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MURRAY–DARLING BASIN AUTHORITY

Assessment of environmental water requirements for the proposed Basin Plan:

Wimmera River Terminal Wetlands

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Wimmera-Avoca region

Assessment of Wimmera River Terminal Wetlands environmental water requirements

1. Introduction

The Water Act 2007 (Cwlth) established the Murray-Darling Basin Authority (MDBA) and tasked it with the preparation of a Basin Plan to provide for the integrated management of the Basin's water resources. One of the key requirements of the Basin Plan is to establish environmentally sustainable limits on the quantities of surface water that may be taken for consumptive use, termed Sustainable Diversion Limits (SDLs). SDLs are the maximum long-term annual average volumes of water that can be taken from the Basin and they must represent an Environmentally Sustainable Level of Take (ESLT).

The method used to determine the ESLT is described in detail within *'The proposed "environmentally sustainable level of take" for surface water of the Murray-Darling Basin: Method and Outcomes,'* (MDBA 2011). A summary of the main steps undertaken to determine the ESLT is presented in Figure 1. The assessment of environmental water requirements including specification of site-specific flow indicators at a subset of hydrologic indicator sites (Step 3 of the overall ESLT method) is the focus of this document.

The work described herein is the MDBA's current understanding of the environmental water requirements of Wimmera River Terminal Wetlands. It is not expected that the environmental water requirements assessments will remain static, rather it is intended that they will evolve over time in response to new knowledge or implementation of environmental watering actions. Within this context, feedback is sought on the material presented within this document whether that be as part of the formal draft Basin Plan consultation phase or during the environmental watering implementation phase within the framework of the Environmental Watering Plan.

1.1. Method to determine site-specific flow indicators

Assessment of environmental water requirements for different elements of the flow regime using the hydrologic indicator site approach is one of the key lines of evidence that has informed the proposed SDLs. Effort focussed on regions and parts of the flow regime with greatest sensitivity to the scale of reduction in diversions necessary to achieve environmental objectives, an ESLT and a healthy working Basin.

Within the overall framework of the ESLT method (Figure 1) the MDBA used an iterative process to assess environmental water requirements and develop site-specific flow indicators.

The hydrologic indicator site approach uses detailed eco-hydrological assessment of environmental water requirements for a subset of the key environmental assets and key ecosystem functions across the Basin. Effort focused on high flow (freshes, bankfull flows and overbank flows) requirements reflecting the prioritisation of effort on parts of the flow regime that are most sensitive to the determination of the ESLT and SDLs. The Wimmera River Terminal Wetlands is one of the key environmental assets where a detailed assessment of environmental water requirements was undertaken.

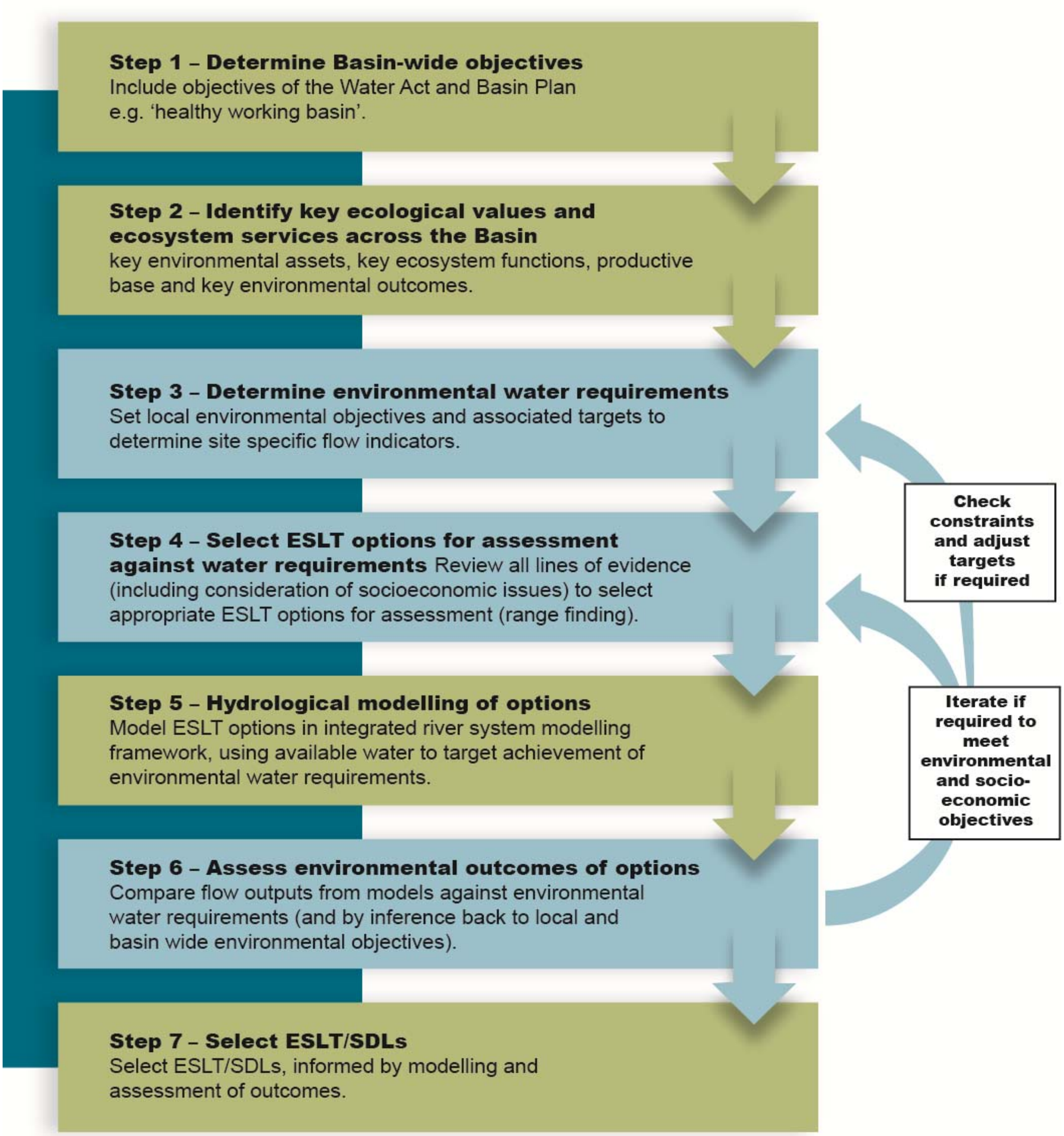

Figure 1: Outline of method used to determine an Environmentally Sustainable Level of Take (Source: MDBA 2011).

Detailed environmental water requirement assessments lead to the specification of site-specific flow indicators to achieve site-specific ecological targets. Flow indicators were expressed at a hydrologic indicator site or sites. Environmental water requirements specified at hydrologic indicator sites are intended to represent the broader environmental flow needs of river valleys or reaches and thus the needs of a broader suite of ecological assets and functions.

This report provides a description of the detailed eco-hydrological assessment of environmental water requirements for the Wimmera River Terminal Wetlands including information supporting the development of site-specific flow indicators for the site (with reference to water levels at Lake Hindmarsh and Lake Albacutya). More information on how the site-specific flow indicators for Wimmera River Terminal Wetlands were used within the Basin-wide modelling process to inform the ESLT (i.e. Step 5 and 6 in Figure 1) can be found in the report *'Hydrologic modelling to inform the proposed Basin Plan: Methods and results'* (MDBA 2012).

A description of the detailed eco-hydrological assessments of environmental water requirements for other indicator sites are described in other documents in the series *'Assessment of environmental water requirements for the proposed Basin Plan'*.

