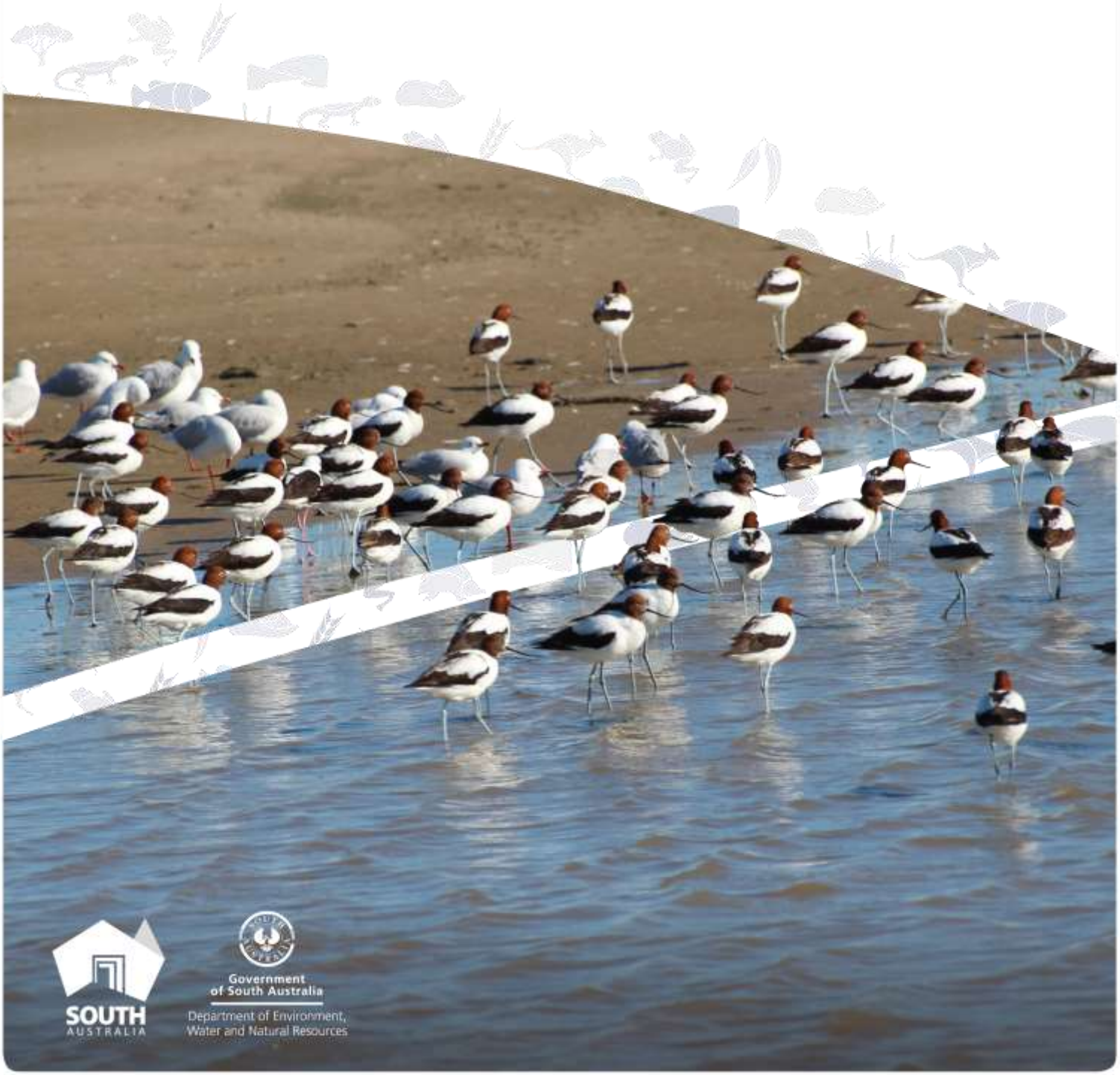
Long term environmental watering plan for the South Australian River Murray water resource plan area

November 2015



SOUTH AUSTRALIA

Government of South Australia

Department of Environment, Water and Natural Resources

Cover photo: Red-necked avocets at the CLLMM © Kirsty Wedge

Acknowledgement of the Traditional Owners

The Department of Environment, Water and Natural Resources acknowledges and pays respect to the Traditional owners, and their Nations, of the Murray-Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

The First Peoples of the River Murray and Mallee Region (FPRMM) and the Ngarrindjeri Nation have occupied, enjoyed, managed and used their inherited lands and waters of the River Murray, Lakes and Coorong since time immemorial. They pay respect to their Creators, ancestors, elders, and young people who have cared for their country since creation.

Foreword

Sustainable management of freshwater resources into the future is one of the most critical challenges facing global communities. By international standards, significant progress towards more sustainable management practices has been made in the Murray-Darling Basin with numerous policy and legislative reforms, and roll-out of on-ground river and wetland restoration programmes, including infrastructure to aid in environmental water management. Perhaps most significantly within the Basin has been the decision under the Murray-Darling Basin Plan (2012) to commit to returning 2,750 GL of water to the system. This is a key step towards restoring some of the balance between meeting the needs of the environment while still providing for productive industries and communities, including water for irrigation and critical human water needs.

Despite the efforts made to date, ongoing and concerted effort will be required to restore a healthy, working Murray-Darling Basin. South Australia, in partnership with other Basin States, the Murray-Darling Basin Authority (MDBA), the Commonwealth Environmental Water Holder (CEWH), local communities and non-government organisations, is progressing well in implementing the Basin Plan, including the environmental water management framework set out in Chapter 8 of that document.

To this end, South Australia is pleased to present this long-term environmental watering plan. It is the first to be developed for the South Australian River Murray Water Resource Plan Area in accordance with the environmental management framework within the Basin Plan and is based on the most recent available scientific knowledge and understanding of the South Australian River Murray ecosystem. This long-term plan complements and builds on the 2014 release of the Basin-wide Environmental Watering Strategy by the MDBA, as well as work completed in South Australia's annual environmental watering plans and many long-running environmental water management projects.

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Glossary

Basin State	Defined in the *Water Act 2007* to mean (a) New South Wales; (b) Victoria; (c) Queensland; (d) South Australia; (e) the Australian Capital Territory.
Bonn Convention	The Convention on the Conservation of Migratory Species of Wild Animals - an environmental treaty aimed at conserving terrestrial, aquatic and avian migratory species throughout their range.
BWEWS	Basin-Wide Environmental Watering Strategy – published by the Murray-Darling Basin Authority, a legislative requirement under Chapter 8 of the Basin Plan.
CAMBA	China-Australia Migratory Bird Agreement – a bilateral agreement to protect and conserve migratory birds and their habitat.
CEW	Commonwealth Environmental Water.
CEWH	Commonwealth Environmental Water Holder.
CEWO	Commonwealth Environmental Water Office.
CLLMM	Coorong, Lower Lakes and Murray Mouth.
CLLMM Recovery Project	Coorong and Lower Lakes Recovery Project - one of DEWNR's major programmes, with funding from the Australian Government.
CMS	Constraints Management Strategy - strategy published by the Murray-Darling Basin Authority in 2013 that identifies further work to be undertaken on physical constraints.
CPS	Components, processes and services – attributes that are identified and described in the ecological character descriptions of Ramsar wetlands.
DEWNR	South Australian Department of Environment, Water and Natural Resources.
Discharge	The volumetric flow rate of water i.e. volume of streamflow over a given time. In South Australia, this is often represented as ML/day.
ECD	Ecological character description - provides a description of a Ramsar wetland at the time of listing, where ecological character is the ecosystem components, processes, benefits and services that characterise the wetland. It can be used to assist in the assessment of possible change in the ecological character of the wetland.
EPBC Act	*Environment Protection and Biodiversity and Conservation Act 1999*.

EWR	Environmental water requirement - the water regime needed to sustain the ecological values of aquatic ecosystems and biological diversity at a low level of risk.
FPRMM	First Peoples of the River Murray and Mallee Region - native title holders in the Riverland, South Australia, including areas of the River Murray around Renmark, Berri, Barmera, Waikerie and Morgan.
GL	Gigalitres – a measure of volume, where a gigalitre equals 1,000 megalitres or 1,000,000,000 litres.
HEW	Held environmental water – defined within Section 4 of the *Water Act 2007*.
JAMBA	Japan-Australia Migratory Bird Agreement – a bilateral agreement to protect and conserve migratory birds and their habitat.
KNYA	Kungun Ngarrindjeri Yunnan Agreement.
LAC	Limits of acceptable change - used in a Ramsar context to define and detect a change in the ecological character of wetlands.
Lower Lakes	Lakes Alexandrina and Albert.
LTAAY	Long-term average annual yield.
LTWP	Long-term environmental watering plan – a legislative requirement under Chapter 8 of the Basin Plan.
MDBA	Murray-Darling Basin Authority.
ML/day	Megalitres per day – a measure of flow or discharge, where a megalitre equals 1,000,000 litres.
NRA	Ngarrindjeri Regional Authority - the peak regional organisation of the Ngarrindjeri people, descendants of the original indigenous inhabitants of the lands and waters of the Murray River, Lower Lakes and Coorong and adjacent areas.
PEA	Priority Environmental Asset – defined in s8.49 of the Basin Plan as an environmental asset that can be managed with environmental water.
PEF	Priority Environmental Function - defined in s8.50 of the Basin Plan as an ecosystem functions that can be managed with environmental water.

PEW	Planned environmental water – defined in Section 6 of the *Water Act 2007*.
Pool-connected wetland	A wetland that can be connected to the main River channel when South Australia is receiving its Entitlement and normal operating pool levels are being maintained.
PPM	Pre-requisite policy measure - constraints that coincide with the unimplemented policy measures identified in s7.15 of the Basin Plan.
QSA	Flow at the South Australian border. Unless otherwise stated, flow rates (or discharges) are expressed with respect to flow at the South Australian border.
RRP	Riverine Recovery Project - one of DEWNR's major programmes, with funding from the Australian Government.
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement – a bilateral agreement to protect and conserve migratory birds and their habitat.
SARFIIP	South Australian Riverland Floodplain Integrated Infrastructure Program - one of DEWNR's major programmes, with funding from the Australian Government.
SA River Murray LTWP	The Long-Term Environmental Watering Plan for the South Australian River Murray Water Resource Plan Area.
SA River Murray WRP Area Also SARM	South Australian River Murray Water Resource Plan Area – defined in Chapter 3 of the Basin Plan. For the purposes of this plan, the Coorong is considered as part of this water resource plan area.
SCB	Southern Connected Basin - a collective term for the valleys located in the southern section of the Murray-Darling Basin, including Goulburn, Campaspe, Loddon, Murray (NSW, Victorian and South Australian), Murrumbidgee and Lower Darling.
SCBEWC	Southern Connected Basin Environmental Watering Committee - a multi-jurisdictional committee that provides advice on the coordinated delivery of environmental water.
SDL	Sustainable diversion limit – defined in the Basin Plan as the long-term average sustainable diversion limit.
Temporary wetland	A wetland basin that is not connected to the main River channel when South Australia is receiving its Entitlement flows and normal operating pool levels are being maintained.

TLM	The Living Murray Program – a long-running collaborative programme between the Murray-Darling Basin Authority and partner governments aimed at restoring the health of the River Murray system by recovering 500 gigalitres of water and constructing major water management structures at six environmental icon sites.
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples.
VEWH	Victorian Environmental Water Holder.
WRP Area	Water Resource Plan Area – water planning units identified for the purpose of implementing the Basin Plan. The water resource plan areas are listed in Chapter 3 of the Basin Plan.

Executive Summary

The purpose of this long-term environmental watering plan (LTWP) is to set out the priority environmental assets of the South Australian River Murray Water Resource Plan Area (SA River Murray WRP Area) and the environmental objectives, targets and environmental water requirements (EWRs) to be achieved for those assets over the longer term.

The LTWP is of strategic importance for the management of the South Australian River Murray, its floodplain and wetlands, and the Coorong, Lower Lakes and Murray Mouth (CLLMM). It provides direction for the most efficient and effective use of environmental water. Environmental water holders and managers will use the content of this LTWP in future environmental water decision making, including to inform the coordination of Basin-wide watering actions.

The SA River Murray WRP Area includes the River Murray and its floodplain (defined by the 1956 flood extent), from the South Australian/New South Wales/Victorian border (the border) to the Murray Mouth, and includes Lakes Alexandrina and Albert (the Lower Lakes). This LTWP also incorporates the Coorong. Although considered by the Basin Plan to be part of the South Australian Murray Region Water Resource Plan Area, ecological outcomes in the Coorong are driven by surface water inputs from the River Murray via the Lower Lakes. Therefore, the Coorong is addressed in this LTWP, consistent with the approach taken by South Australia for annual environmental water planning and prioritisation under the Basin Plan.

A landscape-scale approach has been used to define the environmental assets to reflect the ecological importance of the mosaic of habitats, rather than focussing on discrete management units that represent only a small portion of the SA River Murray WRP Area. It also ensures that a holistic approach is taken to environmental water planning, delivery and evaluation.

Three priority environmental assets have been identified for the SA River Murray WRP Area:

- the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset ('the CLLMM PEA') - equivalent to the Lower Lakes, Coorong and Murray Mouth TLM Icon Site and the Coorong, Lakes Alexandrina and Albert Ramsar Wetland of International Importance
- the South Australian River Murray Channel Priority Environmental Asset ('the Channel PEA') - consists of the area between Wellington, South Australia, and the border - a total distance of approximately 560 River kilometres. The lateral extent comprises the area inundated at flows up to 40,000 ML/day QSA (i.e. flow measured at the border) under normal River operations
- the South Australian River Murray Floodplain Priority Environmental Asset ('the Floodplain PEA') an equivalent longitudinal extent to the Channel PEA, extending from Wellington, South Australia, to the border, and consists of the area that is inundated when flows are between 40,000 ML/day QSA and 80,000 ML/day QSA (under normal River operations).

The outer floodplain (i.e. the area that requires flows above 80,000 ML/day QSA to be inundated) is not included as part of the Floodplain PEA as the Basin Plan defines a priority environmental asset as an environmental asset that can be managed with environmental water (s8.49) and Murray-Darling Basin Authority (MDBA) modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management of environmental water can occur (subject to the implementation of measures to address flow constraints). The outer floodplain represents approximately 40% of the whole floodplain. Despite not being part of the Floodplain PEA, the outer floodplain is still considered to be an area of high importance to South Australia for many reasons, including

supporting a large proportion of the black box woodlands within the water resource plan area (WRP Area), and connecting riparian zones with upland habitats. It is therefore critical that there is no further reduction in the occurrence of the unregulated flow events that are required to inundate the outer floodplain (Government of South Australia, 2012).

In total, 45 ecological objectives, 98 ecological targets and 16 EWRs were identified for the three priority environmental assets. They represent what is needed to support each of the priority environmental assets in a healthy, functioning state. Extensive effort has been directed to ensuring that this plan is based on the best scientific knowledge.

An overall theme of the EWRs is the reinstatement of a more natural flow regime through the delivery of environmental water to the South Australian border, and downstream to the CLLMM. To meet the majority of the EWRs, environmental water will need to be delivered in conjunction with unregulated flows, as the volume of water required is greater than that provided by South Australia's Entitlement alone or available to the environment through water recovery programmes.

The EWRs describe a desired long-term and variable hydrological regime that enables flexibility and adaptive management in response to climate and ecological condition. The EWRs can be used in annual planning to identify vital watering actions together with results from ecological monitoring that indicate current condition, need for water and risk of not watering.

In addition to the ecological information provided, the following management considerations will continue to be taken into account during future annual and long term planning and decision-making:

- Indigenous values – consideration of, and where possible alignment with, Indigenous values in order to maximise the benefits from environmental watering
- Cooperative arrangements – processes to be followed to ensure that watering actions across the WRP Area and Southern Connected Basin (SCB) are coordinated
- Operational constraints – whether it is feasible to deliver the proposed watering action in view of operational constraints
- Long-term risks to providing environmental water – whether the proposed watering action addresses any of the potential long-term risks.

South Australia recognises the importance of and is committed to seeking and incorporating Indigenous values and uses in the development of environmental water plans where possible. Within the SA River Murray WRP Area, Indigenous engagement in environmental water planning has occurred for many years with the Ngarrindjeri Regional Authority (NRA) and the First Peoples of the River Murray and Mallee Region (FPRMM) through formal agreements with the South Australian Government. Further collaboration between the FPRMM, Natural Resources SA Murray-Darling Basin and DEWNR, has enabled the inclusion of FPRMM's perspectives into the management of wetland and floodplain areas. Crucial to the strong working partnership that has developed between Ngarrindjeri and DEWNR staff are the Kungun Ngarrindjeri Yunnan Agreement (KNYA) strategy of engagement and the Ngarrindjeri Yarluwar Ruwe (NYR) caring for country programme, which have facilitated active Ngarrindjeri participation in the CLLMM TLM Icon Site Program, Riverine Recovery Project and CLLMM Project, and involvement in environmental water planning for the CLLMM, Channel and Floodplain Assets for a number of years.

Cooperative arrangements within the WRP Area have been described for each phase of environmental water management. These arrangements are needed to ensure all environmental asset and site managers, environmental water holders and environmental water managers are working towards the common goal for the SA River Murray WRP Area of a healthy, functioning and resilient ecosystem. They lead to decisions that are

transparent, priorities and trade-offs that are understood, and outcomes at the site-scale that contribute to desired outcomes at the LTWP asset and WRP Area scale.

Cooperative arrangements between upstream WRP Areas and the SA River Murray WRP Area will be progressed through the development of an integrated plan for environmental watering in the Southern Connected Basin (SCB). South Australia will work closely with the other Basin States, the MDBA and the CEWH to develop this plan.

Constraints have a significant impact on the feasibility of delivering environmental water to and within the SA River Murray WRP Area. The constraints currently having the greatest impact on environmental water management in the SA River Murray WRP Area are generally being addressed through the Constraints Management Strategy (CMS) or the policy measures relating to the sustainable diversion limit (SDL) adjustment mechanism.

Key long-term risks to providing environmental water include:

- insufficient water available for SA River Murray WRP Area priority assets/functions
- water cannot be delivered to SA River Murray WRP Area priority assets/functions
- water quality is unsuitable for use at SA River Murray WRP Area priority assets/functions.

Key mechanisms for addressing these long-term risks include effective decision-making frameworks; addressing flow constraints, and rigorous monitoring and evaluation programmes.

Effective monitoring, evaluation and reporting will be critical to assessing both the effectiveness of this LTWP and the Basin Plan environmental watering framework more generally. An integrated monitoring and evaluation plan for the SA River Murray WRP Area is proposed, with a particular focus on meeting the state's requirement to report against Basin Plan Matter 8 (the achievement of environmental outcomes at an asset scale). This LTWP represents what is needed to support a healthy, functioning ecosystem and has not been restricted to what is achievable under the Basin Plan, nor what is likely to be monitored in the future. The integrated monitoring and evaluation plan will therefore seek to quantify expected outcomes (consistent with the ecological targets) and prioritise monitoring indicators.

Review and update of this LTWP will ensure that it retains relevance and currency, and this must occur on at least a five yearly basis.

Photo: Irwin Flat and Donald Flat Wetlands © Callie Nickolai

1 Introduction

This long-term environmental watering plan (LTWP) is the first to be developed for the South Australian River Murray Water Resource Plan Area (SA River Murray WRP Area) in accordance with the environmental management framework within the Basin Plan. It builds on many years of annual environmental water planning and integrates the information developed through many long-running and successful projects and programmes within the region.

