during large floods first in the mid 1970s and in the early 1990s (Thoms et al. 2000). Large numbers of fish were reported to move upstream during these times, including golden perch that were tagged in South Australia and recovered 1000 km away in the Barwon and Balonne Rivers (Thoms et al. 2000). The sustained low flows, seasonal shifts and reduced access to the breeding sites are also likely to affect fish communities in the lower Darling River system.

Reduced frequency of flooding

The horizontal benches at high elevations in the Darling River channel, flood runners, floodplain and northern anabranh lakes experience reduced frequency of flooding. All of these habitats potentially contribute large amounts of organic matter to the river system when flooded and are productive sites for microinvertebrates. Elsewhere reductions to flood frequency have led to declines in diversity and density of microinvertebrates (Boulton and Lloyd 1992; Jenkins and Boulton 1998) and waterbirds (Kingsford and Johnson 1998). Also needed is flooding in the lower Darling River system to provide fish passage to potential fish breeding sites on the floodplain, in lakes and flood runners (Thoms et al. 2000).

Constant and unseasonal flows

Persistent unseasonal high flows are eroding the riverine benches in the Darling River (Thoms et al. 2000), and changing the shape of the Darling Anabranh channel (Nias 2002). In summer, low minimum flows alternate with high flows whenever the Menindee Lakes are used to supply the South Australian entitlement (Thoms et al. 2000). This results in unnaturally rapid fluctuations in water levels and prolonged periods of high summer flows (Thoms et al. 2000).

Risk of algal blooms

The weir pools in the lower Darling River and the Darling Anabranh are at risk of algal blooms during summer when temperatures are high and flow in the pools is low.

Permanent inundation

The combination of weir pools and the stock and domestic release along the Darling Anabranh has substantially changed the localised environment by preventing long sections of the channel from drying for months to years between floods. Permanent inundation of the Menindee Lakes significantly reduced the frequency of drying in the main lakes. Permanent inundation favours different vegetation communities, leads to sedimentation and channel incision and promotes favourable conditions for carp. It alters the relationship between surface water and groundwater and can lead to increased salinity in surface waters. Permanent inundation disrupts the pattern of flooding and drying in dryland rivers and associated boom and bust cycles in waterbirds (Kingsford et al. 2002) and fish.

What can be done to restore the environmental values

The value of environmental assets within the lower Darling River system can be improved by changes to the volume and timing of flows, structural and operational changes and other catchment management improvements. A description of some restoration measures follow.

Flows

It may appear that variable flows have largely negative effects, when considered in the context of agricultural production and that 'permanent is better'. However, river systems with highly variable flow regimes are different and call for a different approach to their management (Boulton et al. 2000). One option to avoid the constant flows in the lower Darling River is to pass a percentage of inflows downstream during June to September when the Menindee Lakes are filling (Thoms et al. 2002). This would mimic the natural variability in flow characteristics (apart from volume) and provide higher flows in winter-spring when they historically occurred.

Options to increase the frequency of small to medium floods, such as enhancing the flood peak with releases from Menindee, are critical to enhance watering of floodplain, billabongs and lakes (Thoms et al. 2002). Another option may be to conserve flood events by abandoning the practise of pre-releases from Menindee Lakes (Thoms et al. 2002).

Structural and operational

There should be provision of year round fish passage suitable for all native fish species on the lower Darling River either by removal of weirs or by building fish ladders on weirs (Thoms et al. 2002). The former option would require the provision of alternate water supply, while the latter would be a cheaper option as the weirs are low level weirs and any device (i.e. rock fishways) would be relatively small in size (Thoms et al. 2002). An investigation of the most appropriate type of fish passage would need to be undertaken.

Landholders along the Darling Anabranh and government agencies have investigated options to restore environmental values of the anabranh (Nias 2002). The main proposal was to replace the stock and domestic release with a pipeline to supply water and to remove weirs (Nias 2002). This proposal would provide substantial environmental benefits by allowing the channel to dry periodically, and enabling fish passage during flows (Thoms et al. 2000). The success of the proposal relies on reinstatement of a variable flow regime including small floods every 2–3 years.

There could be rehabilitation of some ecological communities within the Menindee Lake system using a management regime that introduced variable flooding and drying patterns to major lakes within the system (Kingsford et al. 2002). This would produce more diverse and abundant waterbird communities and other aquatic communities. The Menindee Lakes Ecological Sustainable Development project is investigating options for modification of the operation of the lakes to improve water quality and reduce water losses (Moore 2002).

Other catchment management improvements

Two agricultural practices that potentially affect the lower Darling River system are grazing and lakebed cropping. In the case of grazing, fencing of riparian zones and provision of alternate stock watering points would promote regeneration of vegetation communities and increase organic inputs from the floodplain to the river system. Research indicates that seasonal grazing at appropriate rates will not significantly affect riparian zones (Robertson 1997).

Most of the lakes along the Darling Anabranh and less often at Menindee are used for cropping as floodwaters recede. Research on the impacts of lakebed cropping found reduced microinvertebrates and fewer small mammals in cropped sites (Briggs

and Jenkins 1997). Lessening these impacts occurs by leaving parts of lakes uncropped. However, the recommendation is that monitoring the impacts of lakebed cropping continue, given the extent of cropping in this region. In addition, research on the impact of cropping on organic matter and vegetation communities should be undertaken. It may be necessary to develop specific management practices to leave larger areas uncropped when cropping follows environmental flow releases to balance the impacts of cropping against the ecological benefits targeted by the release.

The system-wide perspective

The relationship between the Darling River and the River Murray system

The Darling River is the main tributary to the River Murray, but is distinct from the River Murray due to the geological history and character of its expansive semi-arid catchment. Unlike the River Murray, the Darling River flows through a flat landscape with basalt outcrops and sandy soils (Thoms et al. 2000). The lower Darling River system is characterised by a variable flow regime and unpredictable flooding events that spread onto the vast floodplain and spectacular lakes. The clusters of large lakes in this region are unique compared to other parts of the River Murray system. The lower Darling River system is also significant providing the link between the River Murray system and the Barwon and Darling catchment. The loss of connection between the Murray River and upper reaches of the Darling River is likely to affect fish recruitment in the Murray River in South Australia (Thoms et al. 2000).

Since development of the Menindee Lakes Scheme, the lakes have supplied 39% of the annual entitlement flows to South Australia (Thoms et al. 2000), leading to a constant flow regime. The region plays an important role in water supply in the River Murray system and the challenge in restoring environmental values of the lower Darling River system will be to satisfy these needs while improving connectivity, flow variability and flood frequency.

Boom and bust cycles

The plants and animals of dryland rivers are adapted to flow variability and the dynamic wetting and drying cycles leads to what is called a 'boom and bust' ecology. As floods spread over the vast flat landscape, filling lakes and billabongs, a pulse of nutrients triggers a succession of animal and plant communities. Within a few days, the waters are teeming with microinvertebrates that feed on the rich supply of bacteria, protozoans and algae. Pulses in fish numbers follow, as all larval fish depend on microinvertebrates for their first feed. Soon wetlands are dense with larger invertebrates and plants, and numbers of waterbirds boom. Some ducks feed directly on microinvertebrates, while others graze on plants or forage for larger invertebrates. Eventually the lakes and wetlands dry and the pulse of aquatic life gives way to a dryland phase. As the sediments dry, deep cracks form in the sediments. Both the plants and soil cracks provide habitat to a diverse array of birds, mammals and reptiles that feed on the high numbers of spiders, beetles and insects. When the system floods again many of the terrestrial colonists drown, breaking down in the water to provide a rich supply of nutrients and carbon.

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