1.2. Scope and purpose for setting site-specific flow indicators

The MDBA's assessment of environmental water requirements and associated site-specific flow indicators at hydrologic indicator sites has been used to inform the development of SDLs. This enables the MDBA to estimate the amount of water that will be required by the environment over the long-term to achieve a healthy working Basin through the use of hydrological models. Accordingly, site-specific flow indicators are not intended to stipulate future use of environmental water. MDBA expects that the body of work undertaken to establish these site-specific flow indicators will provide valuable input to environmental watering but this watering will be a flexible and adaptive process guided by the framework of the Environmental Watering Plan and natural eco-hydrological cues. It will be up to the managers of environmental water, such as the Commonwealth Environmental Water Holder, State Government agencies, and local communities to decide how best to use the available environmental water during any one year to achieve environmental outcomes.

2. Site location and extent

The Wimmera River Terminal Wetlands hydrologic indicator site is at the end of the Wimmera River system in north-west Victoria (Figure 2). The wetlands rely on large infrequent flows that originate in the Grampians Mountain Range, flow down the Wimmera River and inundate Lake Hindmarsh and then Lake Albacutya via Outlet Creek.

The Wimmera River has a catchment area of 23,500 km^2 and is Victoria's largest terminal waterway (Ecological Associates 2004). The river's terminal lakes sit in a dry landscape in a region with a mean annual rainfall of 344 mm at south Hindmarsh (Department of the Environment, Water, Heritage and the Arts 2009). The terminal lakes are naturally ephemeral, relying on significant flows from the Wimmera River to fill. The terminal lakes require floods and dry periods to support a range of ecological values with the distinct wet/dry phases of the hydrological cycle determining the unique ecological character of the Lake Albacuyta Ramsar site (Cibilic & White 2010).

The indicator asset's boundaries have been defined using *A directory of important wetlands in Australia* (Environment Australia 2001). The upstream extent is the Wimmera River inlet to Lake Hindmarsh and the downstream extent is the Outlet Creek outlet downstream of Lake Albacutya. Spatial data used in Figure 2 is listed in Appendix A.

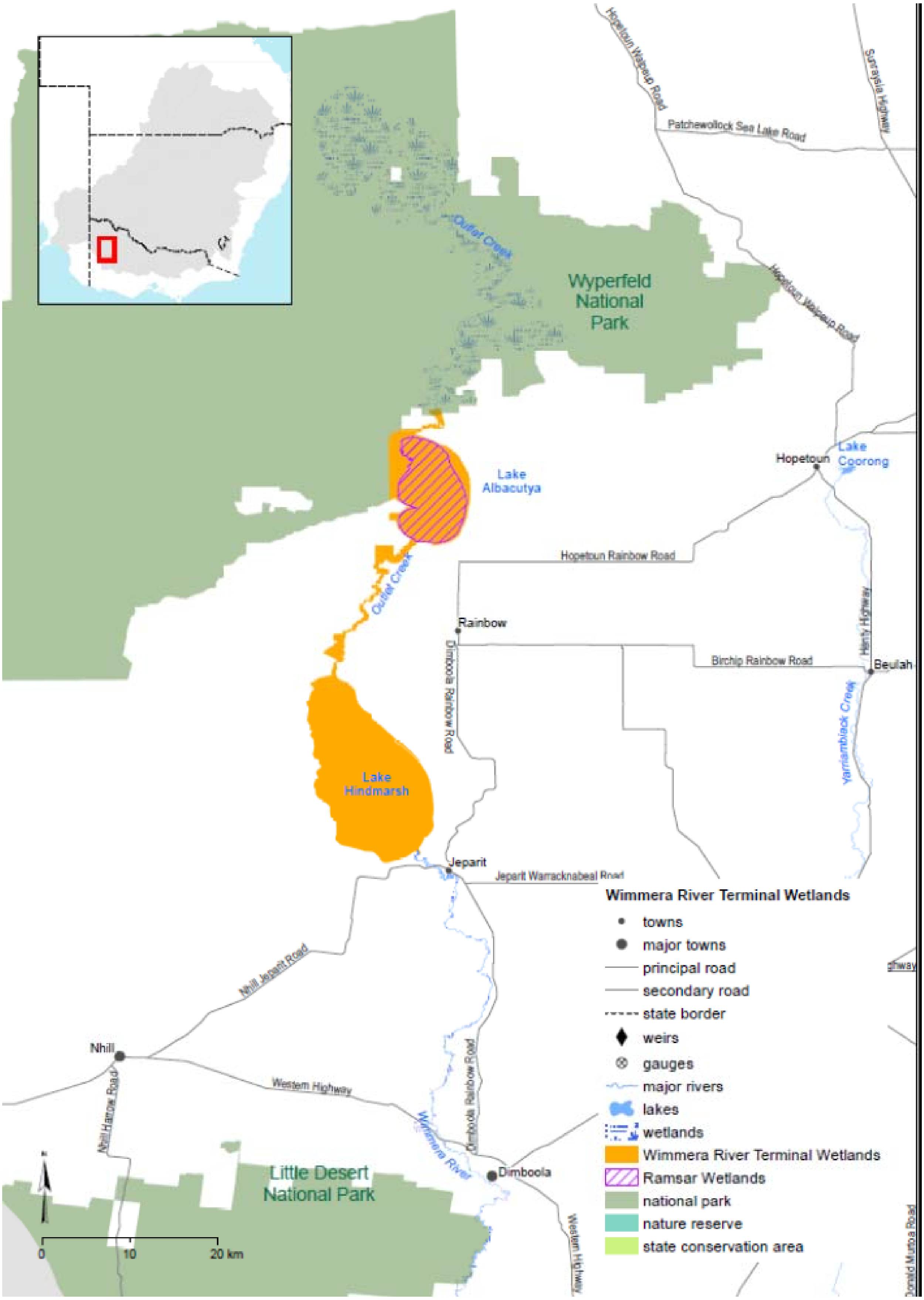

Figure 2 Location and extent of Wimmera River Terminal Wetlands.

3. Ecological Values

Lakes Hindmarsh and Albacutya share similar vegetation communities, which Ecological Associates (2004) characterise into three broad zones:

- central lakebed — during dry spells this area is colonised by terrestrial grasses and herbs such as wallaby grass (*Austrodanthonia* spp.), spear grass (*Austrostipa* spp.) and chenopods (*Maireana* sp.). Lake Hindmarsh has fewer species than Lake Albacutya in this zone because of higher salinities. Exotic plants such as Paterson's curse, horehound and false sow-thistle are also found there. During inundation, these areas supply important nutrients that promote primary productivity. Drowned vegetation provides habitat for invertebrates. Central areas of the lake provide habitat for large fish, including Murray cod (*Maccullochella* peelii peelii), Freshwater catfish (*Tandanus tandanus*) and Golden perch (*Macquaria ambigua*), and birds such as the Australian pelican (*Pelecanus conspicillatus*), pied cormorant (*Phalacrocorax varius*) and black swan (*Cygnus atratus*);
- outer lakebed — the sandier soils of the outer lakebed are colonised by shrubs such as three-nerved wattle (*Acacia trineura*) and sticky hop bush (*Dodonaea viscosa*), lignum (*Muehlenbeckia florulenta*), chenopods (e.g. *Atriplex suberecta*), sedges and grasses. When inundated for longer periods, these terrestrial species are replaced by aquatic species such as eelgrass (*Vallisneria* spp.), water milfoil (*Myriophyllum* spp.) and pondweed (*Potamogeton* spp.). These species provide habitat for smaller native fish species such as Flathead gudgeon (*Philypnodon grandiceps*) and Australian smelt (*Retropinna semoni*), and support waterbirds such as Australian shelduck (*Tadorna tadornoides*), darter (*Anhinga novaehollandiae*), coot (*Fulica atra*), crake (*Porzana* spp.) and Pacific black duck (*Anas superciliosa*). The flooding and desiccation of terrestrial vegetation is important for succession processes once floodwaters recede; and
- fringing woodlands — the river red gum (*Eucalyptus camaldulensis*) and black box (*E. largiflorens*) woodlands that surround lakes Hindmarsh and Albacutya provide important habitat for animals in both the lakes and surrounding mallee landscape. The main canopy species are persistent throughout wet and dry cycles where the understorey changes with the hydrological regime. When dry, the woodlands support an understorey of terrestrial species, such as sticky hop bush, three-nerved wattle, black bluebush (*M. pyramidata*), lignum and several species of saltbush (*Atriplex spp.*). Once inundated, these are replaced by species such as red water milfoil (*M. verrucosum*), southern liquorice (*Glycyrrhiza acanthocarpa*), common reed (*Phragmites australis*) and Australian salt-grass (*Distichlis distichophylla*) (Morton & Heislers 1978). The fringing woodlands provide habitat and nesting sites for terrestrial and aquatic bird species including the nationally vulnerable regent parrot (*Polytelis anthopeplus monarchoides*). In addition, when flooded, lignum provides nesting sites for colonial nesting waterbirds such as nankeen night heron (*Nycticorax caledonicus*), egret and ibis. Flooding is important to the woodlands because it reduces salt concentrations from the root zones and stimulates growth and colonisation.