These projects and programmes are focussed on addressing the major impacts arising from a long history of River regulation and development. Extractions for consumptive use and upstream storages have caused a reduction in the flows needed to generate within-channel pulses and overbank inundation, and provide water to the Lower Lakes, Murray Mouth and the Coorong. In addition, the construction of six weirs along the main channel of the River Murray in South Australia has stabilised water levels and slowed water velocities, creating lentic 'weir pools'. Together, these impacts have resulted in a decline in the ecological condition of the River, and its floodplain, wetlands and estuary. Indigenous nation groups within the SA River Murray WRP Area such as the Ngarrindjeri rely on the interconnectivity between land, waters, spirit and all living things (Ngarrindjeri refer to this as Ruwe/Ruwar), and a decline in the ecological condition of the River system can also be understood as a threat to their health and wellbeing.

In addition to being a legislated requirement under Chapter 8 of the Basin Plan, this LTWP provides an opportunity for South Australia to present the hydrological regimes needed to support a healthy, functioning South Australian River Murray ecosystem. The overall environmental objectives for the water-dependent ecosystems of the SA River Murray WRP Area are derived from those identified in the Basin Plan for the Murray-Darling Basin (s8.04), as follows:

- to protect and restore water-dependent ecosystems of the SA River Murray WRP Area
- to protect and restore the ecosystem functions of water-dependent ecosystems
- to ensure that water-dependent ecosystems are resilient to climate change, and other risks and threats.

This LTWP assists to meet these goals by:

- providing a common understanding of the priority environmental assets and the hydrological regimes needed to support them in a healthy, functioning state
- identifying priority ecosystem functions that focus on linking the assets and aligning environmental water management across the assets
- consolidating ecological information that will facilitate annual environmental water planning and prioritisation, and inform negotiations with water holders
- identifying constraints to the successful delivery of environmental water to and within the water resource plan area
- outlining the mechanisms in place to assist with coordinating environmental watering throughout the region, and ensure priorities and any trade-offs are transparent
- providing a basis for evaluating the success of environmental water management and improving future versions of this LTWP.

The information within this LTWP is presented in the following sections:

Section 2 Context - Explains the spatial and temporal scale of the plan, and the processes and consistencies required under the Basin Plan that were followed when preparing the plan. It also identifies the types and volumes of environmental water potentially available, and the parties responsible for managing the water and environmental assets or sites in the region.

Section 3 Ecology - Describes the priority environmental assets and priority ecosystem functions identified within the SA River Murray WRP Area and the process used to identify them. A suite of ecological objectives, targets and environmental water requirements (EWRs) is provided for each. Guidance on the use of the ecological content in annual and real-time planning is also provided.

Section 4 Management considerations - There are many other factors which need to be taken into account during decision-making or which influence the feasibility of delivering water. Some of these critical factors have been described, including Indigenous values and uses, with a particular focus on those requiring description under the Basin Plan environmental water management framework.

Section 5 Monitoring, evaluation, reporting and improvement - A summary of environmental water reporting requirements is provided, as well as the proposed mechanism for reporting on the achievement of environmental outcomes at an asset scale.

Photo: Lignum flowers © Emily Hoffmann

2 Context

2.1 Planning area

This LTWP has been developed for the SA River Murray WRP Area, which is defined in Chapter 3 of the Basin Plan. The SA River Murray WRP Area includes the River Murray and its floodplain (defined by the 1956 flood extent), from the South Australian/New South Wales/Victorian border to the Murray Mouth, and includes Lakes Alexandrina and Albert (the Lower Lakes).

This plan also incorporates the Coorong, which is considered by the Basin Plan to be part of the South Australian Murray Region Water Resource Plan Area (SA Murray Region WRP Area) (Figure 1). Ecological outcomes in the Coorong are driven by surface water inputs from the River Murray via the Lower Lakes, while the volume of surface water arriving in the Coorong from the SA Murray Region WRP Area is small and the groundwater inputs are not well quantified. The Coorong and Lower Lakes have long been treated as a single environmental asset or site including recognition as a Wetland of International Importance under the Ramsar Convention on Wetlands and as an icon site through The Living Murray Initiative. It is therefore appropriate for the EWRs of the Coorong and the Lower Lakes to be included in the same LTWP.

Murrundi (River Murray), including the Kurangk (Coorong), Lakes and Murray Mouth, is an Indigenous cultural landscape. The whole of the Kurangk (Coorong), Lakes and Murray Mouth site is part of the traditional lands and waters of the Ngarrindjeri nation, the Ngarrindjeri & Ors (SAD 6027/98) native title claim and includes registered Aboriginal sites such as the 'Meeting of the Waters'. The First Peoples of the River Murray and Mallee Region (FPRMM) have a native title consent determination applying to lands and waters of the upper Murray, including the Riverland in South Australia.

2.2 Planning timeframe

The SA River Murray LTWP has an indicative timeframe of five years, covering the period November 2015 to November 2020, and until a subsequent LTWP is released.

The Basin Plan outlines certain triggers for the review and updating of a LTWP, including the accreditation, amendment or adoption of the water resource plan for the water resource plan area, or published updates to the Basin-Wide Environmental Watering Strategy (BWEWS) that materially affect the LTWP. It is anticipated that the first water resource plan for the SA River Murray WRP Area will be accredited in 2019, triggering a need to review and update the SA River Murray LTWP. This aligns well with the timeframe of the SA River Murray LTWP.

The State may also choose to revise and update the SA River Murray LTWP at any time. Some examples include: to reflect new learnings on ecological response to hydrology and hence an improved understanding of the assets' EWRs; to reflect changes as a result of work currently underway on the revision of the ecological character description of the Coorong Lakes Alexandrina and Albert Ramsar Wetland; to address integration issues identified through cross-jurisdictional planning and management, or; to incorporate additional insights into ecological connectivity and health gained through further Indigenous engagement in state water planning.

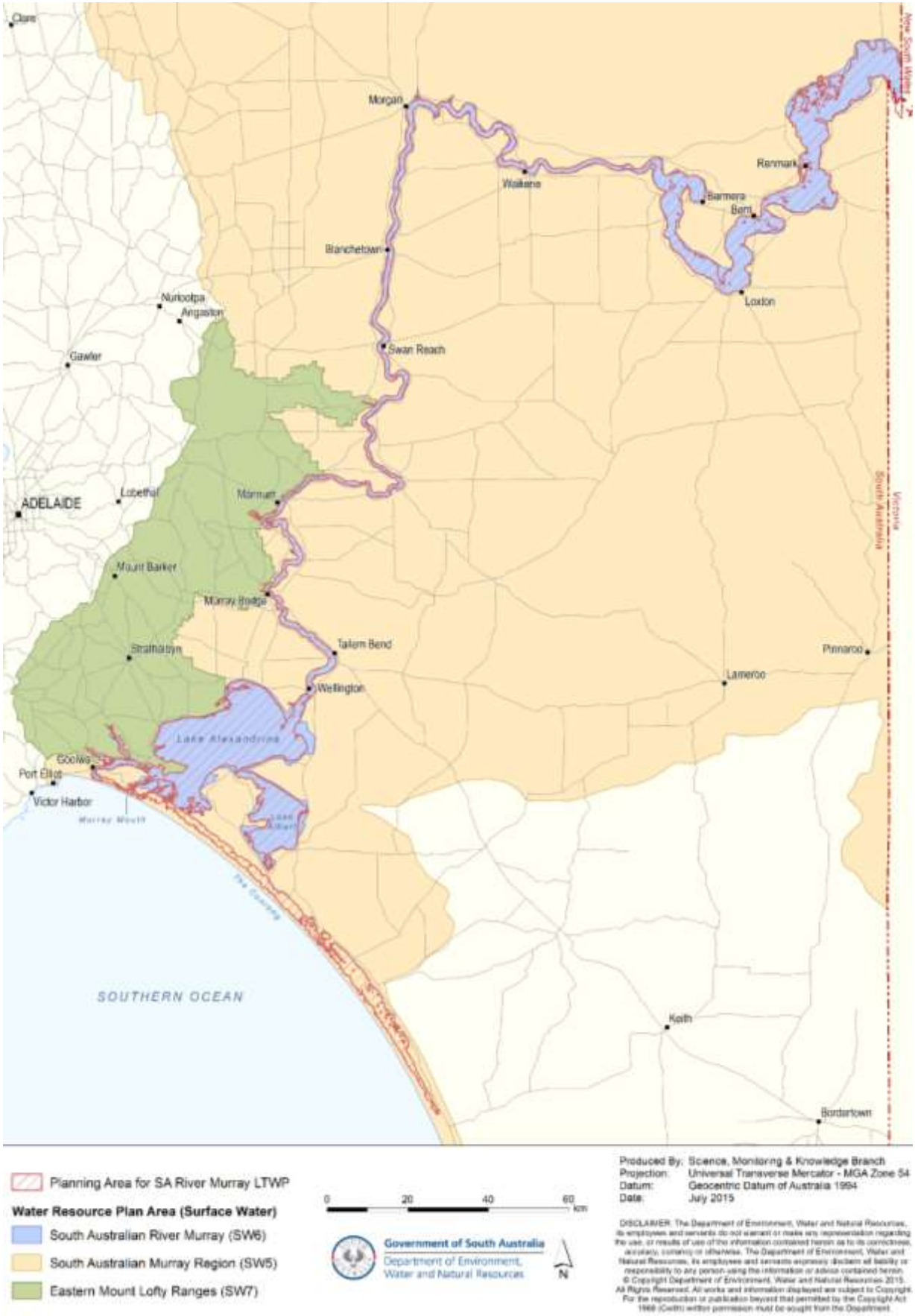

Figure 1. Comparison of the planning area of the SA River Murray LTWP to the SA River Murray WRP Area

2.3 Consistency with preparation requirements

The SA River Murray LTWP was developed by the South Australian Department of Environment, Water and Natural Resources (DEWNR) in accordance with the preparation requirements described in Section 8.20 of the Basin Plan. These requirements include:

- consultation requirements
- having regard to the Murray-Darling Basin Authority's BWEWS
- consistency with the 11 principles to be applied in environmental watering
- to not be inconsistent with relevant international agreements.

2.3.1 Consultation

This LTWP was prepared by staff within DEWNR with input from the South Australian scientific community, Indigenous representative bodies (Ngarrindjeri Regional Authority and First Peoples of the River Murray and Mallee Region) and regional environmental water practitioners.

During preparation of the LTWP, DEWNR liaised with the Murray-Darling Basin Authority (MDBA) and upstream jurisdictions through the Environmental Watering Working Group (an inter-jurisdictional group with representation from all the Basin governments).

In addition, key regional stakeholder groups that have an existing involvement with environmental water management projects were engaged, including:

- River Murray Advisory Committee
- Nature Foundation South Australia
- Coorong, Lower Lakes and Murray Mouth Community Advisory Panel
- Local Action Planning Associations
- Scientific Advisory Group for the Lower Lakes, Coorong and Murray Mouth.

A factsheet titled 'Introducing long-term environmental watering plans for the Murray Darling Basin within South Australia' was produced by DEWNR and circulated to the Indigenous representative bodies and key stakeholder groups in January 2015. The intent of the factsheet was to inform these groups of the legislative requirement to develop long-term plans, broadly explain their purpose, required content and timeframes for development, and gauge the level of interest in these plans. Together with the distribution of the factsheet, presentations at regular meetings of some of the key groups were undertaken.

Four technical reports formed the basis of the ecological content of this LTWP and were the primary mechanism of scientific input from regional experts.

Once compiled, the draft LTWP was released for review by parties external to DEWNR between the 3rd and 30th September 2015. This process included:

- making the draft LTWP publicly available via the Your Say page of the DEWNR website, with submissions accepted via email
- directly advising the Indigenous representative bodies and key regional stakeholder groups of the release of the draft LTWP via email and where possible presentations were given at regular group meetings
- liaising with the MDBA (including staff involved in Basin Plan Implementation, The Living Murray Program and River Operations), the Commonwealth Environmental Water Office and upstream jurisdictions regarding the release of the draft LTWP, inviting them to submit feedback and discussing preliminary comments during the consultation period.

Six feedback submissions were received, and combined these included a total of 20 general and 50 specific (i.e. directly related to a particular section of the LTWP) comments. All submissions were considered in finalising the LTWP. DEWNR appreciates the time taken by organisations and individuals in reading and providing feedback on the SA River Murray LTWP.

2.3.2 Basin-Wide Environmental Watering Strategy

The BWEWS was published by the MDBA in November 2014. Its development was a specific requirement of the Basin Plan (s8.13). The Basin Plan also states that long-term watering plans must be consistent with any particular assets or functions, and their requirements, identified within the BWEWS.

The purpose of the BWEWS is to assist environmental water holders and managers to plan and manage environmental watering at the Basin scale. The BWEWS identifies expected environmental outcomes for four ecological components or 'themes': river flows and connectivity; native vegetation; waterbirds and fish (Murray-Darling Basin Authority, 2014a). Assets considered important for supporting vegetation, waterbirds and fish at the Basin-scale are identified in appendices of the BWEWS, and a number within the SA River Murray WRP Area are listed. The BWEWS also includes a number of expected outcomes under each theme that are specific to the CLLMM.

Given the spatial scale applied to the identification of assets for this LTWP (see Section 1.1), the inclusion of vegetation, waterbird and fish targets for these assets, and the focus on connectivity as a priority ecosystem function, this LTWP is considered to be consistent with the BWEWS. To further demonstrate this, Appendix 1 indicates the alignment between the expected outcomes of the BWEWS and the ecological objectives identified for each of the priority environmental assets in this LTWP.

2.3.3 International agreements

The Basin Plan requires that a LTWP must not be inconsistent with relevant international agreements (s8.20 (5)), which includes the Ramsar Convention, the Bonn Convention, Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA). The methods for identifying environmental assets and their environmental watering requirements (s8.49) also state that the ecological objectives of an environmental asset should be consistent with the criteria used to identify the asset, and provide the example that if the asset is a declared Ramsar wetland, then the objectives must be directed towards maintaining the ecological character of the wetland.

2.3.3.1 Ramsar

Within the SA River Murray WRP Area, there are three wetland and floodplain complexes that are included in the Ramsar List of Wetlands of International Importance (Table 1). The inclusion of a site in the Ramsar List involves a commitment to ensure that the ecological character of the site is maintained (where ecological character is the combination of the ecosystem components, processes and benefits/services[1] that characterise the wetland (Ramsar, 2009)). The ecological character of each of the three Ramsar wetlands was taken into account when developing the ecological objectives and targets of the priority environmental assets within the SA River Murray WRP Area.[2] Consistency was achieved by ensuring that each critical component and process identified within the

[1] The national framework for describing the ecological character of Ramsar wetlands within Australia (Department of the Environment, Water, Heritage and the Arts, 2008) provides the following definition: "benefits and services are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as 'the benefits that people receive from ecosystems' (Ramsar Convention 2005a, Resolution IX.1 Annex A)".

[2] At the time of writing, the ecological character description (ECD) for the Coorong Lakes Alexandrina and Albert Wetland was under revision. The ecological objectives and targets in this LTWP will be revised and updated, if required, in the future to reflect the revised ECD. Ngarrindjeri are

ecological character description of the three Ramsar wetlands was aligned with at least one ecological objective and target for the relevant priority environmental asset. This document does not however replace or supersede the work that is being undertaken on these wetlands specifically in association with their Ramsar listing but seeks to support the maintenance of ecological character by informing the management of environmental water.

2.3.3.2 Migratory bird species

Australia has signed three bilateral agreements seeking to protect and conserve migratory birds and their important habitats in the East Asian - Australasian Flyway (Commonwealth of Australia, 2013a): JAMBA; CAMBA; ROKAMBA. Australia is also a party to the Bonn Convention (or the Convention on Migratory Species), which aims to conserve terrestrial, aquatic and avian migratory species throughout their range (UNEP/CMS Secretariat, 2014).

Birds listed under the JAMBA, CAMBA or ROKAMBA and the Bonn Convention must also be placed on the migratory species list of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), which provides a legal framework within Australia to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places (Commonwealth of Australia, 2013c). EPBC-listed species, including migratory birds that have been recorded within the priority environmental assets of the SA River Murray WRP Area, are listed in Appendix 3. The habitat and breeding requirements of these species have been considered in the development of the ecological objectives and targets of the priority environmental assets.

Table 1. Ramsar Wetlands in the SA River Murray WRP Area

Site	Date of designation	Area	Coordinates [3]
Banrock Station Wetland Complex	21/10/02	1,375 hectares	34°11'S 140°20'E
Riverland	23/09/87	30,640 hectares	34°02'S 140°51'E
The Coorong Lakes Alexandrina & Albert Wetland	01/11/85	142,530 hectares	35°56'S 139°18'E

formally engaged in this ECD revision (see section 4.1). The NRA have advised that this work takes into consideration Ramsar Convention resolutions pertaining to culture (Ramsar Convention 2002 & 2005) and will provide greater alignment of the management of the Ramsar site with other international agreements such as UNDRIP and further support South Australia in the implementation of Basin Plan requirements under Section 10, Part 14.

[3] Notional 'centre point' only

2.4 Environmental water availability and management

2.4.1 Types of environmental water

The environmental water available for use within the SA River Murray WRP Area consists of both 'held' and 'planned' environmental water, where:

- held environmental water is water available under a water access right or held on a water licence for the purposes of achieving environmental outcomes (*Water Act 2007* s4)
- planned environmental water is water that is committed or preserved for achieving environmental outcomes through a plan or legislation, and cannot be used for any other purpose (*Water Act 2007* s6).

The full definitions for held and planned environmental water, as per the *Water Act 2007*, are provided in Appendix 2.

2.4.2 South Australia's Entitlement

Under the *Murray-Darling Basin Agreement 2008* (*Water Act 2007* (Cwlth) Schedule 1), South Australia is entitled to receive up to 1850 GL/year. The 1850 GL comprises:

- a volume of 58 GL/month (696 GL/year) for dilution and losses (clause 88b), unless the Ministerial Council determines otherwise
- a variable monthly volume of up to 1154 GL/year (clause 88a), unless restricted in a period of special accounting (clause 128). This volume is provided over a water year, in monthly quantities that vary according to the historic consumptive (irrigation) pattern of demand. Lesser volumes are provided in the cooler months (April to September), and peak volumes are delivered in the warmer months (December and January).

South Australia's Entitlement includes both held and planned environmental water. The total volume of held environmental water (HEW) on licence is approximately 217 GL/year [4] and the total volume of planned environmental water (PEW) is approximately 157 GL/year [4] provided South Australia receives its full annual entitlement of 1,850 GL (Table 2). Currently, environmental water that is part of South Australia's entitlement is also provided in proportional monthly volumes that vary between months (Figure 2), however this may change in the future if one of the following four mechanisms under the *Murray-Darling Basin Agreement 2008* is implemented:

- Clause 90 Variation to South Australia's Entitlement
- Clause 91 South Australia's Storage Right
- change the timing of the delivery of held environmental water using trade
- permanent change to the pattern of delivery of South Australia's Entitlement.

[4] Volumes of held and planned environmental water were determined in March 2015 to provide an indication of availability within the WRP Area. They have been provided as estimates as these volumes are likely to change through time due to additional environmental water recovery and amendments to the Water Allocation Plan for the River Murray Prescribed Watercourse.