Lake Hindmarsh has a high carrying capacity for waterbirds and a number of native fish species, including Flathead gudgeon, Golden perch, Murray cod and Freshwater catfish. Being more saline than other lakes in the system, the extent of emergent reedy vegetation is limited and thus extensive mudflats and open-water habitat occur.

Lake Albacutya is a Ramsar-listed wetland and both it and Lake Hindmarsh support an array of species listed in migratory bird agreements. Lake Albacutya supports a denser cover of terrestrial vegetation in its dry phase because it is less saline than Lake Hindmarsh. Once Lake Albacutya fills, this vegetation provides important structural habitat for invertebrates, and breeding and roosting sites for waterbirds.

The ecological values of the wetlands are reflected in MDBA's assessment against the criteria used to identify key environmental assets within the Basin. The MDBA established five criteria to identify assets based on international agreements and broad alignment with the National Framework and Guidance for Describing the Ecological Character of Australian Ramsar Wetlands (Department of the Environment, Water, Heritage and the Arts 2008) and the draft criteria for identifying High Conservation Value Aquatic Ecosystems (SKM 2007).

Based on the ecological values identified at the Wimmera River Terminal Wetlands, the site meets all five criteria for determining a key environmental asset (Table 1).

Table 1 Assessment of the Wimmera River Terminal Wetlands against MDBA key environmental assets criteria.

Criterion	Ecological values that support the criterion
1. The water-dependent ecosystem is formally recognised in international agreements, or, with environmental watering, is capable of supporting species listed in those agreements	The Wimmera River Terminal Wetlands is formally recognised in, or is capable of supporting species listed in the Japan–Australia, China–Australia or Republic of Korea – Australia migratory bird agreements. The site contains the Lake Albacutya Ramsar site. Species listed in international agreements that have been recorded in the Wimmera River Terminal Wetlands are in Appendix B.
2. The water-dependent ecosystem is natural or near-natural, rare or unique	The ecological character description for Lake Albacutya (Cibilic & White 2010) states that Lake Albacutya represents a near-natural example of the Ramsar wetland category 'seasonal intermittent freshwater lakes covering over 8 ha including floodplain lakes'. Lake Albacutya is also a relatively intact representative example of an intermittent sub-terminal lake of which there is only two greater than 5,000 ha in the north-flowing endoreic (areas with terminal lakes and an interior drainage basin) Wimmera–Avon sub-basin. The population of river red gum at Lake Albacutya is genetically unique being well adapted to the periodic wetting and drying with particularly high levels of drought and salt tolerance (Cibilic & White 2010)
3. The water-dependent ecosystem provides vital habitat	Lake Hindmarsh provides breeding habitat for the Australian pelican, great cormorant (*P. carbo*), pied cormorant, Pacific heron (*Ardea pacificus*), Australian shelduck (*Tadorna tadornoides*), grey teal (*A. gracilis*), purple swamp hen (*Porphyrio porphyrio*), red-capped plover (*Charadrius ruficapillus*) and red-necked avocet (*Recurvirostra novaehollandiae*). These species have been recorded breeding at Lake Hindmarsh when conditions were suitable (Victorian Department of Natural Resources and Environment 1995). In addition, the Wimmera region supports groundwater-dependent populations of River blackfish (*Gadopsis marmoratus*) and Pygmy perch (*Nannoperca australis*). The area is also important because it supports a relatively abundant and naturally breeding population of Freshwater catfish (*Tandanus tandanus*) (Clunie & Koehn 2001).

Criterion	Ecological values that support the criterion
	Being less saline than Lake Hindmarsh, Lake Albacutya supports a denser cover of vegetation in its dry phase. Once inundated, this vegetation provides important structural habitat for invertebrates, and breeding and roosting sites for waterbirds.
4. Water-dependent ecosystems that support Commonwealth, State or Territory listed threatened species or communities	Species and communities listed as threatened under both State and Commonwealth legislation that have been recorded at the site are in Appendix B.
5 The water-dependent ecosystem supports, or with environmental watering is capable of supporting, significant biodiversity	The lakes have supported internationally significant numbers of banded stilt (*Cladorhynchus leucocephalus*) — greater than 10,000 (Watkins 1993; Robinson 1984); 100 Pacific heron (*Ardea pacificus*); 100 yellow spoonbill (*Platalea flavipes*); 3,000 Australian shelduck (*Tadorna tadornoides*); 3,000 Pacific black duck (*Anas superciliosa*); 20,000 grey teal (*A. gracilis*); 1,000 Australian shoveller (*A. clypeata*); 1,500 hardhead (*Aythya australis*), 2,000 maned duck (*Chenonetta jubata*); and 3,000 Eurasian coot *(Fulica atra)* (Australian Nature Conservation Agency 1996; Environment Australia 2001). There were 700 freckled duck (*Stictonetta naevosa*) on Lake Albacutya during February 1983. Extrapolations from counts made in Australia during January and February of 1983 (a drought year) suggested a total population of approximately 20,000 birds. Thus in 1983, Lake Albacutya held 3.5% of the total population of freckled duck.

4. Hydrology

Significant changes have occurred to the Wimmera River Terminal Wetlands' hydrology due to development and water extractions upstream in the Wimmera catchment. The description of hydrological changes compared to without development conditions below is comprised of two components – the first is the change to hydrology prior to construction of the Wimmera Mallee pipeline; and the second is the change to hydrology post Wimmera–Mallee pipeline construction.

The Wimmera–Mallee Pipeline Project (WMPP) was a large-scale project that replaced about 17,700 km of the highly inefficient Wimmera–Mallee stock and domestic open channel system with a piped water distribution system. The project began in 2001 and was completed in early 2010. The WMPP resulted in water savings of about 103 GL a year, with 83 GL of this allocated to the environment.

4.1. Lake Hindmarsh

Ecological Associates (2004) modelled historical without development and pre WMPP hydrology of Lake Hindmarsh for the period 1903-2000 (Table 2). Under modelled without development conditions, the lake was always above the shallow water level, filling 35 times in 97.5 years, or once every 2.8 years on average. In addition, the lake made the full +2 m level 25 times in the 97.5-year period, for an average duration of nearly three months. Both the full and full +2 m levels would have watered the fringing woodland communities once every three years on average.

Table 2 Spell analysis of Lake Hindmarsh volume thresholds under without development and pre Wimmera Mallee Pipeline construction conditions for the period 1903-2000 (Source: Ecological Associates 2004).