Table 2. Summary of held (HEW) and planned (PEW) environmental water within the SA River Murray WRP Area

Environmental Water Type	Approximate volume (GL) as at March 2015 [4]
HEW – Commonwealth Environmental Water Holder	128
HEW – The Living Murray	45
HEW – SA Minister for Water and the River Murray	44
PEW – Unallocated Class 9 (Wetlands)	157

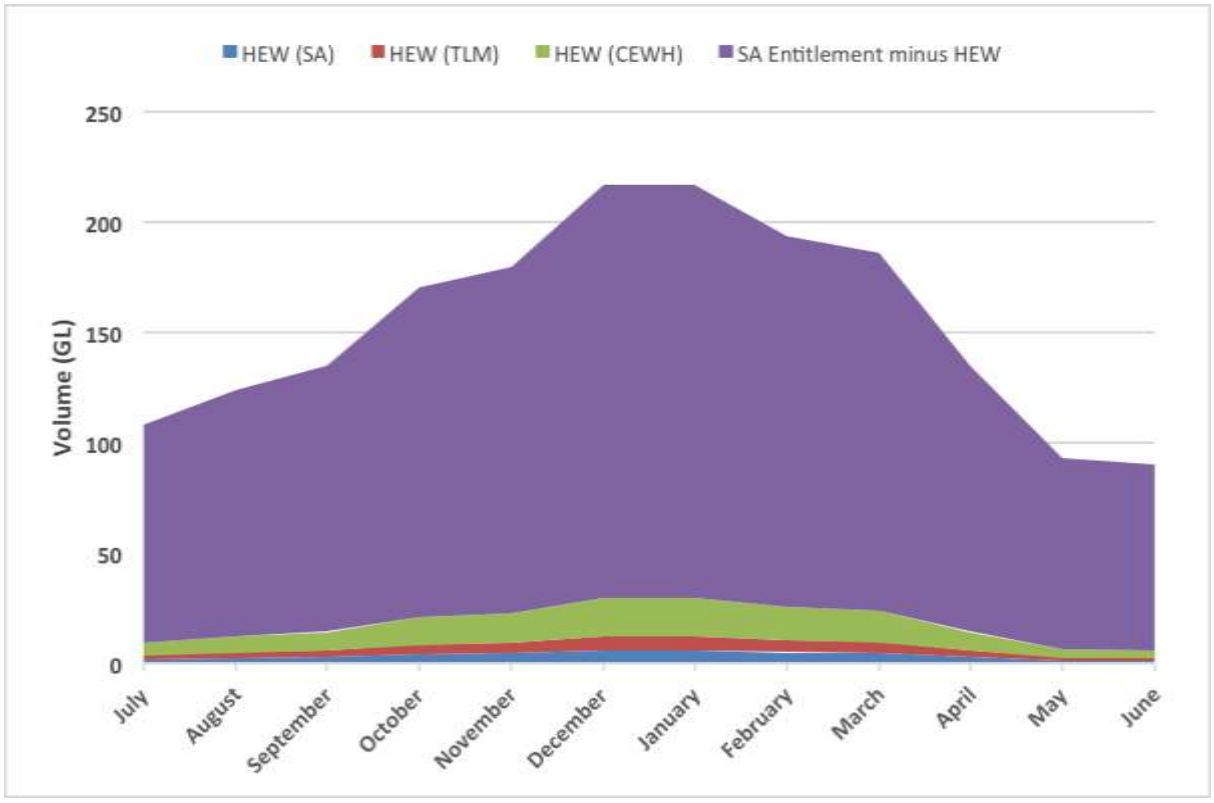

Figure 2. South Australian River Murray entitlement delivery pattern (at full entitlement)

2.4.3 Flows above South Australia's Entitlement

River Murray flows in excess of entitlement may be provided to South Australia as:

- interstate water trade
- deliveries of deferred water (critical human water needs, private carry over)
- environmental water as return flow that is not traded
- Additional Dilution Flow (a volume of 3,000 ML/day that is released once storage volumes in Hume and Dartmouth Reservoirs and Menindee Lakes exceed specified triggers)
- Lindsay River Dilution Flow (the residual of a 250 ML/day 'Lindsay River Dilution Allowance' that is provided down the Lindsay River, via the Mullaroo Offtake, to meet water supply demands (of an acceptable quality) and losses in the Lindsay River. The residual is treated as an unaccounted return flow to South Australia and is additional to the South Australian Dilution and Loss Entitlement. It equates to ~70 GL/year)
- unregulated flow.

Environmental water allocations may be traded to South Australia from elsewhere in the SCB due to the direct allocation of environmental water to an action in the SA River Murray WRP Area or as return flows from an upstream watering action. These allocations are generally from the Commonwealth Environmental Water (CEW) portfolio or The Living Murray portfolio. Under some circumstances, the Victorian Environmental Water Holder (VEWH) may also trade environmental water to South Australia. These traded volumes are in addition to the held and planned environmental water that is part of South Australia's Entitlement, and result in an increase in the flow to the South Australian border.

There is currently no clear mechanism for trading return flows to South Australia from environmental watering actions undertaken in New South Wales. However, this will be addressed through the implementation of the pre-requisite policy measures (see Section 4.3).

Unregulated flow is flow that is not able to be captured by Murray-Darling Basin storages, which may be because storages are full (or in the case of Menindee Lakes or Lake Victoria, the inlet capacity is exceeded) and exceeds all other downstream consumptive demands. Section 5.2 of the Water Allocation Plan for the River Murray Prescribed Watercourse does not allow for the allocation of unregulated flows for consumptive use in South Australia (South Australian Murray-Darling Basin Natural Resources Management Board, 2002). Unregulated flows are critical for the health of the environmental assets within the SA River Murray WRP Area, and as such one of the recommendations in the South Australian Government Response to the Draft Murray-Darling Basin Plan was to maintain the current frequency of unregulated flow events to assist in protecting and restoring key ecosystems, and meeting key salinity and water level outcomes (Government of South Australia, 2012).

2.4.4 Environmental water holders

There are three key environmental water holders that hold water access rights in the SA River Murray WRP Area.

2.4.4.1 Commonwealth Environmental Water Holder (CEWH)

The CEWH, supported by the Commonwealth Environmental Water Office (CEWO), manages the Commonwealth's environmental water portfolio, which has been created through water buy-backs or investment in water-saving infrastructure. At 31 August 2015, the Commonwealth environmental water holdings totalled approximately 2,372 GL of registered entitlements (or 1,645 GL long term average annual yield (LTAAY)) within the Murray-Darling Basin (Commonwealth of Australia, 2013b). Of this, approximately 1,822 GL of registered entitlements (1,367 GL LTAAY) are held within the SCB. The Commonwealth environmental water holdings include

approximately 139 GL of registered entitlements (125 GL LTAAY) in South Australia, which form part of South Australia's entitlement (Figure 2).

Decisions on the use of Commonwealth environmental water holdings are made by the CEWH. The South Australian held water may not be prioritised for use at assets within South Australia; alternatively, a greater volume than that held in South Australia may be prioritised for South Australian assets and this requires environmental water to be traded into South Australia.

2.4.4.2 The Living Murray Program (TLM)

TLM has recovered approximately 480 GL LTAAY of water (Commonwealth of Australia, 2015b), of which approximately 45 GL is held in South Australia. The South Australian held water forms part of South Australia's entitlement (Figure 2). Advice and recommendations on the use of TLM water are provided through inter-jurisdictional forums (where South Australia is represented by DEWNR), with approval for implementation given by the MDBA. Similar to the Commonwealth water holdings, the water held in South Australia is not required to be prioritised for assets within South Australia; and a greater volume than that held in South Australia may be allocated to South Australian assets.

2.4.4.3 South Australian Minister for Water and the River Murray

The South Australian Minister for Water and the River Murray holds approximately 44 GL of water access entitlements that are committed to environmental purposes and form part of South Australia's Entitlement (Figure 2). Of this total volume, approximately 38 GL is tied to the management of specific wetlands within the SA River Murray WRP Area so there is limited flexibility in the use of this water. The remaining volume of approximately 6.3 GL has been committed for environmental use through the *Implementation Plan for Augmentation of the Adelaide Desalination Plant*, and the location of its use is flexible (within the South Australian portion of the Murray-Darling Basin). Decisions on the allocation and use of this 6.3 GL are made within DEWNR.

2.4.5 Managers of planned environmental water

PEW within the SA River Murray WRP Area consists of unallocated water in the Class 9 (Wetlands) water access entitlement class (approximately 157 GL). This volume replaces the annual average evaporative losses from unmanaged pool-connected wetlands and is important for maintaining connectivity, supporting ecological processes and providing off-channel habitat for aquatic biota.

Generally, PEW in South Australia is not actively managed but is delivered to the wetlands through normal River operations. DEWNR, SA Water and MDBA work cooperatively to manage water delivery arrangements. These delivery arrangements may change if South Australia is receiving less than Entitlement or water allocations are less than 100% and the volume of available PEW is reduced. Under these circumstances, DEWNR is the lead manager of PEW within the SA River Murray WRP Area.

2.4.6 Environmental site managers

There are a number of environmental site managers within the SA River Murray WRP Area, with varying levels of involvement and responsibilities in managing environmental water delivery to and within the assets. Key managers include various projects and programmes within DEWNR as well external organisations and individuals, as follows:

- The Living Murray Program (TLM), DEWNR
- Coorong and Lower Lakes Recovery Project (CLLMM Recovery Project), DEWNR
- Environmental Water Trade and River Operations Policy (EWTROP), DEWNR
- Water Resource Operations, DEWNR
- SA Riverland Floodplain Integrated Infrastructure Program (SARFIIP), DEWNR
- Riverine Recovery Project (RRP), DEWNR
- Natural Resources SA MDB, DEWNR
- Ngarrindjeri Regional Authority (NRA)
- Mannum Aboriginal Community Association Incorporated (MACAI)
- First Peoples of the River Murray and Mallee Region (FPRMM)
- Australian Landscape Trust (ALT)
- Banrock Station Wine and Wetland Centre
- Nature Foundation SA (NFSA)
- Local Action Planning Associations
- various local wetland community groups and landholders.

Photo: Tauwitchere Barrage, CLLMM © Adrienne Rumbelow

3 Ecology

3.1 Asset scale

The key purpose of defining priority environmental assets and their EWRs is to inform the allocation and delivery of environmental water, and contribute towards a healthy, functioning South Australian River Murray ecosystem. There are multiple means of delivering environmental water within the SA River Murray WRP Area (including flow provisions, infrastructure operations and pumping), all of which influence different areas, making the selection of an appropriate spatial scale for environmental assets particularly challenging.

When selecting the spatial scale for environmental assets within this water resource plan area (WRP Area), the following aspects of environmental water management were taken into account:

- planning (the identification of objectives, targets and EWRs)
- delivery (the allocation and delivery of environmental water)
- environmental water accounting (reporting, where possible at an asset-scale, on the volumes of held and planned water delivered)
- reporting on ecological outcomes (monitoring, evaluation and reporting on the response to environmental watering at an asset-scale).

Based on these considerations, a landscape-scale approach was chosen for defining environmental assets, with three assets identified within the SA River Murray WRP Area (Figure 3):

- the Coorong, Lower Lakes and Murray Mouth
- the South Australian River Murray Channel
- the South Australian River Murray Floodplain.

This spatial scale was chosen primarily because it reflects the ecological importance of the mosaic of habitats that comprise the South Australian River Murray ecosystem, rather than focussing on discrete management units that represent only a relatively small portion of the WRP Area. It also ensures that a holistic approach is taken to environmental water planning, delivery and evaluation, enabling the contribution of outcomes at smaller scales towards the achievement of outcomes at the larger scale to be considered.

Each of the three environmental assets meet all five of the criteria for identifying an environmental asset provided in Schedule 8 of the Basin Plan.[5] The Basin Plan further defines a ***priority*** environmental asset as an environmental asset that can be managed with environmental water (s8.49). The full extent of two of the three environmental assets within the SA River Murray WRP Area can be managed with environmental water (in conjunction with unregulated flows): the South Australian River Murray Channel Asset and the CLLMM Asset. Therefore, for both of these, the priority environmental asset is equivalent to the environmental asset.

The South Australian River Murray Floodplain Asset extends to the 1956 flood level, requiring flows in excess of 100,000 ML/day QSA to be fully inundated. MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management of environmental water can occur, either through releases of held

[5] Evidence that the assets meets the *Basin Plan Schedule 12 Criteria for Identifying an Environmental Asset* is provided throughout this document where the individual assets are described in more detail, as well as in key references.

environmental water from storages or changes in dam storage operations (subject to the implementation of constraint measures in upstream areas). In addition, delivery through the operation of infrastructure is unlikely, with weirs along the River Murray in South Australia being removed when flows exceed between 55,000 and 70,000 ML/day (depending on the lock). For these reasons, the South Australian River Murray Floodplain Priority Environmental Asset is considered to be the portion of the Floodplain Asset that is inundated by flows up to and including 80,000 ML/day QSA, which is approximately 60% of the whole floodplain (compare Figure 3 and Figure 4). This threshold is based on modelled data and therefore may be altered in the future.

The three priority environmental assets of the SA River Murray WRP Area are:

- the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset ('the CLLMM PEA')
- the South Australian River Murray Channel Priority Environmental Asset ('the Channel PEA')
- the South Australian River Murray Floodplain Priority Environmental Asset ('the Floodplain PEA').

It should be noted that the term 'priority' is used throughout this document in accordance with the Basin Plan definition and is based on the operational feasibility of delivering environmental water. Despite not being part of the 'priority' asset, the outer floodplain (i.e. the area that requires flows above 80,000 ML/day QSA to be inundated) is still considered to be an area of high importance to South Australia for many reasons, including supporting a large proportion of the black box woodlands within the WRP Area, and connecting riparian zones with upland habitats. The close association of these two habitat types is important for species such as the Regent Parrot (a nationally and state-listed threatened species) which nests in floodplain trees but feeds in mallee vegetation (Ecological Associates, 2010). It is critical that there is no further reduction in the occurrence of the unregulated flow events that are required to inundate the outer floodplain (Government of South Australia, 2012). Further research is needed to better understand the condition of the outer floodplain and the role that it plays in the South Australian River Murray ecosystem, including the importance of providing connectivity to the adjacent uplands.

3.2 Identifying ecological objectives, targets and environmental water requirements for the priority environmental assets

The ecological objectives, targets and EWRs within this LTWP represent what is needed in order to support each of the priority environmental assets in a healthy, functioning state. They were identified through three sub-projects that consolidated many years of knowledge and experience from existing projects and programmes such as The Living Murray Initiative and Murray Futures. A full description of the ecological objectives, targets and EWRs, and the methods and detailed background information (including conceptual models and hydrological modelling) used in their development, is presented in four separate background reports:

- Ecological objectives, targets and environmental water requirements for the South Australian River Murray Floodplain environmental asset (Kilsby, et al., 2015)
- Ecological objectives, targets and environmental water requirements for the Coorong, Lower Lakes and Murray Mouth (O'Connor, et al., 2015)
- River Murray Channel environmental water requirements: Ecological objectives and targets (Wallace, et al., 2014a)
- River Murray Channel environmental water requirements: Hydrodynamic modelling results and conceptual models (Wallace, et al., 2014b).

A consistent approach was taken when identifying ecological objectives, ecological targets and EWRs for all three of the priority environmental assets:

- each of the ecological objectives provide a clear statement of what the delivery of the EWRs are intended to achieve. There are a number of objectives for each asset, with each objective focussed on a key biotic group or ecological process; however the inter-dependencies between the objectives should not be overlooked
- ecological targets are nested within an ecological objective and there may be more than one target per objective. As much as possible, the targets are 'SMART' i.e. specific, measurable, achievable, realistic and time-bound. This format informs monitoring and provides a means of assessing the change in condition and progress towards achieving the objectives. This assessment should not be undertaken as a pass or fail on an annual basis but rather as a consideration of trajectory over longer timeframes (see pp 26-27 in Wallace, et al., 2014a)
- the EWRs are descriptions of the water regimes needed to sustain the ecological values of the priority environmental assets at a low level of risk (Department of Environment, Water and Natural Resources, 2014a). They represent a hydrological regime in the appropriate metrics for the given environmental asset. The EWRs are based on hydrological, hydraulic and hydrodynamic modelling outputs together with an understanding of the needs of different biota and processes. The feasibility of meeting the EWRs under various Basin Plan water recovery and constraint management scenarios has not been tested. This assessment may be considered during the development of an integrated monitoring and evaluation plan for the SA River Murray WRP Area (see Section 5.2).

3.2.1 Having regard for groundwater

Consideration was given to groundwater during the development of the EWRs, although no groundwater metrics are expressed in the EWRs either because it is not considered a significant ecological driver (relative to surface water) or because there is insufficient data.

Regional groundwater is highly saline and groundwater-derived base flows do not contribute to meeting the EWRs of the Channel and Floodplain assets. Ecological targets relating to groundwater recharge have been expressed for the Channel and the Floodplain.

There is very little known about groundwater flows to or from the CLLMM. With Lakes Alexandrina and Albert being such large bodies of surface water, groundwater levels in the surrounding shallow aquifers are strongly influenced by water levels in the Lakes; however there is insufficient data to quantify this relationship. Freshwater soaks along the edge of the Coorong are important ecologically, but are primarily rainfall-fed. There are indications that groundwater discharge is widespread in the Coorong South Lagoon; however no estimate of volume is currently available (Haese, et al., 2008).

3.2.2 Integration of Indigenous knowledge

Note: The information expressed in this section on the integration of Indigenous knowledge into ecology was directly provided by the Ngarrindjeri Regional Authority for inclusion in this plan.

Indigenous knowledge of the relationship between flow regimes and ecosystem components is a potentially valuable addition to scientific knowledge of flow-biota relationships within the South Australian Murray-Darling Basin (SA MDB). It must be kept in mind that the integration of Indigenous interests, knowledge and perspectives in the identification of ecological objects, targets and EWRs as described in this plan are only in the initial stages.

The developing Kungun Ngarrindjeri Yunnan Agreement (KNYA) Indigenous Engagement Framework is providing the mechanism for projects that bring Indigenous values and knowledge into the 'models' and processes that support environmental water management in the SA MDB. For example, Ngarrindjeri are formally engaged in a review of the Coorong, Lakes Alexandrina and Albert Ramsar Wetland Ecological Character Description (ECD) in

partnership with DEWNR to integrate Ngarrindjeri perspectives on ecological objectives, targets and concepts to better reflect the Ngarrindjeri principle of Ruwe/Ruwar (see section 4.1).

The report by Hemming, et al. (2014) discusses existing Indigenous engagement in water planning in South Australia drawing attention to gaps in existing frameworks where there are opportunities to improve the relationship between Ngarrindjeri, scientists and the government, and use long-term Ngarrindjeri knowledge and understandings to fill non-Indigenous knowledge gaps (see Sections 3.5 and 4.1).

The following sections of the LTWP provide further information for each of the priority environmental assets, including:

- Location and geographic extent
- Conservation significance
- Ecological attributes
- Ecological objectives, targets and EWRs.

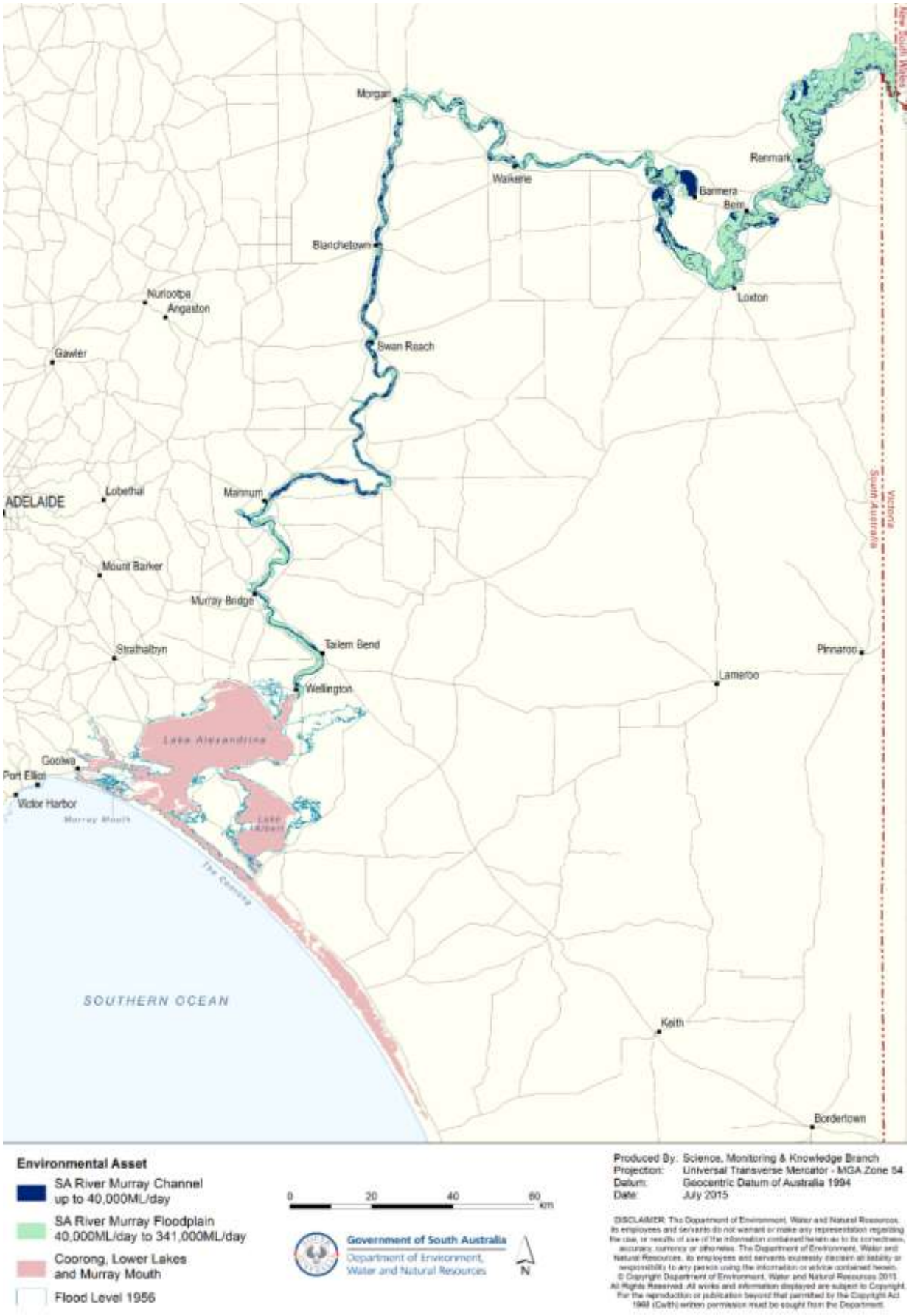

Figure 3. Map of the three environmental assets within the SA River Murray WRP Area

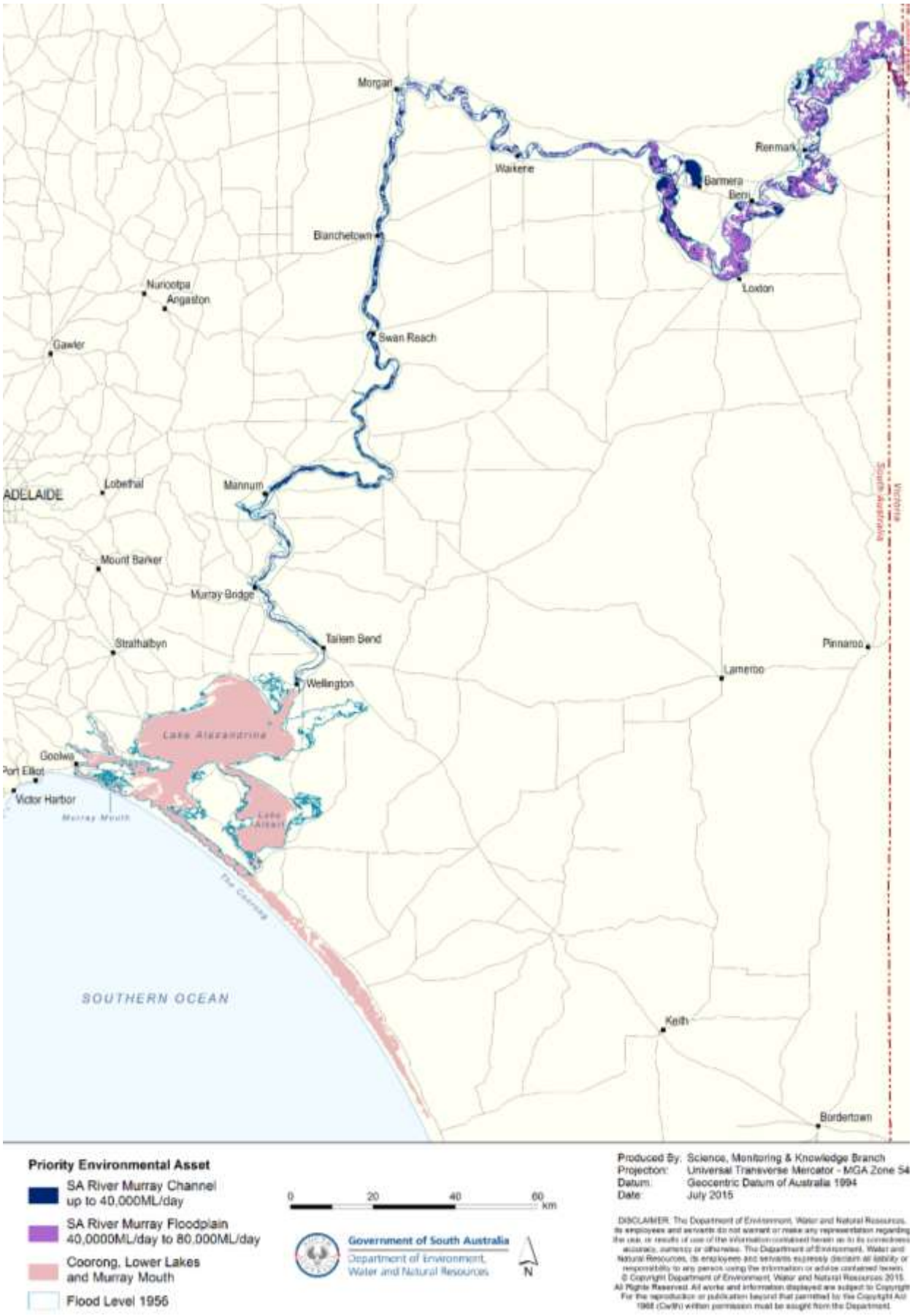

Figure 4. Map of the three priority environmental assets within the SA River Murray WRP Area

3.3 The SA River Murray Channel Priority Environmental Asset

3.3.1 Location and geographic extent

The South Australian River Murray Channel Priority Environmental Asset ('the Channel PEA') covers an area of approximately 28,800 hectares (Figure 5 and Figure 6). The longitudinal extent is from Wellington, South Australia, to the South Australian border - a total distance of approximately 560 River kilometres. The lateral extent consists of the area that is inundated at flows up to 40,000 ML/day QSA (under normal River operations), which is considered to be the discharge at which overbank flows commence and water starts to spread more broadly across the floodplain. The Channel PEA incorporates ephemeral habitats as well as areas of permanent water, including the main River channel, and permanently inundated wetlands and anabranches (where anabranches are distinguished as flowing habitats).

3.3.2 Conservation significance

The Channel PEA intersects two Ramsar-listed Wetlands of International Importance - the Riverland Ramsar Site and Banrock Station Wetland Complex.

The Riverland Ramsar site is described in Newall, et al. (2009). The site extends from Renmark, South Australia, to the New South Wales/Victoria/South Australian border (approximately 80 River kilometres). It encompasses the floodplain on both sides of the River, covering a total area of 30,615 hectares. The permanent waterbodies and the areas that are inundated by flows up to 40,000 ML/day QSA (approximately 3,840 hectares) fall within the Channel PEA.

The Banrock Station Wetland Complex Ramsar site is described in Butcher, et al. (2009). It is located approximately 430 River kilometres from the Murray Mouth and covers a total area of 1,375 hectares, which includes 1,068 hectares of floodplain and 307 hectares of mallee uplands. The part of the floodplain that is inundated by flows up to 40,000 ML/day QSA (approximately 190 hectares) falls within the Channel PEA.

The Living Murray Initiative (TLM) recognises six icon sites for their high ecological and cultural values (Commonwealth of Australia, 2015a), including the River Murray Channel TLM icon site.[6] The Channel Icon Site extends for over 2,000 River kilometres from Hume Dam near Albury, New South Wales, to Wellington, South Australia (Murray-Darling Basin Commission, 2006b). The icon site is separated into five reaches, two of which occur in South Australia. The vision for the River Murray Channel Icon Site is 'a healthy and productive River Murray' (Commonwealth of Australia, 2015a). There is consistency between the vision and extent of the South Australian reaches of the Channel Icon Site and the Channel PEA. The Channel PEA also intersects the Chowilla Floodplain TLM icon site, namely the section of the Chowilla Floodplain that is within the SA River Murray WRP Area and is inundated by up to 40,000 ML/day QSA.

Data from the DEWNR's biological database indicates that within the Channel PEA the following species of conservation significance have been recorded at least once[7]:

- 54 plant species (Table 19 in Appendix 3) listed as Endangered, Vulnerable or Rare under the South Australian *National Parks and Wildlife Act 1972* ('state-listed')

[6] Murrundi (River Murray) is central to Ngarrindjeri culture and spiritual beliefs. The NRA note that, while they received formal recognition from the Australian Government through incorporation of the preferred Ngarrindjeri engagement process into the development and implementation of the MDBA's Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Watering Plan (Murray-Darling Basin Authority, 2013b), this was not the case for the River Murray Channel TLM Icon Site (see Section4.1 for further details).

[7] Presence/absence records from DEWNR's biological database have been provided as an indication of the number of threatened species that have been found within each PEA only. Currently there are very few fish records and no invertebrate records entered into the dataset. This is not a comprehensive list and does not reflect species records that have not been provided to DEWNR for input to the database.

- 64 protected fauna species (Table 20 in Appendix 3), of which 56 are state-listed species, two species are listed as nationally threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and six species are both state and nationally listed.

3.3.3 Ecological attributes

In 2014, a project was undertaken through the Goyder Institute for Water Research to identify ecological objectives and targets for in-channel habitats and processes, as well as the EWRs needed to meet those targets (Wallace, et al., 2014a). In doing so, a series of conceptual models describing the hydro-ecological relationships for key components of the Channel asset were developed (Wallace, et al., 2014b), including:

- ecosystem processes and physio-chemical conditions - carbon and nutrient loads, productivity, dissolved oxygen, cyanobacteria, groundwater and salinity, hydraulic conditions (velocity)
- biofilm composition
- vegetation - aquatic and understorey vegetation (11 functional groups based on water-regime preferences); dominant floodplain perennial species (approximately 2,600 hectares of River red gum woodlands, 250 hectares of black box[8] and 670 hectares of lignum[8])
- fish - long-lived apex predators (Murray cod); flow-dependent specialists (golden perch and silver perch); foraging generalists (mostly small-bodied, short-lived species e.g. Australian smelt); floodplain specialists (southern purple-spotted gudgeon and Murray hardyhead); other natives (freshwater catfish); and non-native species (common carp, redfin perch, eastern gambusia, goldfish)
- temporary wetlands - approximately 3,100 hectares, important habitat and breeding sites for frogs (11 species), waterbirds (six functional groups) and invertebrates.

3.3.4 Ecological objectives, targets and environmental water requirements

A total of 16 ecological objectives and 29 nested ecological targets have been identified for the Channel PEA (Table 3 taken from Wallace, et al., 2014a) based on the previously identified key components. These objectives and targets focus on abiotic processes, water quality, biofilms, vegetation, wetlands, groundwater and fish.

Seven EWRs have been identified for the Channel PEA (Table 4 taken from Wallace, et al., 2014a) with median discharges ranging from 10,000 to 40,000 ML/day QSA. Together these EWRs described the desired variable flow regime to meet the ecological objectives and targets. The metrics for the Channel PEA EWRs include:

- discharge - measured as ML/day QSA, the EWR specifies both a median value and the range that the discharge should remain within
- duration - the number of days that the discharge needs to remain within the specified range
- timing - the season during which the EWR event needs to occur
- average return frequency - how often the EWR event needs to occur. The frequency metric represents an average return interval in years (not a regular pattern) and should be calculated as a rolling average over an appropriate timeframe. This can also be calculated as the percent of years that an event occurs on average
- maximum interval - the maximum number of years between events that meet the EWR metrics.

[8] Due to the small areas of black box woodlands and lignum shrublands within the Channel PEA, these vegetation communities are not represented in the ecological objectives and targets for this asset

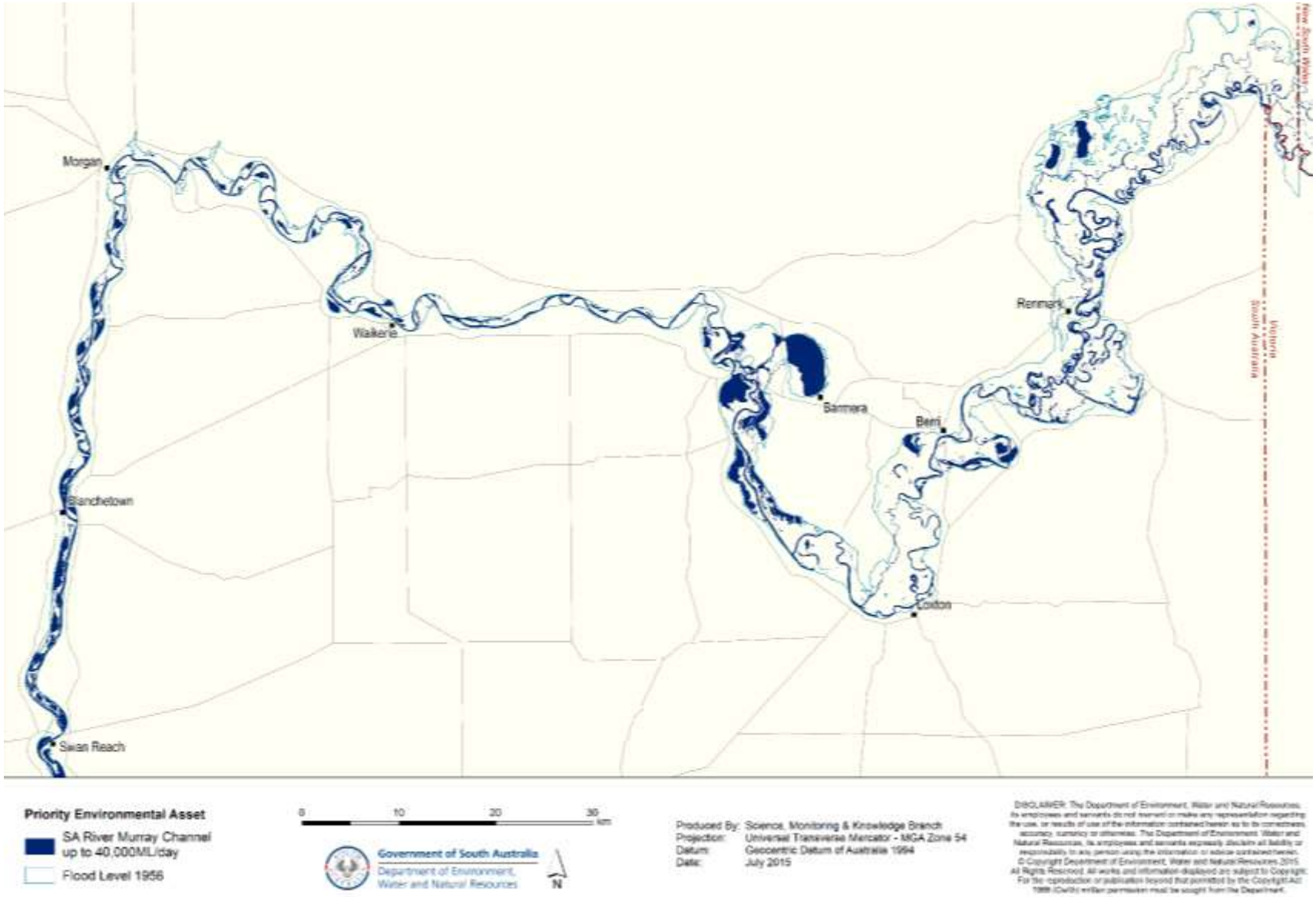

Figure 5. Spatial extent of the Channel Priority Environmental Asset between the border and Swan Reach