Scenario	Threshold[a]	Lake level below threshold			Lake level above threshold		
		Number of events (in 97.5 years)	Average spell duration (months)	Maximum spell duration (months)	Number of events (in 97.5 years)	Average spell duration (months)	Maximum spell duration (months)
Without development	Empty	(always above threshold)			(always above threshold)		
	Shallow	(always above threshold)			(always above threshold)		
	Full	36	9.2	55	35	24.0	92
	Full +2 m	26	42.4	226	25	2.7	6
Pre Wimmera Mallee Pipeline	Empty	14	9.0	19	14	74.6	329
	Shallow	10	34.8	94	9	91.3	306
	Full	22	43.6	366	21	10.0	32
	Full +2 m	4	290.3	642	3	3.0	4

a For Lake Hindmarsh: empty = 10 GL; shallow = <80 GL; full = 378 GL (spill level into Outlet Creek); full +2 m = 630 GL + level required to flow in Outlet Creek at 57 GL/m.

Modelling indicates that under pre WMPP conditions, the lake filled far less often and for a shorter duration. Instead of being above the shallow threshold all the time, the lake would have dried to empty. Lake-full frequencies dropped to once every 4.6 years on average, with average durations shortening by over half. Larger flows (full +2 m) showed an even greater (92%) reduction in occurrence. Dry spells also increased, with the lake failing to reach full for 22 years after 1928, affecting the health of the fringing river red gum communities.

MDBA has undertaken analysis similar to Ecological Associates (2004) of Lake Hindmarsh key thresholds under without development and post Wimmera Mallee Pipeline conditions for the period 1895-2009 (Table 3). MDBA modelling of without development conditions indicates that some significant changes in the hydrological regime of Lake Hindmarsh occur by extending the modelling period to include the Federation Drought and the more recent Millennium drought post 1996. Significantly, Lake Hindmarsh would have dried during the Millennium Drought under modelled without development conditions. Lake full and lake full + 2m events results are similar in terms of the number and duration of events to those reported by Ecological Associates (2004); however, the maximum spell between lake full events more than doubles to 138 months or 11.5 years.

Extending the modelling period to include the Federation and Millennium Droughts provides a highly relevant insight to the hydrology of Lake Hindmarsh during extreme drought conditions. However, direct comparison between pre and post WMPP using analysis presented within Table 2 and Table 3 is difficult. Table 3 indicates that compared to without development conditions, Lake Hindmarsh post WMPP still experiences an increase in the number, average duration and maximum duration of empty and shallow events with a corresponding decrease in lake full events. However, some benefits associated with the WMPP are evident for example the maximum duration between full and full + 2m events decreases compared to pre WMPP conditions. Further analysis of changes to key ecologically relevant thresholds pre and post WMPP for Lake Hindmarsh is presented in Section 5.2.

Table 3 Spell analysis of Lake Hindmarsh volume thresholds under without development and post Wimmera Mallee Pipeline construction conditions for the period 1895-2009 (Source: MDBA analysis).

Scenario	Threshold[a]	Lake level below threshold			Lake level above threshold		
		Number of events (in 114 years)	Average spell duration (months)	Maximum spell duration (months)	Number of events (in 114 years)	Average spell duration (months)	Maximum spell duration (months)
Without development	Empty	3	10	17	3	446	1327
	Shallow	2	38	67	2	646	1289
	Full	40	12	138	40	22	68
	Full +2 m	26	50	226	26	3	6
Post Wimmera Mallee Pipeline	Empty	4	14	43	4	328	1292
	Shallow	16	11	91	16	74	415
	Full	35	24	320	35	15	44
	Full +2 m	12	112	393	11	2	5

4.2. Lake Albacutya

When full, Lake Albacutya covers 5,500 ha, is 8 m deep and holds about 230 GL. Once Lake Albacutya fills water remains for between four and six years providing long-term habitat availability for aquatic biota (Cibilic & White 2010).

Being second in the line of terminal lakes in the Wimmera system, flows into Lake Albacutya from the Wimmera River have to first pass through Lake Hindmarsh. Therefore, the inundation regime of Lake Albacutya depends on flows in and out of Lake Hindmarsh and breaching of the sill height of Outlet Creek which occurs when the volume in Lake Hindmarsh exceeds 378 GL. If Lake Hindmarsh is not full, then even large floods in the Wimmera River may not reach Lake Albacutya as illustrated in January 2011, which although estimated as a one in 50-100 year event in the Lower Wimmera River, was insufficient to fill Lake Hindmarsh. In order to fill Lake Albacutya significant inflows are required that may not be provided by a single inflow event. Analysis of the modelled without development flow data suggests that in many cases when Lake Albacutya is full for any length of time, it is in response to several large lake-fill events in Lake Hindmarsh (see example in Figure 3).

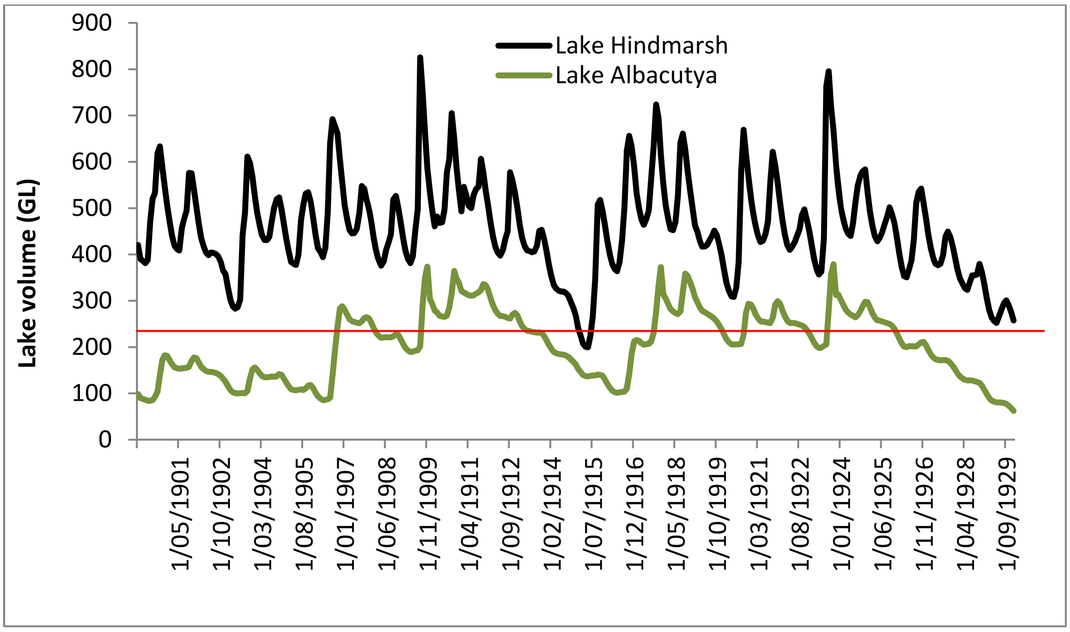

Figure 3 Modelled volumes in lakes Hindmarsh and Albacutya under without development conditions for the period 1900-1930. Lake full in Lake Albacutya (230 GL) is represented by the red line.

Accordingly the impact of diversions on the inundation regime of Lake Albacutya (Tables 4 and 5) is exacerbated in comparison to Lake Hindmarsh (Tables 2 and 3). Ecological Associates (2004) modelled historical without-development and pre WMPP hydrology of Lake Albacutya for the period 1903-2000. Under modelled without development conditions, Lake Albacutya filled to a capacity of 230 GL for an average duration of 19 months, 22 times in 97.5 years, or once every 2.2 years. Under pre WMPP conditions, this same capacity was achieved only twice in the 97.5-year record, for an average duration of 11 months. In terms of low lake levels, while the number of times the lake dried increased by only one event under pre WMPP conditions, the average length of time the lake was empty increased markedly — going from an average duration of 16.2 months to 123 months (Table 4). This is a sevenfold increase in the average duration of dry spells for the lake with development in the Wimmera catchment.