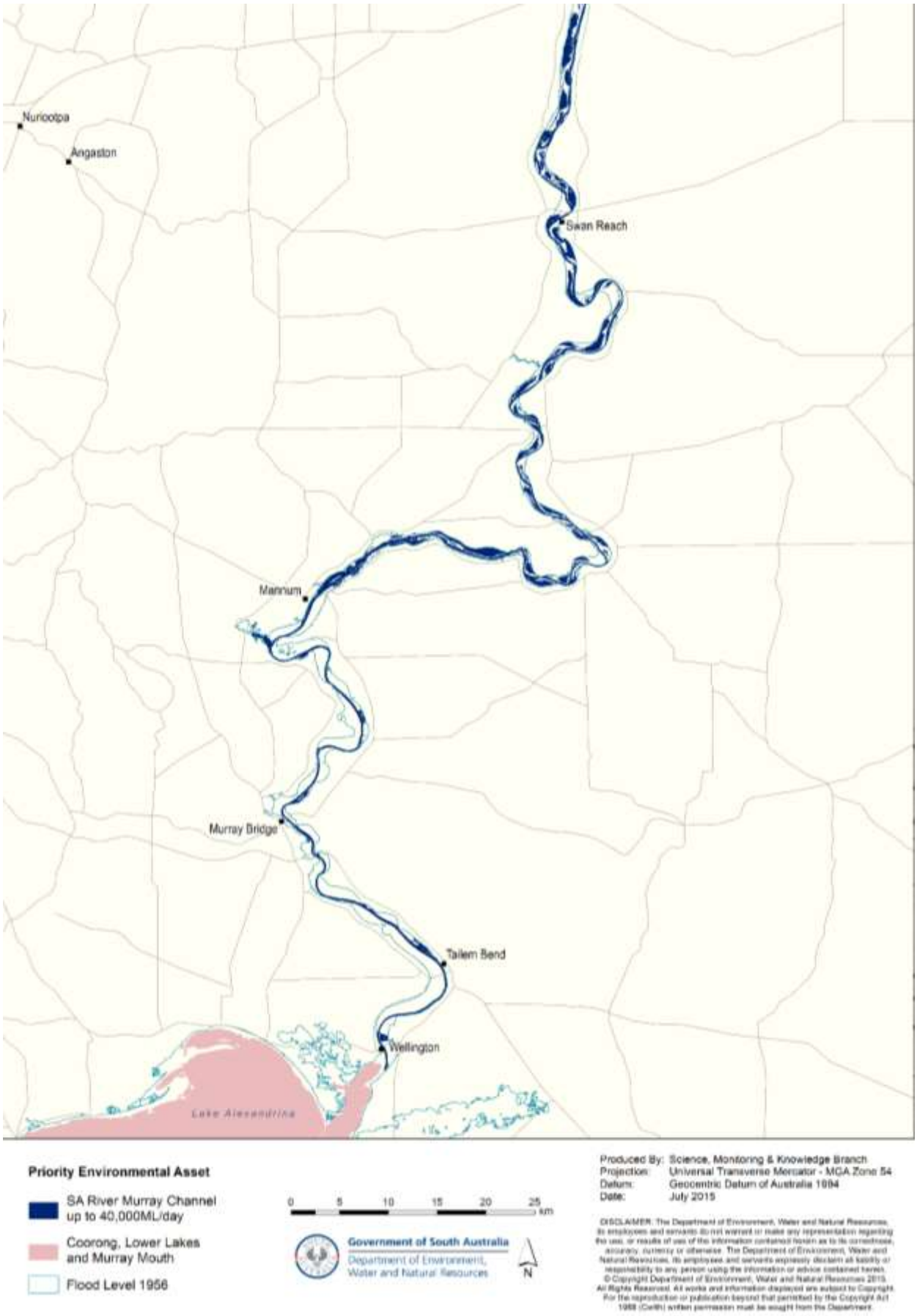

Figure 6. Spatial extent of the Channel Priority Environmental Asset between Swan Reach and Wellington

Table 3. Ecological objectives and targets for the SA River Murray Channel Priority Environmental Asset

Table taken from Wallace, et al. (2014a)

Type	Ecological Objective	Ecological Target
Ecosystem processes	Provide for the mobilisation of carbon and nutrients from the floodplain to the river to reduce the reliance of in-stream foodwebs on autochthonous productivity.	Open-water productivity shows a temporary shift from near zero or autotrophic dominance (positive Net Daily Metabolism) towards heterotrophy (negative Net Daily Metabolism) when QSA >30,000 ML/day.
	Provide diverse hydraulic conditions over the range of velocity classes in the lower third of weir pools so that habitat and processes for dispersal of organic and inorganic material between reaches are maintained.	Habitat across the range of velocity classes is present in the lower third of weir pools for at least 60 consecutive days in Sep–Mar, at a maximum interval of 2 years.
	Maintain a diurnally-mixed water column to ensure diverse phytoplankton and avoid negative water quality outcomes.	Thermal stratification does not persist for more than 5 days at any time.
	Ensure adequate flushing of salt from the Murray to the Southern Ocean.	Basin Plan Objective: Salt export, averaged over the preceding 3 years, is ≥2 million tonnes per year.
	Maintain habitats and provide for dispersal of organic and inorganic material and organisms between river and wetlands.	Inundation periods in temporary wetlands have unrestricted lateral connectivity between the river and wetlands in >90% of inundation events.

Water Quality	Maintain water quality to support aquatic biota and normal biogeochemical processes.	Biovolume <4 mm^3/L for all Cyanobacteria, where a known toxin producer is dominant.
		Biovolume <10 mm^3/L for all Cyanobacteria, where toxins are not present.
		Basin Plan Target: Maintain dissolved oxygen above 50% saturation throughout water column at all times.
Groundwater and soil	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain groundwater and soil moisture conditions conducive to improving riparian vegetation.	Establish and maintain freshwater lenses in near-bank recharge zones.
		Maintain soil water availability, measured as soil water potential > -1.5 MPa at soil depth 20–50 cm, to sustain recruitment of long-lived vegetation across the elevation gradient in the target zone.
		Reduce soil salinity (measured as EC 1:5) to <5000 µS/cm to prevent shifts in understorey plant communities to salt-tolerant functional groups across the elevation gradient in the target zone.
Biofilms	Promote bacterial rather than algal dominance of biofilms and improve food resource quality for consumers.	Annual median biofilm composition is not dominated (>80%) by filamentous algae.
		Annual median biofilm C:N ratios are <10:1.

Vegetation	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain a diverse native flood-dependent plant community in areas inundated by flows of 10,000–40,000 ML/day QSA.	In standardised transects spanning the elevation gradient in the target zone[9], 70% of river red gums have a Tree Condition Index score ≥ 10.
		A sustainable demographic is established to match the modelled profile for a viable river red gum population in existing communities spanning the elevation gradient in the target zone.
		Species from the Plant Functional Group 'flood-dependent/responsive' occur in 70% of quadrats spanning the elevation gradient in the target zone at least once every 3 years.
	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain a diverse macrophyte community in wetlands inundated by flows up to 40,000 ML/day QSA.	Native macrophytes from the emergent, amphibious and flood- dependent functional groups occur in 70% of quadrats spanning the elevation gradient in the target zone at least once every 3 years.
Fish	Restore the distribution of native fish.	Expected species[10] occur in each mesohabitat (channel, anabranch, wetlands) in each weir pool/reach.
	Restore resilient populations of Murray cod (a long-lived apex predator).	Population age structure[11] of Murray cod includes recent recruits[12], sub-adults and adults in 9 years in 10.

[9] The target zone is the area inundated by flows of 10,000-40,000 ML/day (under normal River operations)
[10] Expected species are those that were historically abundant (e.g. silver perch, freshwater catfish) and would not be considered beyond their extant range (e.g. trout cod), vagrants (i.e. spangled perch) or not expected to occur (e.g. mature Murray cod in temporary wetlands)
11 Population age structure is inferred from length-frequency distributions and validated by otoliths where appropriate
12 'Recent recruits' are fish <2 years old

		Population age structure of Murray cod indicates a large recruitment[13] event 1 year in 5, demonstrated by a cohort representing >50% of the population.
		Abundance (CPUE[14]) of Murray cod increases by ≥50% over a 10-year period.
	Restore resilient populations of golden perch and silver perch (flow-dependent specialists).	Population age structure of golden perch and silver perch includes YOY[15] with sub-adults and adults in 8 years in 10.
		Population age structure of golden perch and silver perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.
		Abundance (CPUE) of golden perch and silver perch increases by ≥30% over a 5-year period.
	Restore resilient populations of freshwater catfish.	Population age structure of freshwater catfish includes YOY, with sub-adults and adults in 9 years in 10.

13 'Recruitment' refers to survival and growth of the larvae and juveniles to YOY (young of year).
[14] CPUE is 'catch per unit effort' resulting from formal surveys using standard techniques (e.g. boat-mounted electrofishing, fyke nets)
[15] YOY = Young of Year.

		Population age structure of freshwater catfish indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.
		Abundance (CPUE) of freshwater catfish increases by ≥30% over a 5-year period.
	Restore and maintain resilient populations of foraging generalists (e.g. Australian smelt, bony herring, Murray rainbowfish, unspecked hardyhead, carp gudgeons, flathead gudgeons).	The length-frequency distributions for foraging generalists include size classes showing annual recruitment.
	Minimise the risk of carp recruitment.	The relative abundance and biomass of common carp does not increase in the absence of increases in abundance and biomass of flow-dependent native fish.

Table 4. Environmental Water Requirements for the SA River Murray Channel Priority Environmental Asset

Table taken from Wallace, et al. (2014a)

EWR #	Median discharge (ML/day QSA)	Discharge variability (ML/day QSA)	Duration (days)	Preferred timing	Average return frequency (years)	Maximum interval (years)
IC1	10,000	7,000 - 12,000	60	Sep-Mar	1.05	2
IC2	15,000	15,000 -20,000	90	Sep-Mar	1.33	2
IC3	20,000	15,000 - 25,000	90	Sep-Mar	1.8	2
IC4	25,000	20,000 - 30,000	60	Sep-Mar	1.7	2
IC5	30,000	25,000 - 35,000	60	Sep-Mar	1.8	2
IC6	35,000	30,000 - 40,000	60	Sep-Mar	1.8	2
IC7	40,000	35,000 - 45,000	90	Sep-Mar	2.1	3

3.4 The SA River Murray Floodplain Priority Environmental Asset

3.4.1 Location and geographic extent

The South Australian River Murray Floodplain Priority Environmental Asset ('the Floodplain PEA') covers an area of approximately 54,300 hectares (**Figure 7** and **Figure 8**). The longitudinal extent is equivalent to the Channel PEA, extending from Wellington, South Australia, to the South Australian border - a total distance of approximately 560 River kilometres. The Floodplain PEA consists of the area that is inundated when flows are between 40,000 and 80,000 ML/day QSA (under normal River operations). It runs immediately adjacent to the Channel PEA, and at any given cross-section, the Channel PEA must be fully inundated before inundation of the Floodplain PEA commences. The outer floodplain, which requires flow of greater than 80,000 ML/day QSA to be inundated, is also ecologically important. However it is unable to be managed with environmental water and so does not meet the Basin Plan definition of a priority environmental asset.

The Floodplain PEA consists of a mosaic of ephemeral habitats. A key factor is the influence of landform on water retention capacity as high flows recede, with some areas shedding water ('shedding floodplain') and others retaining water in depressions or basins ('temporary wetlands'). The Floodplain PEA does not contain any areas of permanent water and the distance to the main River channel differs along the length of the floodplain. Above Overland Corner is the Valley geomorphic zone where the floodplain is up to 10 kilometres wide, while below Overland Corner is the Gorge geomorphic zone which is constrained to approximately 2 - 3 kilometres (Walker and Thoms 1993). The area between Mannum and Wellington is dominated by reclaimed swamps and very little floodplain habitat remains.

3.4.2 Conservation significance

The Floodplain PEA intersects two Ramsar-listed Wetlands of International Importance - the Riverland Ramsar Site and Banrock Station Wetland Complex (see Section 3.3.2 for brief descriptions). The areas of these Ramsar sites that are inundated by flows between 40,000 and 80,000 ML/day QSA (approximately 13,250 hectares and 710 hectares, respectively) fall within the Floodplain PEA.

The Floodplain PEA intersects the portion of the Chowilla Floodplain TLM Icon Site that is within the SA River Murray WRP Area and is inundated by flows between 40,000 and 80,000 ML/day QSA. There is a strong link between the Floodplain PEA and the Chowilla Icon Site, with Chowilla targets used to develop the Floodplain PEA targets as this site has the most comprehensive baseline data available for any area of the floodplain. Further information on the Chowilla Icon Site is available in Murray-Darling Basin Authority (2012) and Wallace, et al. (2014).

Data from the DEWNR's biological database indicates that within the Floodplain PEA the following species of conservation significance have been recorded at least once[16]:

- 40 plant species (Table 19 in Appendix 3) listed as Endangered, Vulnerable or Rare under the South Australian *National Parks and Wildlife Act 1972* ('state-listed')
- 50 protected fauna species (Table 20 in Appendix 3) of which 44 are state-listed species, two species are listed as nationally threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and four species are both state and nationally listed.

3.4.3 Ecological attributes

The development of the ecological objectives and targets for the Floodplain PEA (Kilsby, et al., 2015) largely drew on a recent synthesis of the current understanding of the likely response of key ecological components of the floodplain ecosystem to changes in flow (see Bice, et al., 2014). The ecological components of the Floodplain PEA overlap considerably with those of the Channel PEA as these two assets are adjacent and continuous with each other. The main difference between the two is the effect that changes in geomorphology (i.e. elevation) have on hydrology. The Floodplain PEA consists of ephemeral areas that sit at higher elevations and are inundated later, and hence less frequently and for shorter durations, than the Channel PEA.

Bice, et al. (2014) presents hydro-ecological conceptual models for three flow bands relevant to the Floodplain PEA: 40,000 ML/day QSA - the threshold between the Channel and Floodplain PEAs; 60,000 ML/day QSA - a small overbank flow; and 80,000 ML/day QSA - a large overbank flow. Based on this report, the key abiotic and biotic components of the Floodplain PEA are:

- nutrients, carbon, biofilms and microbes
- microfauna (microcrustaceans and rotifers)
- vegetation (11 functional groups based on water-regime preferences; dominant floodplain perennial species including approximately: 12,150 hectares of River red gum woodlands; 4,330 hectares of black box; 9,010 hectares of lignum; 210 hectares of River cooba)[17]
- macroinvertebrates (five trait groups)
- frogs (eight species commonly found on the floodplain)

[16] Presence/absence records from DEWNR's biological database have been provided as an indication of the number of threatened species that have been found within each PEA only. Currently there are very few fish records and no invertebrate records entered into the dataset. This is not a comprehensive list and does not reflect species records that have not been provided to DEWNR for input to the database.
[17] As inundation of the Floodplain PEA does not commence until the Channel PEA is inundated, the areas of vegetation are inclusive of the areas found within the Channel PEA

- fish (four guilds of native species: circa-annual spawning nester; flow dependent specialist; foraging generalist; and wetland/floodplain specialist)
- waterbirds (continental nomads, international migratory species and regional residents).

3.4.4 Ecological objectives, targets and environmental water requirements

Twenty one ecological objectives and 40 nested ecological targets have been identified for the Floodplain PEA (refer Table 5 from Kilsby, et al., 2015). These objectives and targets are based on the key components (identified above) as well as existing objectives and targets for the Channel (Wallace, et al., 2014a), Chowilla Floodplain (Wallace, et al., 2014), and Pike and Katarapko Floodplains (Wallace, et al., in prep).

Five EWRs have been identified for the Floodplain PEA (Table 6 taken from Kilsby, et al., 2015) with median discharges ranging from 50,000 to 80,000 ML/day QSA. Together these EWRs described the desired variable flow regime to meet the ecological objectives and targets. The metrics of the Floodplain PEA EWRs are:

- discharge - measured as ML/day QSA, the EWR specifies both a median value and the range that the discharge should remain within
- duration - the number of days that the discharge needs to remain within the specified range
- timing - the season during which the EWR event needs to occur
- average return frequency - how often the EWR event needs to occur. The frequency metric represents an average return interval in years (not a regular pattern) and should be calculated as a rolling average over an appropriate timeframe
- rate of rise and fall - represented as the change in water level over time (metres per day). In the lower Murray, the rate of change is influenced by a change in discharge and weir operations
- maximum interval - the maximum number of years between events that meet the EWR metrics.

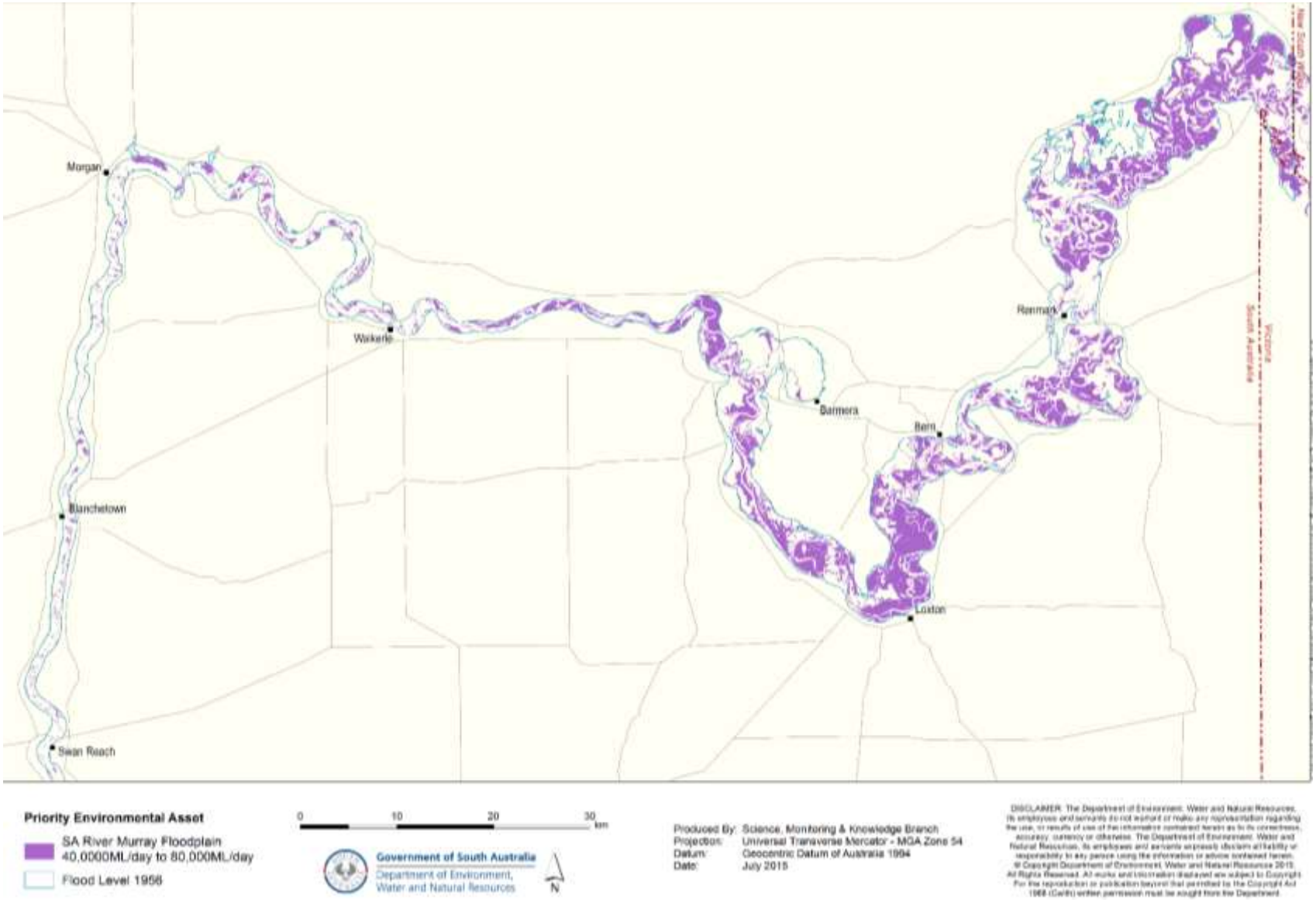

Figure 7. Spatial extent of the Floodplain Priority Environmental Asset between the border and Swan Reach

Figure 8. Spatial extent of the Floodplain Priority Environmental Asset between Swan Reach and Wellington

Table 5. Ecological objectives and targets for the SA River Murray Floodplain Priority Environmental Asset

Modified from Table 3-1 in (Kilsby, et al., 2015). All ecological objectives and targets are taken directly from or are consistent with objectives and targets developed through the Chowilla and SARFIIP projects and presented in Wallace (2014) and Wallace, et al. (in prep), respectively.