MDBA has undertaken analysis similar to Ecological Associates (2004) of Lake Albacutya key thresholds under without development and post Wimmera Mallee Pipeline conditions for the period 1895-2009 (Table 5). MDBA modelling of without development conditions indicates that some changes in the hydrological regime of Lake Albacutya occur by extending the modelling period to include the Federation Drought and the more recent Millennium Drought post 1996. However, the changes are less marked than those described for Lake Hindmarsh. Similar to Lake Hindmarsh, increasing the model period results in an increase in the average and maximum duration of empty and shallow events with less marked impact on lake full and lake full + 2m events.

Extending the modelling period to include the Federation and Millennium Droughts provides a highly relevant insight to the hydrology of Lake Albacutya during extreme drought conditions. However, direct comparison between pre and post WMPP using analysis presented within Table 4 and Table 5 is difficult. Generally, compared to without development conditions, Lake Albacutya post WMPP still experiences an increase in the number, average duration and/or maximum duration of empty and shallow events with a corresponding decrease in lake full events. However, some benefits associated with the WMPP are evident with increases in the number and duration of lake full and lake full + 2m events compared to pre WMPP conditions. A corresponding decrease in the average duration and maximum duration of empty and shallow events is also expected post WMPP compared to pre WMPP conditions. Further analysis of changes to key ecologically relevant thresholds pre and post WMPP for Lake Albacutya is presented in Section 5.2.

Table 4 Spell analysis of Lake Albacutya volume thresholds under without-development and pre Wimmera Mallee Pipeline construction conditions for the period 1903-2000 (Source: Ecological Associates 2004).

Scenario	Threshold[a]	Lake level below threshold			Lake level above threshold		
		No. events (in 97.5 years)	Average spell duration (months)	Maximum spell duration (months)	No. events (in 97.5 years)	Average spell duration (months)	Maximum spell duration (months)
Without development	Empty	6	16.2	43	6	178.8	392
	Shallow	7	32.7	55	7	134.4	322
	Full	23	32.5	321	22	19.2	50
	Full +2 m	18	61.3	382	17	3.9	8
Pre Wimmera Mallee Pipeline	Empty	7	122.9	368	6	51.7	112
	Shallow	6	159.7	387	5	42.4	98
	Full	3	382.7	647	2	11	21
	Full +2 m	2	583.5	875	1	3	3

a For Lake Albacutya: empty = 10GL; shallow = <25 GL; full = 230 GL (spill level into Outlet Creek); full +2 m = 320 GL + level required to create substantial flow in Outlet Creek.

Table 5 Spell analysis of Lake Albacutya volume thresholds under without-development and post Wimmera Mallee Pipeline construction conditions for the period 1895-2009 (Source: MDBA analysis).

Scenario	Threshold[a]	Lake level below threshold			Lake level above threshold		
		No. events (in 114 years)	Average spell duration (months)	Maximum spell duration (months)	No. events (in 114 years)	Average spell duration (months)	Maximum spell duration (months)
Without development	Empty	7	26.9	68	7	168.6	474
	Shallow	7	46.7	88	7	148.7	426
	Full	20	47.7	335	20	20.75	50
	Full +2 m	18	77.5	384	17	3.7	7
Post Wimmera Mallee Pipeline	Empty	6	88.8	288	6	139.2	292
	Shallow	8	86.4	322	8	84.6	163
	Full	3	436	727	3	20	36
	Full +2 m	4	338.8	735	3	4.3	5

5. Determining the site-specific flow indicators for the Wimmera River Terminal Wetlands

5.1. Setting site-specific ecological targets

The objective setting framework used to determine the ESLT is outlined in the report '*The proposed "environmentally sustainable level of take" for surface water of the Murray-Darling Basin: Method and Outcomes*' (MDBA 2011). In summary, the MDBA developed a set of Basin-wide environmental objectives and ecological targets, which were then applied at a finer scale to develop site-specific objectives for individual key environmental assets. Using these site-specific objectives, ecological targets that relate specifically to the Wimmera River Terminal Wetlands were developed (Table 6). Information underpinning site-specific ecological targets is shown in Table 6.

Site-specific ecological targets formed the basis of an assessment of environmental water requirements and the subsequent determination of site-specific flow indicators for the Wimmera River Terminal Wetlands, as described below.

Table 6   Site-specific ecological targets for the Wimmera River Terminal Wetlands.

Site-specific ecological targets	Justification of targets
• Provide a flow regime which ensures the current extent of native vegetation of the fringing and wetland communities is sustained in a healthy, dynamic and resilient condition • Provide a flow regime which supports the habitat requirements of waterbirds and is conducive to successful breeding of colonial nesting waterbirds • Provide a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates) • Provide a flow regime which supports key ecosystem functions, particularly those related to longitudinal connectivity and transport of sediment, nutrients and carbon.	The key component of vegetation at Lake Albacutya is the approximately 1,271 ha of fringing woodland dominated by river red gum and black box with an understorey of lignum in some locations (Cibilic and White 2010). Fringing river red gum and black box woodland communities play a fundamental role in the ecology of the lakes - fringing woodlands provide habitat and nesting sites for terrestrial bird species including the nationally vulnerable regent parrot (*Polytelis anthopeplus monarchoides*) (Cibilic and White 2010). Emergent macrophyte beds that are likely to establish when the lake fills will form habitat and feeding sites for frogs, fish and birds. Inundation of the outer lake bed is also important for the flooding and desiccation of terrestrial vegetation species, which reset the successional processes once flood waters recede. Lake Hindmarsh and Lake Albacutya have high carrying capacity for waterbirds including habitat for migratory waterbirds protected under international agreements During the wet phase the lakes becomes important breeding and roosting habitat for many waterbirds such as heron, cormorant, darter and numerous species of duck. The site supports important habitat and species that are listed in international agreements, and include vulnerable and endangered species such as Murray cod (*Maccullochella peelii peelii*) and Freshwater catfish (*Tandanus tandanus*). Achieving the targets for wetlands and waterbirds will ensure inundation of breeding and feeding habitats considered key for a range of fish, amphibian and water-dependent reptile and invertebrate species. Key ecosystem functions support fish, birds and invertebrates through habitat maintenance, energy transfer and facilitating connections between rivers and floodplains. Overbank flows supply the floodplains with nutrients and sediments from the river, accelerate the breakdown of organic matter and supply water to disconnected wetlands, billabongs and oxbow lakes. As the floodwaters recede, the floodplains provide the main river channel with organic matter. The hydrological connection between watercourses and their associated floodplain provides for the exchange of carbon and nutrients (Thoms 2003). The connections are considered essential for the functioning and integrity of floodplain-river ecosystems.

5.2. Information used to determine site-specific flow indicators

Determination of the Wimmera River Terminal Wetlands' site-specific flow indicators focused on the two terminal lakes, Hindmarsh and Albacutya. The Lake Albacutya ecological character description identifies the hydrological cycle as arguably the most important process defining the ecological character of Lake Albacutya with floods of both short and long duration playing a role in supporting flora and fauna (Cibilic & White 2010). Hydrology plays a crucial role in a number of ecological processes, including: maintaining health and stimulating recruitment of river red gums; stimulating waterbird arrival and breeding; replenishing groundwater and diluting saline groundwater; resetting succession of terrestrial lakebed vegetation; and contributing to nutrient cycling through driving successional phases (Cibilic & White 2010). The hydrological cycle is likely to be equally important to environmental values of Lake Hindmarsh.

5.2.1. Lake Hindmarsh

Ecological Associates (2004) assessed the water requirements of Lake Hindmarsh and reported that flooding events of different duration need to occur sufficiently frequently to support a variety of ecological outcomes. It is not so much what happens in any given year that is important, rather the interval between flooding events is critical (Ecological Associates 2004; SKM 2011).

To achieve desired ecological outcomes such as: maintaining fringing woodland communities, enabling breeding success of fish and waterbirds and development of a mature and diverse aquatic ecosystem, lake full events between 6 and 36 months have been recommended for Lake Hindmarsh (Ecological Associates 2004). Lake full equates to 378 GL, which is the sill level of Outlet Creek where water will start to flow from Lake Hindmarsh towards Lake Albacutya.

Lake full events of 6 months duration are recommended to occur relatively frequently (5 year average recurrence interval). Regular floods of this duration will relieve drought and salinity stress and maintain the structure and persistence of fringing vegetation communities by promoting the growth, health and recruitment of fringing river red gum woodland communities (SKM 2011). It is also expected that emergent macrophytes will form stands at the lake fringe enhancing the habitat values of the site. Waterbirds, native fish and frogs with short life cycles and ability to respond rapidly to favourable conditions will complete one breeding cycle.

Longer duration events of 24-36 months with Lake Hindmarsh at full capacity would contribute to maintaining the lake as a productive open-water wetland. Prolonged inundation will eradicate terrestrial vegetation from the lake bed and contribute to nutrient cycling via successional phases. It is expected that Lake Hindmarsh will develop the characteristics of a permanent lake community with the establishment of extensive fringing macrophyte vegetation and more defined aquatic animal communities (SKM 2011). Long duration flooding is likely to support significant growth and recruitment of fringing woodland communities with replenishment of groundwater and diluting saline groundwater likely to be important to increase resilience of vegetation during inter-flood periods. The mature aquatic ecosystem that develops associated with healthy stands of fringing macrophyte and woodland vegetation communities will provide suitable feeding and nesting habitat with both native fish and waterbird communities expected to reach a high reproductive capacity and complete multiple breeding cycles. SKM (2011) identify lake full events that last for 24-36 months as essential to maintain habitat for fish and to support waterbird breeding.

5.2.2. Lake Albacutya

Ecological Associates (2004) assessed the environmental water requirements of Lake Albacutya and reported that flooding events of 6 and 24 month duration needs to occur sufficiently frequently to support a range of ecological outcomes. Recommendations in Ecological Associates (2004), which are further described in SKM (2011) along with information presented within the Lake Albacutya Ramsar site ecological character description (Cibilic and White 2010) have been used as the key sources of information describing Lake Albacutya's water requirements.

Ecological Associates (2004) recommend lake full events of 6 month duration to maintain the structure and persistence of fringing vegetation communities by supporting growth and recruitment. It has been widely documented that river red gums require regular inundation for their ongoing survival and their health relies heavily on the natural hydrological cycle (Cibilic and White 2010). Changes to the hydrological cycle of Lake Albacutya have been linked with observed dieback of river red gums (Cibilic and White 2010). Red gum communities also require flooding for successful recruitment, with flooding at Lake Albacutya leading to mass recruitment above and below the high water mark (Cibilic and White 2010). Regular recruitment is necessary to preserve a viable age structure and secure the long-term viability of populations and hence an 8 year average recurrence interval has been recommended (Ecological Associates 2004).

Although not as widespread as river red gums, black box is an important part of Lake Albacutya's fringing woodlands in some areas (Cibilic and White 2010). Persistence, growth and regeneration of black box are dependent on periodic flooding (Cibilic and White 2010).

In addition to supporting fringing woodlands, 6 month duration lake full events at Lake Albacutya will provide a significant temporary wetland habitat for aquatic flora and fauna and provide foraging and breeding habitat for many significant waterbird species, particularly those with short life cycles and an ability to respond rapidly to favourable conditions (Ecological Associates 2004; SKM 2011). A reduction in the frequency of 6 month lake full events at Lake Albacutya may reduce the viability of aquatic herbland communities and lead to less productive events during larger floods (Ecological Associates 2004; SKM 2011).

Fringing woodland communities at Lake Albacutya are well adapted to the wet and dry phases with river red gums surrounding the lake being the most tolerant to drought and salinity of all varieties tested in Australia (Cibilic and White 2010). Although these communities have an ability to cope with variable conditions, regular inundation will alleviate drought and salinity stress and like the recommended flows in Lake Hindmarsh, may aid in the recharge of localised groundwater lenses that could assist with maintaining the fringing river red gum and black box communities between larger lake-full events (Cibilic & White 2010). River red gums are flexible in their water use and will use groundwater of varying quality from fresh to saline (Roberts & Marston 2011).

As with Lake Hindmarsh, longer duration events of 24 months with Lake Albacutya at full capacity would contribute to maintaining the lake as a productive open-water wetland. Prolonged inundation will eradicate terrestrial vegetation from the lake bed and contribute to nutrient cycling via successional phases. It is expected that Lake Albacutya will develop the characteristics of a permanent lake community with the establishment of widespread aquatic fauna communities (Ecological Associates 2004). Ecological productivity in Lake Albacutya is at its highest following longer duration flooding events (SKM 2011). Long duration flooding is also likely to support significant growth and recruitment of fringing woodland communities. The mature aquatic ecosystem that develops associated with healthy stands of aquatic and woodland vegetation communities are expected to support large populations of breeding waterbirds making a significant contribution to regional populations (Ecological Associates 2004). The processes supported by floods of 24 month duration are an important aspect of the ecological character of the site being particularly important for waterbird breeding (Ecological Associates 2004; Cibilic and White 2010; SKM 2011).

5.2.3. Proposed flow indicators

The site-specific flow indicators for Lake Hindmarsh and Lake Albacutya are summarised in Table 7. The desired frequencies of lake full events are expressed as an average recurrence interval (ARI) based on the original recommendations of Ecological Associates (2004). This approach is consistent with the interval between flooding events being identified as critical rather than what happens in any given year (Ecological Associates 2004; SKM 2011). ARIs of lake full events of different durations are shown under the modelled without development and pre and post Wimmera Mallee Pipeline conditions (Table 7).

Table 7 Site-specific ecological targets and associated flow indicators for the Wimmera River Terminal Wetlands (Source: SKM 2011 based on analysis for period 1891-2009).

<table>
<tr><th rowspan="3">Site-Specific Ecological Targets</th><th colspan="4">Site-Specific Flow Indicators</th><th colspan="3">Without development, pre WMPP and post WMPP scenario event frequencies</th></tr>
<tr><th colspan="4">Event</th><th rowspan="2">Average recurrence interval event occurs under modelled without development conditions (years)</th><th rowspan="2">Average recurrence interval event occurs under modelled pre WMPP conditions (years)</th><th rowspan="2">Average recurrence interval event occurs under modelled post WMPP conditions (years)</th></tr>
<tr><th>Volume (GL)</th><th>Duration</th><th>Timing</th><th>Frequency - Average recurrence interval event required (years)</th></tr>
<tr><td rowspan="7">Provide a flow regime which ensures the current extent of native vegetation of the fringing and wetland communities is sustained in a healthy, dynamic and resilient condition

Provide a flow regime which supports the habitat requirements of waterbirds and is conducive to successful breeding of colonial nesting waterbirds

Provide a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates)

Provide a flow regime which supports key ecosystem functions, particularly those related to longitudinal connectivity and transport of sediment, nutrients and carbon.</td><td colspan="7">LAKE HINDMARSH</td></tr>
<tr><td>378</td><td>6 months</td><td rowspan="3">July to June</td><td>5</td><td>3</td><td>7</td><td>4</td></tr>
<tr><td>378</td><td>24 months</td><td>10</td><td>7</td><td>29</td><td>11</td></tr>
<tr><td>378</td><td>36 months</td><td>20</td><td>12</td><td>> 100</td><td>39</td></tr>
<tr><td colspan="7">LAKE ALBACUTYA</td></tr>
<tr><td>230</td><td>6 months</td><td rowspan="2">July to June</td><td>8</td><td>7</td><td>59</td><td>39</td></tr>
<tr><td>230</td><td>24 months</td><td>20</td><td>11</td><td>> 100</td><td>59</td></tr>
</table>

6. Flow Delivery Constraints

Basin wide environmental objectives have been developed within the context of being deliverable in a working river system that contains public and private storages and developed floodplains. To understand and assess the implications of key constraints on the ability to achieve flow indicators specified for the Wimmera River Terminal Wetlands, MDBA has drawn upon a combination of existing information (e.g. Water Sharing Plans, operating rules of water agencies, flood warning levels) and practical knowledge of river operators supported by testing using hydrological modelling.