Type	Ecological Objective	Ecological Target
Ecosystem processes	Provide for the mobilisation of carbon, nutrients and propagules from the floodplain to the river	During inundation periods, record an increase in the abundance and diversity of invertebrate food resources, nutrients and DOC relative to those available during base flow[18]
	Provide diverse hydraulic conditions and complex habitat for flow dependent biota and processes	Deliver flows in a manner that reduces the proportion of slow flowing habitat and increases the proportion of moderate velocity habitat thereby reinstating a diversity of velocity classes representative of natural conditions[18]
	Implement a seasonal and multi-year hydrograph that encompasses variation in discharge, velocity and water levels	Discharge, water level and duration metrics of planned e-water represent a seasonally variable hydrograph
Water quality	Maintain water quality to support water dependent biota and normal biogeochemical processes[19]	Maintain dissolved oxygen above 50% saturation throughout water column at all times, in connected waters

[18] Further data is required to populate a SMART target; this may be progressed through the development of an integrated monitoring and evaluation plan for the SA River Murray WRP Area

[19] Normal biogeochemical processes are defined in (Wallace, et al., in prep)

Type	Ecological Objective	Ecological Target
Groundwater and soil	Establish groundwater conditions conducive to maintaining diverse native vegetation across the Floodplain PEA	Establish and maintain freshwater lenses in near-bank recharge zones[18]
	Establish soil conditions conducive to maintaining diverse native vegetation across the Floodplain PEA	Maintain soil water availability, measured as soil water potential at soil depth 20-50cm, greater than -1.5 MPa in order to sustain the recruitment of long-lived vegetation
		Reduce soil salinity (EC 1:5) to below 5,000 µS/cm to prevent permanent shifts in understorey plant communities to salt tolerant functional groups
		Maintain soil sodicity below the exchangeable sodium percent (ESP) value of 15 (highly sodic)
	Maintain sedimentation and erosion processes within normal ranges during overbank flows within the Floodplain PEA	Limit the maximum rate of drawdown (averaged over 3 consecutive days) to ≤0.025 m/day (0.05m/day in any one day) to minimise risk of bank failure
Vegetation	Maintain a viable, functioning River Red Gum population within the Floodplain PEA	In standardised transects that span the Floodplain PEA elevation gradient and existing spatial distribution, >70% of all trees have a Tree Condition Index Score (TCI) ≥10[20].

[20] Methodology follows (Souter, et al., 2009), which describes the scoring system and considers 30 trees along a transect within a 0.25 hectare quadrat (100 m x 25 m).

Type	Ecological Objective	Ecological Target
		A sustainable demographic[21] that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient.
	Maintain a viable, functioning Black Box population within the Floodplain PEA	In standardised transects that span the Floodplain PEA elevation gradient and existing spatial distribution, >70% of all trees have a TCI ≥10[20]
		A sustainable demographic[21] that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient
	Maintain a viable, functioning River Cooba population within the Floodplain PEA	In standardised transects that span the Floodplain PEA elevation gradient and existing spatial distribution, >70% of all trees have a TCI ≥10[20]
		A sustainable demographic[21] that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient

[21] Sustainable demographic is described in (Wallace, et al., in prep)

Type	Ecological Objective	Ecological Target
	Maintain a viable, functioning Lignum population within the Floodplain PEA	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, ≥70% of Lignum plants have a Lignum Condition Score (LCI) ≥6 for colour[22]
	Establish and maintain diverse water dependent vegetation within aquatic zones across the Floodplain PEA	In aquatic zones, a minimum of 40% of cells either inundated or dry containing inundation-dependent or amphibious plant taxa once every two years on average with maximum interval no greater than 4 years[23]. Native water dependent species richness >30 across the Floodplain PEA.
		In aquatic zones, a minimum of 80% of cells either inundated or dry containing native flood dependent or amphibious plant taxa once every four years on average with maximum interval no greater than 6 years[23]. Native water dependent species richness >50 across the Floodplain PEA.
	Establish and maintain diverse native vegetation comprising native flood dependent and amphibious species within the shedding floodplain zones across the Floodplain PEA	In shedding floodplain zones, a minimum of 20% of cells containing native flood dependent or amphibious plant taxa once every three years on average with maximum interval no greater than 5 years[23]. Native flood dependent and amphibious species richness >20 across the Floodplain PEA.

[22] Condition of lignum plants that intersect or lie within 2.5 m from either side of a 100 m transect (0.05 hectare quadrat) (Wallace, et al., in prep) are assessed using the standardised LCI method (Scholz, et al., 2007).

Type	Ecological Objective	Ecological Target
		In shedding floodplain zones, of 40% of cells containing native flood dependent or amphibious plant taxa once every five years on average with maximum interval no greater than 7 years[23]. Native flood dependent and amphibious species richness >30 across the Floodplain PEA.
		In shedding floodplain zones, of 65% of cells containing native flood dependent or amphibious plant taxa once every seven years on average with maximum interval no greater than 10 years[23]. Native flood dependent and amphibious species richness >50 across the Floodplain PEA.
Fish	Restore resilient populations of circa-annual nester-spawners within the South Australian River Murray	Population age structure of Murray cod includes recent recruits, sub-adults and adults in 9 years in 10.
		Population age structure of Murray cod indicates a large recruitment event 1 year in 5, demonstrated by a cohort representing >50% of the population.
		Abundance, as measured by Catch Per Unit Effort (CPUE), of Murray cod increases by ≥50% over a 10-year period.

[23] Methodology follows (Gehrig, et al., 2014); measurement of 45 one-metre by one-metre cells at each site, distributed across three elevation bands (15 cells per band), 50 m apart

Type	Ecological Objective	Ecological Target
		Population age structure of freshwater catfish includes Young Of Year (YOY), with sub-adults and adults in 9 years in 10.
		Population age structure of freshwater catfish indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.
		Abundance (CPUE) of freshwater catfish increases by ≥30% over a 5-year period.
	Restore resilient populations of flow-dependent specialists within the SARM	Population age structure of golden perch and silver perch includes YOY with sub-adults and adults in 8 years in 10.
		Population age structure of golden perch and silver perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.
		Abundance, as measured by CPUE, of golden perch and silver perch increases by ≥30% over a 5-year period.

Type	Ecological Objective	Ecological Target
	Restore resilient populations of wetland/floodplain specialists within aquatic zones across the Floodplain PEA during floodplain flow events	The length-frequency distributions for wetland/floodplain (native fish) specialists within aquatic zones across the Floodplain PEA include size classes showing annual recruitment.
		Increase range and abundance of wetland/floodplain (native fish) specialists within aquatic zones across the Floodplain PEA.
	A low proportion of total fish community, measured as abundance and biomass, is comprised of non-native species	The relative abundance and biomass of non-native species does not increase in the absence of increases in abundance and biomass of native fish.
Frogs	Provide habitat conducive to supporting diverse communities of riparian frogs within the Floodplain PEA	Each of 8 riparian frog species present within the Floodplain PEA will be recorded across the floodplain in any three year period.
		Tadpoles will be recorded from 8 species in later stages of metamorphosis across the Floodplain PEA in any three year period.
Waterbirds	Create conditions conducive to successful, small scale breeding events for waterbirds across the Floodplain PEA	Minimum inundation periods required for successful breeding by a range of water bird species are provided. Preliminary minimum 120 days.

Type	Ecological Objective	Ecological Target
	Provide refuge for the maintenance of adult populations of waterbirds across the Floodplain PEA	During continental dry periods an increase in the observed to expected ratio of waterbird species[18]
Other fauna	Provide habitat conducive to supporting communities of native woodland birds, reptiles and mammals across the Floodplain PEA	Each of the bird species known to utilise similar floodplain woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three year period[18].
		Each of the reptile species known to utilise similar floodplain/woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three year period[18].
		Each of the native mammal species known to utilise similar floodplain/woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three year period[18].

Table 6. Environmental Water Requirements for the SA River Murray Floodplain Priority Environmental Asset

Taken from Kilsby, et al. (2015)

EWR #	Median discharge (ML/day QSA)	Discharge variability (ML/day QSA)	Duration (days)	Preferred timing	Average return frequency (years)	Max interval (years)	Max rate of water level rise (m/day)	Max rate of water level fall (m/day)
FP1	50,000	45,000-55,000	30	Sep-Dec	1.6	5	0.05	0.025
FP2	60,000	55,000-65,000	30	Sep-Dec	2.0	5	0.05	0.025
FP3	70,000	65,000-75,000	30	Sep-Dec	2.6	5	0.05	0.025
FP4	80,000	75,000-85,000	30	Sep-Dec	3.6	5	0.05	0.025
FP5	80,000	75,000-85,000	60	Sep-Dec	7.6	8	0.05	0.025

3.5 The Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset

3.5.1 Location and geographic extent

The Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset (the 'CLLMM PEA') is equivalent to:

- the Lower Lakes, Coorong and Murray Mouth TLM Icon Site (CLLMM Icon Site)
- the Coorong, Lakes Alexandrina and Albert Ramsar Wetland of International Importance (Coorong and Lakes Ramsar Site).

The CLLMM PEA and surrounding areas represent the central homelands of the Traditional owners, the Ngarrindjeri, who have occupied, enjoyed, managed and used their inherited lands and waters within the area since the Kaldowinyeri (Creation). This association is expressed through Kaldowinyeri stories (cultural and spiritual histories) about Yarluwar-Ruwe (Sea Country) which reveals the significance of the relationship between the country and the people, both practically and spiritually (See Ngarrindjeri Nation 2006). The whole CLLMM PEA is a Ngarrindjeri cultural landscape.

The geomorphology, hydrology and water quality of the CLLMM PEA is extremely complex. The site is already well described in a number of documents, particularly the Lower Lakes, Coorong and Murray Mouth Environmental Water Management Plan (Murray-Darling Basin Authority, 2013b) and the Ecological Character Description of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance (Phillips, et al.,

2006), with a synopsis provided in O'Connor, et al. (2015). The following summary has been adapted from text provided in these documents.

The CLLMM PEA covers a total approximate area of 142,530 hectares (Figure 9), and consists of four sub-regions:

1. the Lower Lakes - comprised of Lake Alexandrina (approximately 65,000 hectares) and Lake Albert (approximately 23,000 hectares); both are large, shallow, permanent lakes surrounded by fringing, ephemeral wetlands
2. the lower reaches of the Eastern Mount Lofty Ranges (EMLR) tributaries - the lower reaches of the tributaries within the boundaries of the CLLMM PEA while the tributaries themselves are part of the EMLR Water Resource Plan Area, which requires a separate LTWP
3. the Murray Mouth estuary - the area from the Goolwa Barrage to Pelican Point
4. the Coorong - a long (approximately 140 km), narrow (approximately 2 - 3 km), shallow lagoon, which is separated into the North Lagoon and South Lagoon by a narrow constriction at Parnka Point.

Flows from upstream areas of the Murray-Darling Basin arrive via the Channel PEA and pass into Lake Alexandrina (approximately 5 km south of Wellington) and out to the Southern Ocean via the Murray Mouth Estuary. Lake Alexandrina also connects to the terminal Lake Albert by a small channel to its east. The Lower Lakes are physically separated from the Murray Mouth and Coorong via a complex of islands, channels and five barrages. The barrages were constructed in the 1930s to prevent ingress of saline water to the Lower Lakes and to regulate lake water levels. Since 2002, five fishways have been incorporated into two barrages and an associated channel to allow fish movement between freshwater and saline environments and up to seven additional fishways are currently under construction (Rumbelow, 2015).

At times, small volumes of freshwater pass into Lake Alexandrina from the EMLR tributaries, which are fed by unconfined aquifers and regional rainfall. When conditions are dry in the EMLR and there is no flow in the tributaries, freshwater from Lake Alexandrina helps to maintain inundation of the wetlands in the lower reaches of the EMLR tributaries, providing important habitat for birds, frogs and fish.

The salinity and morphology of the Murray Mouth estuary varies depending on freshwater flows and coastal conditions and processes. Freshwater outflows are required to keep the Murray Mouth open. Due to the impacts of River regulation and extraction, constriction and closure of the Murray Mouth has occurred in recent history, with dredging required at times to maintain an open Murray Mouth.

The Coorong receives inflows at the northern end from Lake Alexandrina and the Southern Ocean, and at times to the southern end via Salt Creek. It is a 'reverse estuary' (i.e. salinity increases with distance from the Mouth), with salinities ranging from fresh to brackish in parts of the Murray Mouth estuary to hyper-saline in areas of the South Lagoon. This gradient varies temporally depending on inflows from the Lower Lakes, Southern Ocean and Salt Creek.

3.5.2 Conservation significance

The CLLMM PEA is recognised as a site of high ecological and cultural value through The Living Murray Initiative and as a Wetland of International Importance under the Ramsar Convention. As the only estuary of the Murray-Darling Basin, the CLLMM is also a unique geomorphological feature of the Basin.

Detailed descriptions of the conservation values of the CLLMM are provided in the Lower Lakes, Coorong and Murray Mouth Environmental Water Management Plan (Murray-Darling Basin Authority, 2013b) and the Ecological Character Description of the Coorong, Lakes Alexandrina and Albert Wetland of International

Importance (Phillips, et al., 2006). O'Connor, et al. (2015) provided the following summary of some of the key values of the asset:

- waterbirds: regularly supports >200,000 waterbirds during summer (Paton, 2010), significant numbers of colonial-nesting and beach-nesting waterbirds (O'Connor, et al., 2013) and a number of threatened waterbird species (Department of Environment, Water and Natural Resources, 2013b)
- fish: play an important role for 49 native fish species, including diadromous, endangered and commercially caught species (Phillips, et al., 2006; Ye, et al., 2014)
- vegetation: characterised by a range of ecologically significant submerged, emergent and fringing vegetation species and communities including, *Gahnia* sedgelands, Fleurieu Peninsula swamps and *Ruppia tuberosa* (Phillips, et al., 2006).

Data from the DEWNR's biological database indicates that within the CLLMM PEA the following species of conservation significance have been recorded at least once[24]:

- 34 plant species (Table 19 in Appendix 3) listed as Endangered, Vulnerable or Rare under the South Australian *National Parks and Wildlife Act 1972* ('state-listed')
- 93 protected fauna species (Table 20 in Appendix 3), of which 56 are state-listed species, two species are listed as nationally threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and six species are both state and nationally listed.

The significance of the CLLMM PEA is further indicated by the inclusion of three overall environmental objectives within the Basin Plan that specifically relate to this asset, as follows:

s8.06 (3) An objective is to protect and restore connectivity within and between water-dependent ecosystems by ensuring that:

> (c) the Murray Mouth remains open at frequencies, for durations, and with passing flows, sufficient to enable the conveyance of salt, nutrients and sediment from the Murray-Darling Basin to the ocean; and
>
> (d) the Murray Mouth remains open at frequencies, and for durations, sufficient to ensure that the tidal exchanges maintain the Coorong's water quality (in particular salinity levels) within the tolerance of the Coorong ecosystem's resilience; and
>
> *Note: This is to ensure that water quality is maintained at a level that does not compromise the ecosystem and that hydrologic connectivity is restored and maintained.*
>
> (e) the levels of the Lower Lakes are managed to ensure sufficient discharge to the Coorong and Murray Mouth and help prevent river bank collapse and acidification of wetlands below Lock 1, and to avoid acidification and allow connection between Lakes Alexandrina and Albert, by:
>
> > (i) maintaining levels above 0.4 metres Australian Height Datum for 95% of the time, as far as practicable; and
> >
> > (ii) maintaining levels above 0.0 metres Australian Height Datum all of the time

The CLLMM PEA also includes a significant 'Sacred Site' – the Meeting of the Waters' (registered Aboriginal heritage site under the SA *Heritage Act 1988*). This includes the waters and the bed of the lakes, river and estuary.

[24] Presence/absence records from DEWNR's biological database have been provided as an indication of the number of threatened species that have been found within each PEA only. Currently there are very few fish records and no invertebrate records entered into the dataset. This is not a comprehensive list and does not reflect species records that have not been provided to DEWNR for input to the database.

Its spiritual and cultural significance is essential to the wellbeing and productivity of the Ngarrindjeri nation, Ngarrindjeri lands and waters, and all living things (Ngarrindjeri Nation 2006).

3.5.3 Ecological attributes

A project was undertaken within DEWNR in 2015 (O'Connor, et al., 2015) that reviewed information from the following key sources:

- the existing objectives and targets for the CLLMM TLM Icon site (Maunsell Australia Pty Ltd, 2009; Murray-Darling Basin Commission, 2006a) and a recent TLM condition monitoring refinement project (Robinson, 2014)
- the critical components, processes and services (CPS), and limits of acceptable change (LAC) from the draft, updated ecological character description (ECD) for the Coorong and Lakes Alexandrina and Albert Ramsar site Coorong (Department of Environment Water and Natural Resources, in prep (a))
- outputs from the MDBA's quantitative environmental outcomes workshops for shorebirds, general waterbirds, Coorong fish and *Ruppia tuberosa*, and subsequent content in the BWEWS (Murray-Darling Basin Authority, 2014e; Murray-Darling Basin Authority, 2014a).

This exercise indicates the following summary list of key ecological attributes for the CLLMM PEA:

- ecosystem processes and physio-chemical conditions - hydrology, connectivity, salinity gradients, diversity and extent of wetland types, Murray Mouth openness
- vegetation – freshwater submergent and emergent communities, submergent and emergent halophytes, *Ruppia tuberosa*
- macroinvertebrates - taxonomic richness, distribution, biomass and sediment conditions
- fish – diversity, diadromous species, endangered species, estuarine species, small-mouthed hardyhead
- waterbirds - diversity, abundance, breeding, state and nationally threatened species, species listed under international treaties and migratory agreements, 1% populations.

High-level conceptual models of the Lower Lakes and of the Coorong are provided in Maunsell Australia Pty Ltd (2009). Hydro-ecological conceptual models of the likely response of vegetation, macroinvertebrates, fish and waterbirds in the CLLMM under six discharges ranging from entitlement to 80,000 ML/day QSA are provided in Bice, et al. (2014).

3.5.4 Ecological objectives, targets and environmental water requirements

In total, eight ecological objectives and 29 nested ecological targets have been identified for the CLLMM PEA (Table 7 from O'Connor, et al. 2015)). The detailed methods for developing these objectives and targets are described in O'Connor, et al. (2015). Seven of the eight ecological objectives are exact representations of TLM 'targets', as their content and wording was consistent with the definition of 'ecological objectives' used in this LTWP (refer Section 3.2). Two additional objectives relating to fish diversity and salinity were developed as they were identified as a critical CPS but there was no corresponding TLM target. This ensured that all CPS and LAC[25] described in the ECD have been represented by an ecological objective within the LTWP.

Four EWRs have been identified for the CLLMM PEA (Table 8 taken from O'Connor, et al. 2015). The EWRs for the LTWP consider the EWRs described in Lester, et al. (2011) and Heneker (2010) that are needed to maintain

[25] LAC are not equivalent to ecological objectives or targets, and instead represent thresholds that indicate a change in ecological character. Their use in the development of ecological objectives in the LTWP was limited to ensuring that all relevant attributes of the asset had been incorporated

salinities of < 700 µS/cm and < 1000 µS/cm in Lake Alexandrina, but incorporate additional metrics to further describe the desired hydrological regime for the site (O'Connor, et al., 2015).

The Coorong South Lagoon metrics were developed based on expert advice and represent the best available information at the time of writing this plan. Further work analysing the interaction between volume, timing and mouth openness would be beneficial. The metric represents target water levels and shows an incremental increase when moving though the EWRs, with the water level for the lowest EWR (EWR-CLLMM1) indicating target levels under low flow conditions. Under these conditions, strong *Ruppia tuberosa* recruitment events are unlikely, however the target water level range will support the refuge population of *Ruppia tuberosa* within the deeper channel, and is important for general mudflat health to support waterbird populations, including migratory waders. This metric provides guidance for environmental water planning but should not preclude targeting higher levels in real-time event planning should the opportunity arise for improved outcomes.