As described in Section 4 the hydrology of Lake Hindmarsh and Lake Albacutya is driven by significant inflows and filling of the lakes may not be achieved by a single inflow event. Modelled flow data and historical observations show that a wet sequence of years is likely to be required to fill Lake Hindmarsh and subsequently spill via Outlet Creek to fill Lake Albacutya.

The MDBA has a vision of a healthy working Basin that has vibrant communities, productive and resilient industries, and healthy and diverse ecosystems. The delivery of environmental flows as a managed watering event within a healthy working Basin is highly dependent on existing system constraints, accordingly the site-specific flow indicators have been classified into three broad types (Table 9). Consistent with this rationale, within the hydrological modelling process used by the MDBA to assess the achievement of site-specific flow indicators orders for environmental flows have been limited to be within the constraints represented by the baseline model. This limits the delivery of regulated flows to the Wimmera River Terminal Lakes.

Given the episodic natural hydrology of Lake Hindmarsh and Lake Albacutya, the achievement of site-specific ecological targets and flow indicators will be heavily reliant on large inflow events from a number of tributaries and potential storage spills. Regulated releases from storage may be used to augment unregulated high flows, however the flow indicators are beyond the scope of an entirely managed watering event.

Table 9 Site-specific flow indicators for Wimmera River Terminal Wetlands and the effect of system constraints

Site-specific ecological targets	Site-specific flow indicators
Provide a flow regime which ensures the current extent of native vegetation of the fringing and wetland communities is sustained in a healthy, dynamic and resilient condition Provide a flow regime which supports the habitat requirements of waterbirds and is conducive to successful breeding of colonial nesting waterbirds Provide a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles, invertebrates) Provide a flow regime which supports key ecosystem functions, particularly those related to longitudinal connectivity and transport of sediment, nutrients and carbon.	Fill and maintain Lake Hindmarsh (378 GL) for 6 months duration to achieve an average recurrence interval of 5 years
	Fill and maintain Lake Hindmarsh (378 GL) for 2 years duration to achieve an average recurrence interval of 12 years
	Fill and maintain Lake Hindmarsh (378 GL) for 3 years duration to achieve an average recurrence interval of 20 years
	Fill and maintain Lake Albacutya (230 GL) for 6 months to achieve an average recurrence interval of 12 years
	Fill and maintain Lake Albacutya (230 GL) for 2 years to achieve an average recurrence interval of 20 years

Key

(blue)	Achievable under current operating conditions Flow indicators highlighted in blue are considered deliverable as mostly regulated flows under current operating conditions.
(yellow)	Achievable under some conditions (constraints limit delivery at some times) Flow indicators highlighted in yellow are considered achievable when delivered in combination with tributary inflows and/or unregulated flow events. They may not be achievable in every year or in some circumstances, and the duration of flows may be limited to the duration of tributary inflows.
(brown)	Difficult to influence achievement under most conditions (constraints limit delivery at most times) Flow indicators highlighted in brown require large flows that cannot be regulated by dams and it is not expected that these flows can currently be influenced by river operators due to the river operating constraints outlined above.

7. Summary and conclusion

The Wimmera River Terminal Wetlands system is a key environmental asset within the Basin and is an important site for the determination of the environmental water requirements of the Basin. MDBA has undertaken a detailed eco-hydrological assessment of the Wimmera River Terminal Wetlands system environmental water requirements. Specified flow indicators are indicative of a long-term flow regime required to enable the achievement of site-specific ecological targets at Lake Hindmarsh and Lake Albacutya and for the broader river valley and reach. Along with other site-specific flow indicators developed across the Basin at other hydrologic indicator sites, these environmental flow requirements were integrated within hydrological models to inform the ESLT. This process including consideration of a range of constraints such as those outlined in Section 6 is described in further detail within the companion report on the modelling process '*Hydrologic modelling to inform the proposed Basin Plan: Methods and results*' (MDBA 2012).

The flow indicators in this report are used to assess potential Basin Plan scenarios. MDBA (2012) summarises how the proposed draft Basin Plan released in November 2011 performs against flow indicators for the Wimmera River Terminal Wetlands system.

References

Australian Nature Conservation Agency 1996, *A directory of important wetlands in Australia*, 2nd edn, Australian Nature Conservation Agency, Canberra.

Carter, O & Downe, J 2006, *National recovery plan for the dwarf yellow heads* Trichanthodium baracchianum, Victorian Department of Sustainability and Environment, Melbourne.

Cibilic, A & White, L 2010, *Ecological character description for Lake Albacutya, a wetland of international importance*, report prepared for the Department of the Environment, Water, Heritage, and the Arts, WetlandCare Australia, Ballina, New South Wales.

Clunie, P & Koehn, J 2001, *Freshwater catfish: a resource document, final report for natural resource management strategy project R7002 to the Murray–Darling Basin Commission*, Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria.

Department of the Environment, Water, Heritage and the Arts 2008, National framework and guidance for describing the ecological character of Australian Ramsar wetlands, module 2 of the national guidelines for Ramsar wetlands — implementing the Ramsar Convention in Australia,viewed 5 January 2010.

Department of the Environment, Water, Heritage and the Arts 2009, *Directory of important wetlands in Australia — information sheet: Lake Hindmarsh* — VIC012, viewed November 2009, <www.environment.gov.au/cgi-bin/wetlands/search.pl?smode=DOIW>.

Ecological Associates 2004, *The environmental water needs of the Wimmera Terminal Lakes — final report*, Wimmera Catchment Management Authority, Horsham, Victoria.

Environment Australia 2001, *A directory of important wetlands in Australia,* 3rd edn, Environment Australia, Canberra, viewed 20 July 2010, <www.environment.gov.au/water/publications/environmental/wetlands/pubs/directory.pdf>.

MDBA (Murray-Darling Basin Authority) 2011*, The proposed "environmentally sustainable level of take" for surface water of the Murray-Darling Basin: Method and Outcomes.* Murray-Darling Basin Authority, Canberra.

MDBA (Murray-Darling Basin Authority) 2012*, Hydrologic modelling to inform the proposed Basin Plan: Methods and results.* Murray-Darling Basin Authority, Canberra.

Morton, AG & Heislers, A 1978, *An investigation of flooding and its ecological effects at Wyperfeld National Park, Victoria 1975–1977*. Parks Victoria, Melbourne, Victoria.

Roberts, J & Marston, F 2011, *Water regime for wetland and floodplain plants. A source book for the Murray–Darling Basin.* National Water Commission, Canberra.

Robinson, D (ed) 1984, *Victorian bird report 1983*, Bird Observers Club, Melbourne.

SKM 2007, *High Conservation Value Aquatic Ecosystems project - identifying, categorising and managing HCVAE, Final report, Department of the Environment and Water Resources,* 16 March 2007. <www.environment.gov.au/water/publications/environmental/ecosystems/hcvae.html>

SKM (Sinclair Knight Merz) 2011, *Ecological benefits of the Wimmera and Glenelg Rivers Environmental Entitlement: an assessment of flow scenarios in the Wimmera River and terminal lakes.* Final report to the Wimmera Catchment Management Authority and Victorian Department of Sustainability and Environment.

Thoms, M 2003 *Floodplain-river ecosystems: lateral connections and the implications of human interference*. Geomorphology 56: pp. 335–349.

Victorian Department of Natural Resources and Environment 1995, *Wetland database*, Parks, Flora and Fauna Division, Victorian Department of Natural Resources and Environment, East Melbourne.

Victorian Department of Sustainability and Environment 2003, *Lake Albacutya Ramsar site strategic management plan*, Victorian Department of Sustainability and Environment, Melbourne.

Victorian Department of Sustainability and Environment 2009, *Flora and/or fauna distribution data*, Victorian Department of Sustainability and Environment, Melbourne.

Watkins, D 1993, *A national plan for shorebird conservation in Australia*, Australian Wader Studies Group, Royal Australian Ornithologists Union, Melbourne.

Wetlandcare Australia 2004, *Ecological character description for the Lake Albacutya Ramsar site — a report prepared for the Department of the Environment, Water, Heritage and the Arts*, Wetlandcare Australia, Ballina, New South Wales.

Appendix A

Data used in producing hydrologic indicator site maps

Data	Dataset name	Source[a]
Basin Plan regions	Draft Basin Plan Areas 25 May 2010	Murray–Darling Basin Authority (2010)
Dam walls/barrages	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia 2006
Gauges	100120 Master AWRC Gauges	
Icon sites	Living Murray Indicative Icon Site Boundaries	Murray–Darling Basin Commission (2007)
Irrigation areas	Combined Irrigation Areas of Australia Dataset	Bureau of Rural Sciences (2008)
Lakes	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia (2006)
Maximum wetland extents	Wetlands GIS of the Murray–Darling Basin Series 2.0 (Kingsford)	Murray–Darling Basin Commission (1993)
National parks/nature reserves	Digital Cadastral Database	New South Wales Department of Lands (2007)
National parks/nature reserves	Collaborative Australian Protected Areas Database — CAPAD 2004	Department of the Environment, Water, Heritage and the Arts (2004)
Nationally important wetlands	Directory of Important Wetlands in Australia Spatial Database	Department of the Environment, Water, Heritage and the Arts (2001)
Ocean and landmass	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia (2006)
Ramsar sites	Ramsar wetlands in Australia	Department of the Environment, Water, Heritage and the Arts (2009)
Rivers	Surface Hydrology (AUSHYDRO version 1-6)	Geoscience Australia (2010)
Roads	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia (2006)
State border	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia (2006)
State forests	Digital Cadastral Database	New South Wales Department of Lands (2007)
Towns	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia (2006)
Weirs	Murray–Darling Basin Weir Information System	Murray–Darling Basin Commission (2001)
Weirs 2	River Murray Water Main Structures	Murray–Darling Basin Authority (2008)

[a] Agency listed is custodian of relevant dataset; year reflects currency of the data layer.

Appendix B

Species relevant to criteria 1 and 4: Wimmera River Terminal Wetlands

Species	Recognised in international agreement(s)[1]	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Flora and Fauna Guarantee Act 1998* (Vic.)
Birds			
Australian bustard (*Ardeotis australis*)[6]			CE
Australasian shoveler (*Anas rhynchotis*)[6]			V
Baillon's crake (*Porzana pusilla*)[2]			V
Black falcon (*Falco subniger*)[6]			V
Black-tailed godwit (*Limosa limosa*)[3]	✔		
Blue-billed duck (*Oxyura australis*)[3, 4, 6]			E
Bush stone-curlew (*Burhinus grallarius*)[2, 6]			E
Caspian tern (*Sterna caspia*)[3]	✔		NT
Common sandpiper (*Actitis hypoleucos*)[6]			V
Crested bellbird (*Oreoica gutturalis*)[2]			NT
Curlew sandpiper (*Calidris ferruginea*)[3]	✔		
Eastern great egret (*Ardea modesta*)[6]			V
Freckled duck (*Stictonetta naevosa*)[3, 4, 6]			E
Glossy ibis (*Plegadis falcinellus*)[3]	✔		
Great egret (*Ardea alba*)[3, 6]	✔		V
Greenshank (*Tringa nebularia*)[2]	✔		
Gull-billed tern (*Sterna nilotica*)[3, 6]			E
Hardhead (*Aythya australis*)[6]			V
Hooded robin (*Melanodryas cucullata*)[2]			NT
Major Mitchell's cockatoo (pink cockatoo) (*Lophochroa leadbeateri*)[2, 6]			V
Mallee emu-wren (*Stipiturus mallee*)[2, 6]		V	E
Malleefowl (*Leipoa ocellata*)[2, 6]		E	E
Marsh sandpiper (*Tringa stagnatilis*)[3]	✔		
Musk duck (*Biziura lobata*)[6]			V

Species	Recognised in international agreement(s)[1]	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Flora and Fauna Guarantee Act 1998* (Vic.)
Painted snipe (*Rostratula benghalensis*)[2]	✔	V	CE
Purple-gaped honeyeater (*Lichenostomus cratitius*)[6]			V
Red-necked stint (*Calidris ruficollis*)[3]	✔		
Regent parrot (*Polytelis anthopeplus monarchoides*)[2, 6]		V	V
Royal spoonbill (*Platalea regia*)[6]			V
Ruddy turnstone (*Arenaria interpres*)[3]	✔		
Sharp-tailed sandpiper (*Calidris acuminata*)[3]	✔		
White-bellied sea-eagle (*Haliaeetus leucogaster*)[3, 6]	✔		V
Fish			
Freshwater catfish (*Tandanus tandanus*)[2, 6]			E
Murray cod (*Maccullochella peelii peelii*)[7]		V	E
Plants			
Button immortelle (*Leptorhynchos waitzia*)[6]			V
Button rush (Lipocarpha microcephala)[6]			V
Desert jasmine (*Jasminum didymum lineare*)[6]			V
Downy swainson-pea (Swainsona swainsonioides)[2, 6]			E
Dwarf flat sedge (curly flat-sedge) (*Cyperus rigidellus*)[6, 4]			E
Dwarf myall (*Acacia ancistrophylla* var. *lissophylla*)[6]			V
Dwarf yellow head (*Trichanthodium baracchianum*)[5]		V	V
Inland pomaderris (*Pomaderris paniculosa paniculosa*)[6]			V
Native scurf-pea (*Cullen australasicum*)[2, 6]			E
Ridged water-milfoil (*Myriophyllum porcatum*)[3, 6]		V	V
Round templetonia (*Templetonia egena*)[6]			V
Salt paperbark (*Melaleuca halmaturorum halmaturorum*)[6]			V
Six-point arrowgrass (*Triglochin hexagona*)[6]			V
Three-nerve wattle (*Acacia trineura*)[6]			V
Umbrella wattle (*Acacia oswaldii*)[6]			V
Western leek-orchid (*Prasophyllum* sp. aff. *occidentale*)[6]			V

Species	Recognised in international agreement(s)[1]	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Flora and Fauna Guarantee Act 1998* (Vic.)
Yellow-tongue daisy (*Brachyscome chrysoglossa*)[6]			V

E = endangered V = vulnerable CE = critically endangered NT = near threatened

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

2 Victorian Department of Sustainability and Environment (2003)

3 Wetlandcare Australia (2004)

4 Department of the Environment, Water, Heritage and the Arts (2009)

5 Carter & Downe (2006)

6 Victorian Department of Sustainability and Environment (2009)

7 Ecological Associates (2004)