In total there are nine metrics for each of the EWRs, as follows:

1. Annual barrage flow - the minimum volume (gigalitres per year) released from the barrages (all gates) over the course of a water-year. For some EWRs this should be calculated as a rolling average (i.e. average volume over multiple years).
2. Average return interval - the desired average frequency that the minimum annual volume is released e.g. 1-in-3 ARI means once every three years (or 33% of years) on average and does not seek to describe a regular pattern.
3. Maximum interval - the maximum number of years between events that meet the EWR metrics.
4. Timing – barrage releases should occur over the entire water-year but the EWRs seek to vary the monthly outflow volume with peaks outflows in late spring/early summer in order to support seasonal ecological processes. This variation is described in
5. Figure 10.
6. Lake water level range - the range that Lake water levels should remain within throughout the year (in mAHD); water level values should be calculated as the average across the Lower Lakes rather than a minimum or maximum at any given location.
7. Lake water level timing - describes the months when maximum and minimum water levels should occur.
8. Coorong South Lagoon water level - the range that water levels (in mAHD) should remain within at the indicated time. This should be based on the minimum water level at any given point rather than an average across multiple locations.
9. Coorong South Lagoon water level timing - the months when South Lagoon water levels need to remain within the specified range.
10. Coorong South Lagoon duration - the number of days that South Lagoon water levels need to remain within the specified range.

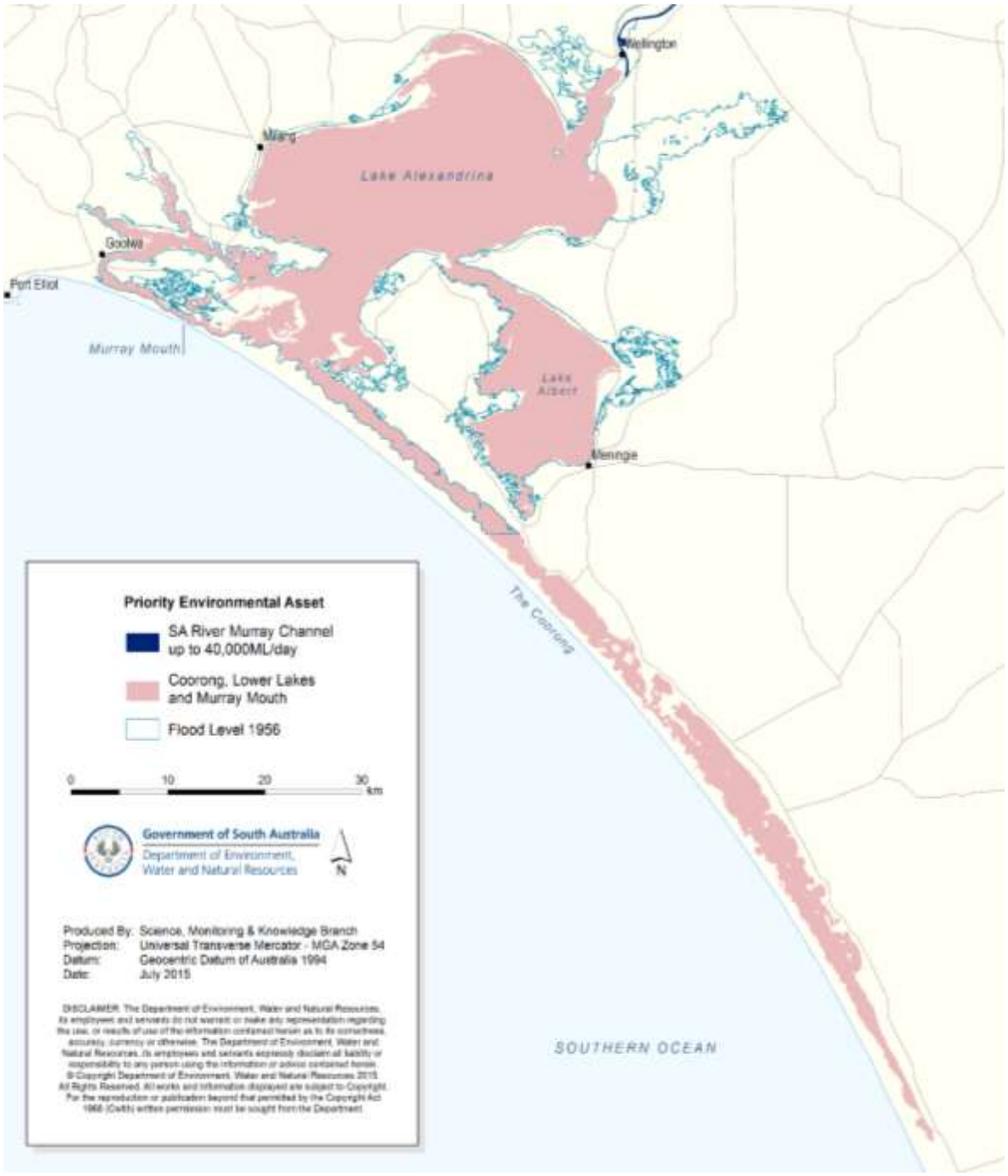

Figure 9. Spatial extent of the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset

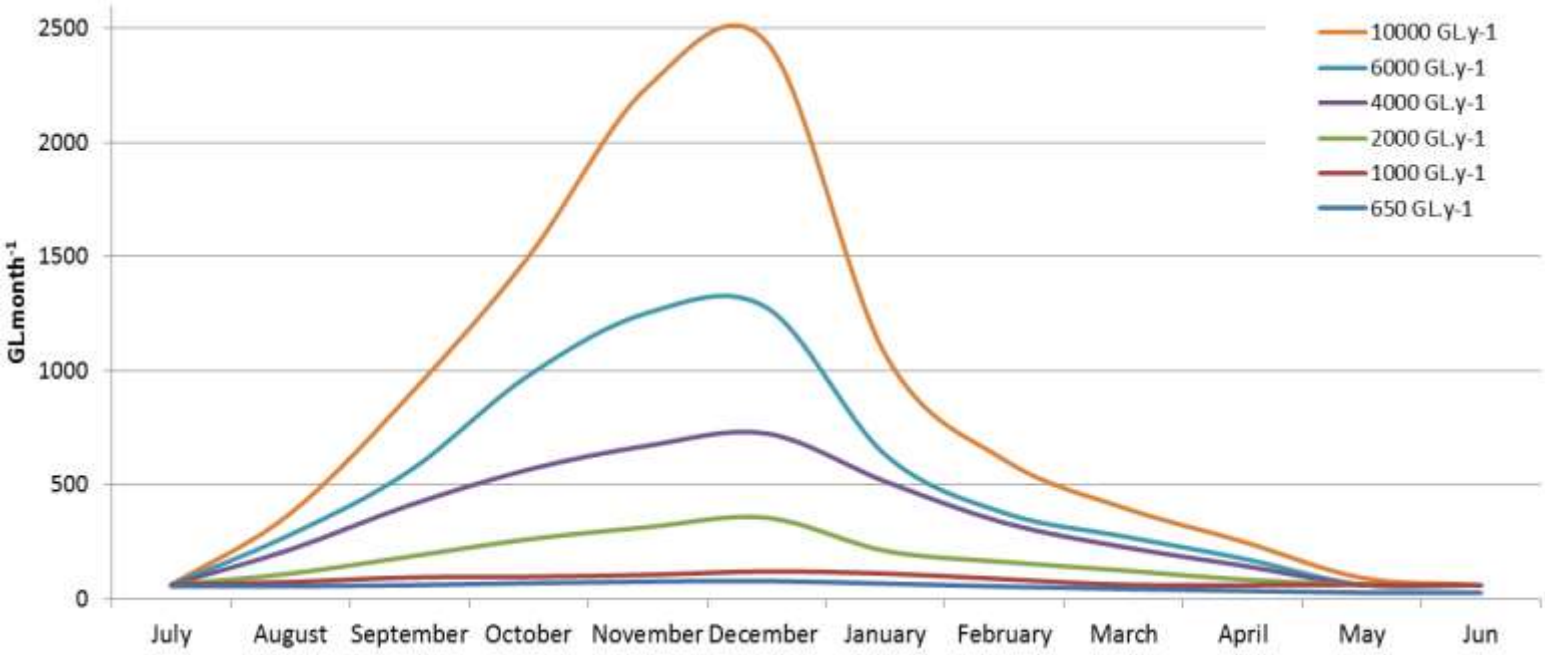

Figure 10. Hypothetical optimal timing of barrage releases for various annual flow scenarios

(Developed by J. Higham, CLLMM Recovery Project)

Table 7. Ecological objectives and targets for the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset

Table taken from O'Connor, et al. (2015). Note, additional target detail and supplementary information, and the source reference for the target information have not been transferred into this long-term plan and should be sourced from Table 1 in the original document

Type	Ecological objective	Ecological targets
Waterbirds	Maintain or improve waterbird populations in the Coorong and Lower Lakes	Abundances, area of occupation and extent of occurrence of TLM target waterbird species (Table 21 in Appendix 4) to be above defined median reference values (median of data from the 15 years between 2000 and 2014) (Paton, 2014a)
		Detect annual breeding activity in waterbird species that are expected to breed annually at the site (Table 22 **Error! Reference source not found.**in Appendix 4) and at least two breeding events in any four consecutive years in species that breed regularly at the site (Table 23 in Appendix 4) (Department of Environment Water and Natural Resources, in prep (a))
		Provide functional mudflat habitat to sustain active shorebird foraging behaviour during November-March with a foraging effort of <50%. (Murray-Darling Basin Authority, 2014e)
		Maintain abundances of 12 waterbird species (Table 24 in Appendix 4) at or above 1% of the total flyway population size (Department of Environment Water and Natural Resources, in prep (a))
Fish	Maintain a spatio-temporally diverse fish community and resilient populations of key native fish species in the lower lakes and Coorong	A spatio-temporally diverse fish community is present including all 23 fish families stated in the Ramsar site draft Ecological Character Description (Table 25 in Appendix 4) (Department of Environment Water and Natural Resources, in prep (a))
		Annual detection of juvenile Catadromous fish at abundances ≥ that of defined 'Recruitment Index' values (44.5 for *Congolli*, and 6.1 for *Common galaxias*) (Bice, et al., 2014)

		Annual detection of migration for Anadromous species (short-headed and pouched lamprey) at index values of >0.6 (Bice, et al., 2014)
		Maximise fish passage connectivity between the Lower Lakes and Coorong, and between the Coorong and the sea by allowing fishways to operate year-round (Murray-Darling Basin Authority, 2013b)
		Maintain or improve abundances of Murray hardyheads and pygmy perch so that 'Relative Abundance Index' values of ≥1 are achieved on an annual basis (Wedderburn, 2014)
		Detect recruitment success of Murray hardyheads and pygmy perch at least every second year (Wedderburn, 2014)
		Maintain or improve abundances, distribution and recruitment of black bream and greenback flounder with population condition score ≥3 (Ye, et al., 2014a)
		Facilitate regular recruitment and a broader distribution of juvenile mulloway (Ye, et al., 2014a)
		Maintain an average Catch-Per-Unit-Effort (CPUE) of small-mouthed hardyhead sampled in spring/early summer of > 120 for adults, and >790 for juveniles (Ye, et al., 2014b)
		Maintain the proportional abundance of small-mouthed hardyhead juveniles at >60% in 75% of defined monitoring sites within the CLLMM (Ye, et al., 2014b)
Macroinvertebrates	Maintain or improve invertebrate communities in estuarine and lagoon sediments	Macroinvertebrate taxonomic distinctness falls within the expected ranges of a regional reference (Dittman, 2014)
		The distribution of macroinvertebrate species remains within or above the species-specific reference level for their index of occurrence (Dittman, 2014)

		The area of occupancy where abundance and biomass are at or above the reference level should be >20% of the monitoring sites (Dittman, 2014)
		The macroinvertebrate community has a higher multivariate similarity to the community present in years with flow than without flow (Dittman, 2014)
	Maintain habitable sediment conditions in mudflats	Median grain size of sediments in the Coorong and Murray Mouth will remain between 125 – 500 µm (Dittman, 2014)
		Sediment organic matter content between 1 and 3.5 % dry weight in the Coorong and Murray Mouth (Dittman, 2014)
Vegetation	Restore *Ruppia tuberosa* colonisation and reproduction in the Coorong at a regional and local scale	A continuous distribution of *Ruppia tuberosa* beds along a 50 km section of the southern Coorong (excluding outliers) (Paton, 2014b)
		Within the abovementioned distribution, 80% of the monitored sites should have *Ruppia tuberosa* plants present in winter and summer (Paton, 2014b)
		50% of sites with *Ruppia tuberosa* to exceed the local site indicators for a healthy *Ruppia tuberosa* population (Paton, 2014b)
		Support a resilient *Ruppia tuberosa* population with seed densities of 2000 seeds/m^2 by 2019 and 50% of sites having 60% cover in winter and a seed bank of 10,000 seeds/m^2 by 2029 in the Coorong South Lagoon (Paton, 2014b)
	Maintain or improve aquatic and littoral vegetation in the Lower Lakes	Maintain or improve diversity of aquatic and littoral vegetation in the Lower Lakes as quantified using the LLCMM vegetation indices (Nicol, et al., 2014b)

Water quality	Establish and maintain stable salinities in the lakes and a variable salinity regime in the Murray estuary and Coorong.	Barrage outflows sufficient to maintain electrical conductivity in Lake Alexandrina at a long term average of 700 µS/cm, below 1,000 µS/cm 95% of years and below 1,500 µS/cm 100% of the time (Heneker, 2010)
		To support aquatic habitat: maintain a salinity gradient from 0.5 ppt to 35ppt between the Barrages and Murray Estuary area, <45ppt in the North lagoon, and from 60ppt to 100 ppt in the South lagoon (Lester, et al., 2011)
Ecosystem processes	Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity between the Coorong and the sea	Maintain an open Murray Mouth, as indicated when the Diurnal Tidal Ratio (DTR) at Goolwa exceeds 0.3, with minimum DTR values of 0.05 and 0.2 at Tauwitchere and Goolwa respectively (Murray-Darling Basin Authority, 2013b; Department of Water Land and Biodiversity Conservation, 2008)
		Maintain a minimum annual flow required to keep the Murray Mouth open (730—1,090 GL/year) (Murray-Darling Basin Authority, 2013b)

Table 8. Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset

Table taken from O'Connor, et al. (2015). 'Timing' of barrage flows, lake levels and Coorong South Lagoon water levels include the entire duration of each month specified (i.e. from the beginning of the first month to the end of the final month).

EWR #	Average return interval (years)	Maximum interval (years)	Annual barrage flow (GL/year)	Barrage flow timing	Lakes water level range (mAHD)	Lakes water level timing	Coorong south lagoon water level (mAHD)	Coorong south lagoon water level timing	Coorong south lagoon duration (days)
CLLMM1	1-in-1	N/A	>650[26]	Jul-Jun, with peak barrage outflows in Oct-Dec	0.4-0.75	Maximum lake levels Dec-Feb and minimum lake levels in Mar-May	0.0 to 0.2	Sept-Nov	≥90
							-0.2 to -0.4	Feb-Mar	-
CLLMM2	1-in-2	N/A	>3150[27]	Jul-Jun, with peak barrage outflows in Oct-Dec	0.4-0.83	Maximum lake levels Dec-Feb and minimum lake levels in Mar-May	0.35-0.45	Sept-Dec	≥120
							0 to -0.5	Mar-April	-
CLLMM3	1-in-3	5	>6,000	Jul-Jun, with peak barrage outflows in Oct-Dec	0.4-0.83	Maximum lake levels Dec-Feb and minimum lake levels in Mar-May	0.35-0.45	Sept-Jan	≥150
							0 to -0.5	Feb-April	-
CLLMM4	1-in-7	17	>10,000	Jul-Jun, with peak barrage outflows in Oct-Dec	0.4-0.9	Maximum lake levels Dec-Feb and minimum lake levels in Mar-May	0.35-0.45	Sept-end Feb	≥180
							n/a	n/a	-

[26] A total average barrage outflow of 2,000 GL/year over a three year rolling period (i.e. not less than 6,000 GL over three years) and not less than 650 GL/year in any one of the three years (Heneker 2010; Lester et al. 2011)

[27] A total average barrage outflow of 4,000 GL/year over a three year rolling period (i.e. not less than 12,000 GL over three years) and not less than 3150 GL/year in any one of the three years (Heneker 2010; Lester et al. 2011)

3.6 Application of the environmental water requirements

3.6.1 EWRs contribution to targets

The methods used to develop the EWRs for this LTWP do not provide a single EWR per objective or target; rather, the suite of EWRs for each PEA describes a variable flow regime which is required to achieve the ecological targets. To assist with annual planning and environmental watering decisions, such as potential benefits or trade-offs under different flow scenarios, a matrix was developed that assessed the likely contribution of each EWR in isolation towards achieving each of the ecological targets. The assessment uses a coarse ranking system and so a result of no change in ranking does not necessarily mean there is no improvement in contribution, and outcomes will be dependent on antecedent flows and prevailing ecosystem condition (Wallace, et al., 2014a). The matrices were populated based on the flow-ecology conceptual models (see PEA descriptions above) and expert opinion, and the results are presented in the three tables below:

- Table 9. Assessment of contribution of SA River Murray Channel Priority Environmental Asset EWRs towards Ecological Targets
- Table 10. Assessment of contribution of SA River Murray Floodplain Priority Environmental Asset EWRs towards Ecological Targets
- Table 11. Assessment of contribution of Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset EWRs towards Ecological Targets.

The matrices developed for the Floodplain PEA and the CLLMM PEA show the importance of irregular flows of 70,000 ML/day QSA or greater in achieving ecological outcomes, with the higher EWRs likely to result in a 'large positive contribution' to the greatest number of targets. However, the need for a long-term variable flow regime consisting of baseflows, in-channel freshes and overbank flows (as represented by the suite of EWRs for each asset) should not be overlooked.

3.6.2 EWRs and annual planning

The EWRs for the priority environmental assets are not presented in the form of prescriptive five-year hydrographs because the feasibility of delivery will be highly dependent on climatic conditions. In order to meet the majority of the EWRs, environmental water will need to be delivered in conjunction with unregulated flows, as the volume of water required is greater than that provided by South Australia's Entitlement or available to the environment through water recovery programmes. The need to deliver an EWR in any given year will also depend on antecedent climate conditions and the condition of the different ecological components of the asset. Therefore the EWRs describe a desired long-term and variable hydrological regime in a way that enables flexibility and adaptive management in response to climate and ecological condition.

In recent years, South Australia has used a scenario-based approach to plan and prioritise environmental watering actions each year. The process is described in the Annual Environmental Watering Plans for the South Australian River Murray, which are published on the DEWNR website. The EWRs can be used to inform annual planning by:

- comparing desired return frequency (i.e. the average return frequency metric of EWR) to actual return frequency (i.e. how often the EWR has been met based on surface water data) over a 20-year period, where an EWR is considered to be met within any given water-year when the volume/discharge, duration, timing, water level and rate of change metrics have all been satisfied. A 20-year timeframe is used as it captures the longest 'maximum interval' specified by any of the EWRs (i.e. 17 years for EWR - CLLMM4) and ensures results are based on long-term watering histories
- assessing the number of years since the EWR was met and comparing to the maximum interval metric of the EWR.

These assessments are hydrological and assume the flow-ecology relationship is well understood. Decisions should also be informed by results from ecological monitoring that indicate current condition, need for water and risk of not watering. Once accurate forecasts of climatic conditions are available then the assessment should be revisited and watering actions refined based on what is feasible to deliver.

In addition to the ecological information, management considerations within Section 4 should also be taken into account during planning and decision-making, including:

- Indigenous values – consideration of, and where possible alignment with, Indigenous values in order to maximise the benefits from environmental watering
- cooperative arrangements – processes to be followed to ensure that watering actions across the WRP Area and SCB are coordinated, and potential risks to water quality are considered
- operational constraints – whether it is feasible to deliver the proposed watering action in view of operational constraints
- long-term risks to providing environmental water – whether the proposed watering action addresses any of the potential long-term risks.

3.6.3 EWRs and management levers

The description of landscape-scale environmental assets for the SA River Murray LTWP and their EWRs encourages the reinstatement of a more natural flow regime through the delivery of environmental water to the South Australian border, and subsequently downstream to the CLLMM. To meet most EWRs will require an unregulated flow event to occur, with environmental water used to boost the magnitude or duration of the event. However, the PEAs incorporate many smaller scale management units that offer alternative opportunities for delivering environmental water and meeting the EWR metrics in discrete locations. In particular, the Chowilla Environmental Regulator and the main channel weirs can be raised to increase the extent of inundation of parts of the Channel and Floodplain PEAs, while pumps can be used to deliver water to discrete temporary wetland basins in any of the three PEAs. Each of these management units have their own management plans and site-specific objectives and targets, but these types of actions will also contribute to partially meeting the ecological targets of the PEAs. The mechanism for evaluating the contribution of localised environmental water delivery to the PEA ecological targets will be addressed through the development of a separate integrated monitoring and evaluation plan, and the information used to inform adaptive management of both the site and the PEA.

Conversely, the discrete management sites that are likely to receive water as a result of enhancing flows at the South Australian border can be identified. Appendix 5 provides a table of the modelled flow rates when inundation of selected[28] temporary wetlands begins (commence-to-flow), which has been developed by staff within the Natural Resources SA MDB branch of DEWNR (Turner, 2015). Natural Resources SA MDB staff are developing a floodplain wetland management plan which presents this information, as well as the management objectives and desired return frequency of inundation events (based on commence-to-flow levels and modelled natural hydrological regimes). Cross-referencing the wetland commence-to-flow values and the discharge metrics of the EWRs for the Channel PEA and the Floodplain PEA provides an indication of which of the managed temporary wetlands is influenced by the delivery of different flow events, noting that this relationship will change in lock reaches where weir manipulations or operation of large environmental regulators are undertaken.

[28] Temporary wetlands listed are those that have previously been inundated through pumping or have been identified as potential pump sites - it does not represent all temporary wetlands on the SA River Murray floodplain. This list is likely to change in the future.

Fringing temporary wetlands of the CLLMM PEA are influenced by water levels in the Lower Lakes (which are largely influenced by barrage operations) and the effects of wind seiching, and their desired hydrological regime is provided by the variable Lake levels specified in the CLLMM PEA EWRs. Pumping water to these wetlands may be required at times, depending on climatic conditions and the ability to maintain the appropriate seasonal Lake level pattern.

The Channel PEA also includes a large number of pool-connected wetlands; that is wetlands that are permanently inundated due to the stable water levels created by the weirs. At some of these wetlands, wetting and drying regimes have been reinstated through the installation of infrastructure that enables them to be disconnected from the River. These managed pool-connected wetlands have their own management plans that describe site-specific objectives and targets. The unmanaged and the managed pool-connected wetlands use planned environmental water and held environmental water, respectively. It may be difficult to determine the direct contribution that pool-connected wetlands make to the Channel PEAs ecological targets, which focus largely on outcomes from the delivery of *additional* water to South Australia. However, increased flows and the re-establishment of lotic habitats in the main channel will increase the value of the lentic conditions provided by off-channel habitats.

Table 9. Assessment of contribution of SA River Murray Channel Priority Environmental Asset EWRs towards Ecological Targets

Table taken from Wallace, et al. (2014a)

Assessment based on the following ranking system:

Score	Requirements or processes met	Contribution towards Ecological Targets
1	All or most	Large positive contribution
2	Some	Moderate positive contribution
3	Very few or none	Contribution unlikely to be detectable or expected

Channel Ecological Target	EF[29]	Channel EWR[30]						
		IC1 (10,000)	IC2 (15,000)	IC3 (20,000)	IC4 (25,000)	IC5 (30,000)	IC6 (35,000)	IC7 (40,000)
Open-water productivity shows a temporary shift from near zero or autotrophic dominance (positive Net Daily Metabolism) towards heterotrophy (negative Net Daily Metabolism) when QSA >30,000 ML/day.	3	3	3	3	2	2	1	1
Habitat across the range of velocity classes is present in the lower third of weir pools for at least 60 consecutive days in Sep–Mar, at a maximum interval of 2 years.	3	3	3	2	1	1	1	1

[29] EF = entitlement flow and is provided as a comparison only

[30] Refer Table 4 for full description of Channel EWRs. The discharge magnitude has been provided (in brackets) to assist with cross-referencing, however the EWR consists of several metrics including duration, return frequency and timing.

Channel Ecological Target	EF[29]	Channel EWR[30]						
		IC1 (10,000)	IC2 (15,000)	IC3 (20,000)	IC4 (25,000)	IC5 (30,000)	IC6 (35,000)	IC7 (40,000)
Thermal stratification does not persist for more than 5 days at any time.	3	1	1	1	1	1	1	1
Basin Plan Objective: Salt export, averaged over the preceding 3 years, is ≥2 million tonnes per year.	3	3	2	2	2	1	1	1
Inundation periods in temporary wetlands have unrestricted lateral connectivity between the river and wetlands in >90% of inundation events.	3	3	3	3	2	2	2	1
Biovolume <4 mm^3/L for all Cyanobacteria, where a known toxin producer is dominant, **or** <10 mm^3/L for all Cyanobacteria where toxins are not present.	3	2	1	1	1	1	1	1
Basin Plan Target: Maintain dissolved oxygen above 50% saturation throughout water column at all times.	3	3	3	2	2	2	1	1
Establish and maintain freshwater lenses in near-bank recharge zones.	3	3	2	2	2	2	1	1
Maintain soil water availability, measured as soil water potential > -1.5 MPa at soil depth 20–50 cm, to sustain recruitment of long-lived vegetation across the elevation gradient in the target zone.	3	3	3	2	2	2	2	1
Reduce soil salinity (measured as EC 1:5) to <5000 µS/cm to prevent shifts in understorey plant communities to salt-tolerant functional groups across the elevation gradient in the target zone.	3	3	3	2	2	2	2	1
Median biofilm composition is not dominated (>80%) by filamentous algae.	3	2	2	2	1	1	1	1

Channel Ecological Target	EF[29]	Channel EWR[30]						
		IC1 (10,000)	IC2 (15,000)	IC3 (20,000)	IC4 (25,000)	IC5 (30,000)	IC6 (35,000)	IC7 (40,000)
Median biofilm C:N ratios are <10:1.	3	2	2	2	1	1	1	1
In standardised transects spanning the elevation gradient in the target zone, 70% of river red gums have a Tree Condition Index score ≥ 10.	3	3	2	2	2	2	2	1
A sustainable demographic is established to match the modelled profile for a viable river red gum population in existing communities spanning the elevation gradient in the target zone.	3	3	3	2	2	2	2	1
Species from the Plant Functional Group 'flood-dependent/responsive' occur in 70% of quadrats spanning the elevation gradient in the target zone at least once every 3 years.	3	3	3	2	2	2	2	1
Native macrophytes from the emergent, amphibious and flood- dependent functional groups occur in 70% of quadrats spanning the elevation gradient in the target zone at least once every 3 years.	3	3	3	3	2	2	2	1
Expected fish species occur in each mesohabitat (channel, anabranch, wetlands) in each weir pool/reach.	3	3	3	3	3	2	1	1
Population age structure of Murray cod includes recent recruits, sub-adults and adults in 9 years in 10.	3	3	3	2	2	2	2	2
Population age structure of Murray cod indicates a large recruitment event 1 year in 5, demonstrated by a cohort representing >50% of the population.	3	3	3	3	3	3	3	2
Abundance (CPUE) of Murray cod increases by ≥50% over a 10-year period.	3	3	3	2	2	2	2	2

Channel Ecological Target	EF[29]	Channel EWR[30]						
		IC1 (10,000)	IC2 (15,000)	IC3 (20,000)	IC4 (25,000)	IC5 (30,000)	IC6 (35,000)	IC7 (40,000)
Population age structure of golden perch and silver perch includes YOY with sub-adults and adults in 8 years in 10.	3	3	2	2	2	2	2	1
Population age structure of golden perch and silver perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.	3	3	2	2	2	2	2	1
Abundance (CPUE) of golden perch and silver perch increases by ≥30% over a 5-year period.	3	3	3	2	2	2	2	1
Population age structure of freshwater catfish includes YOY, with sub-adults and adults in 9 years in 10.	3	3	3	2	2	2	2	1
Population age structure of freshwater catfish indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.	3	3	3	3	3	2	2	1
Abundance (CPUE) of freshwater catfish increases by ≥30% over a 5-year period.	3	3	3	3	3	2	2	1
Length-frequency distributions for foraging generalists include size classes showing annual recruitment.	1	1	1	2	2	2	2	2
Relative abundance and biomass of common carp do not increase in the absence of increases in abundance and biomass of flow-dependent native fish.	1	1	2	2	2	1	1	1

Table 10. Assessment of contribution of SA River Murray Floodplain Priority Environmental Asset EWRs towards Ecological Targets

Table taken from Kilsby, et al. (2015)

Assessment based on the following ranking system:

Score	Requirements or processes met	Contribution towards Ecological Targets
1	All or most	Large positive contribution
2	Some	Moderate positive contribution
3	Very few or none	Contribution unlikely to be detectable or expected

Floodplain Ecological targets	Floodplain EWR[31]				
	FP1 (50,000)	FP2 (60,000)	FP3 (70,000)	FP4 (80,000; 30-days)	FP5 (80,000; 60-days)
During inundation periods, record an increase in the abundance and diversity of invertebrate food resources, nutrients and DOC relative to those available during base flow	2	1	1	1	1
Deliver flows in a manner that reduces the proportion of slow flowing habitat and increases the proportion of moderate velocity habitat thereby reinstating a diversity of velocity classes representative of natural conditions	1	1	1	1	1
Discharge, water level and duration metrics of planned e-water represent a seasonally variable hydrograph	1	1	1	1	1

[31] Refer Table 6 for full description of Floodplain EWRs. The discharge magnitude has been provided (in brackets) to assist with cross-referencing, however the EWR consists of several metrics including duration, return frequency and timing.

Floodplain Ecological targets	Floodplain EWR[31]				
	FP1 (50,000)	FP2 (60,000)	FP3 (70,000)	FP4 (80,000; 30-days)	FP5 (80,000; 60-days)
Maintain dissolved oxygen above 50% saturation throughout water column at all times, in connected waters	1	1	1	1	1
Establish and maintain freshwater lenses in near-bank recharge zones	2	1	1	1	1
Maintain soil water availability, measured as soil water potential at soil depth 20-50cm, greater than -1.5 MPa in order to sustain the recruitment of long-lived vegetation	2	2	1	1	1
Reduce soil salinity (EC 1:5) to below 5000 µS/cm to prevent permanent shifts in understorey plant communities to salt tolerant functional groups	2	2	1	1	1
Maintain soil sodicity below the exchangeable sodium percent (ESP) value of 15 (highly sodic)	2	2	1	1	1
Limit the maximum rate of drawdown (averaged over 3 consecutive days) to ≤0.025 m/day (0.05m/day in any one day) to minimise risk of bank failure	1	1	1	1	1
In standardised transects that span the Floodplain PEA elevation gradient and existing spatial distribution >70% of all River red gum trees have a TCI ≥10	3	3	2	1	1
A sustainable demographic that matches the modelled profile for a viable River red gum population is established within existing communities across the floodplain elevation gradient	3	3	3	2	1
In standardised transects that span the Floodplain PEA elevation gradient and existing spatial distribution, >70% of all black box trees have a TCI ≥10	3	3	2	2	1

Floodplain Ecological targets	Floodplain EWR[31]				
	FP1 (50,000)	FP2 (60,000)	FP3 (70,000)	FP4 (80,000; 30-days)	FP5 (80,000; 60-days)
A sustainable demographic that matches the modelled profile for a viable black box population is established within existing communities across the floodplain elevation gradient	3	3	3	2	1
In standardised transects that span the Floodplain PEA elevation gradient and existing spatial distribution, >70% of all River cooba trees have a TCI ≥10	3	3	2	1	1
A sustainable demographic that matches the modelled profile for a viable River cooba population is established within existing communities across the floodplain elevation gradient	3	3	3	2	1
In standardised transects that span the floodplain elevation gradient and existing spatial distribution , ≥70% of Lignum plants have a LCI ≥6 for colour	3	3	3	1	1
In aquatic zones, a minimum of 40% of cells either inundated or dry containing inundation- dependent or amphibious plant taxa once every two years on average with maximum interval no greater than 4 years. Native water dependent species richness >30 across the Floodplain PEA.	3	2	1	1	1
In aquatic zones, a minimum of 80% of cells either inundated or dry containing native flood dependent or amphibious plant taxa once every four years on average with maximum interval no greater than 6 years. Native water dependent species richness >50 across the Floodplain PEA.	3	3	2	1	1
In shedding floodplain zones, a minimum of 20% of cells containing native flood dependent or amphibious plant taxa once every three years on average with maximum interval no greater than 5 years. Native flood dependent and amphibious species richness >20 across the Floodplain PEA.	2	2	1	1	1

Floodplain Ecological targets	Floodplain EWR[31]				
	FP1 (50,000)	FP2 (60,000)	FP3 (70,000)	FP4 (80,000; 30-days)	FP5 (80,000; 60-days)
In shedding floodplain zones, of 40% of cells containing native flood dependent or amphibious plant taxa once every five years on average with maximum interval no greater than 7 years. Native flood dependent and amphibious species richness >30 across the Floodplain PEA.	3	2	1	1	1
In shedding floodplain zones, of 65% of cells containing native flood dependent or amphibious plant taxa once every seven years on average with maximum interval no greater than 10 years. Native flood dependent and amphibious species richness >50 across the Floodplain PEA.	3	3	2	1	1
Population age structure of Murray cod includes recent recruits, sub-adults and adults in 9 years in 10.	2	2	1	1	1
Population age structure of Murray cod indicates a large recruitment event 1 year in 5, demonstrated by a cohort representing >50% of the population.	2	2	1	1	1
Abundance (CPUE) of Murray cod increases by ≥50% over a 10-year period.	2	2	1	1	1
Population age structure of Freshwater catfish includes YOY, with sub-adults and adults in 9 years in 10.	2	2	1	1	1
Population age structure of Freshwater catfish indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.	2	2	2	1	1
Abundance (CPUE) of Freshwater catfish increases by ≥30% over a 5-year period.	2	2	2	1	1
Population age structure of Golden perch and Silver perch includes YOY with sub-adults and adults in 8 years in 10.	1	1	1	1	1

Floodplain Ecological targets	Floodplain EWR[31]				
	FP1 (50,000)	FP2 (60,000)	FP3 (70,000)	FP4 (80,000; 30-days)	FP5 (80,000; 60-days)
Population age structure of Golden perch and Silver perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.	1	1	1	1	1
Abundance (CPUE) of Golden perch and Silver perch increases by ≥30% over a 5-year period.	1	1	1	1	1
The length-frequency distributions for wetland/floodplain (native fish) specialists within aquatic zones across the Floodplain PEA include size classes showing annual recruitment.	3	3	2	1	1
Increase range and abundance of wetland/floodplain (native fish) specialists within aquatic zones across the Floodplain PEA	3	3	2	1	1
The relative abundance and biomass of non-native species does not increase in the absence of increases in abundance and biomass of native fish.	2	2	1	1	1
Each of eight riparian frog species present within the Floodplain PEA will be recorded across the floodplain in any three year period.	2	1	1	1	1
Tadpoles will be recorded from eight species in later stages of metamorphosis across the Floodplain PEA in any three year period.	2	2	1	1	1
Minimum inundation periods required for successful breeding by a range of water bird species are provided. Preliminary minimum 120 days.	3	3	2	1	1
During continental dry periods an increase in the observed to expected ratio of waterbirds	2	2	1	1	1

Floodplain Ecological targets	Floodplain EWR[31]				
	FP1 (50,000)	FP2 (60,000)	FP3 (70,000)	FP4 (80,000; 30-days)	FP5 (80,000; 60-days)
Each of the bird species known to utilise similar floodplain woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three year period.	3	3	3	2	1
Each of the reptile species known to utilise similar floodplain/woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three year period.	3	3	3	2	1
Each of the native mammal species known to utilise similar floodplain/woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three year period.	3	3	3	2	1

Table 11. Assessment of contribution of Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset EWRs towards Ecological Targets

Table taken from O'Connor, et al. (2015)

Assessment based on the following ranking system:

Score	Requirements or processes met	Contribution towards Ecological Targets
1	All or most	Large positive contribution
2	Some	Moderate positive contribution
3	Very few or none	Contribution unlikely to be detectable or expected

CLLMM Ecological Targets	Species or wetland	CLLMM EWRs[32]			
		CLLMM1 (>650)	CLLMM2 (>3,150)	CLLMM3 (>6,000)	CLLMM4 (>10,000)
Abundances, area of occupation, and extent of occurrence of TLM target waterbird species to be above defined median reference values (median of data from the 15 years between 2000 and 2014)	n/a	3	2	1	1
Detect annual breeding activity in waterbird species that are expected to breed annually at the site and at least two breeding events in any four consecutive years in species that breed regularly at the site	n/a	3	2	1	1
Provide functional mudflat habitat to sustain active shorebird foraging behaviour during November-March with a foraging effort of <50%	n/a	3	2	1	1

[32] Refer Table 8 for full description of CLLMM EWRs. The annual barrage outflow volume has been provided (in brackets) to assist with cross-referencing, however the EWR consists of several metrics including water levels, duration, return frequency and timing.

CLLMM Ecological Targets	Species or wetland	CLLMM EWRs[32]			
		CLLMM1 (>650)	CLLMM2 (>3,150)	CLLMM3 (>6,000)	CLLMM4 (>10,000)
Maintain abundances of 12 waterbird species at or above 1% of the total flyway population size	n/a	3	2	1	1
A spatio-temporally diverse fish community is present including all 23 fish families stated in the Ramsar site draft Ecological Character Description	n/a	2	2	1	1
Annual detection of juvenile Catadromous fish at abundances ≥ that of defined 'Recruitment Index' values (44.5 for *Congolli*, and 6.1 for *Common galaxias*.	n/a	2	1	1	1
Annual detection of migration for Anadromous species (short-headed and pouched lamprey) at index values of >0.6.	n/a	3	2	1	1
Maximise fish passage connectivity between the Lower Lakes and Coorong, and between the Coorong and the sea by allowing fishways to operate year-round	n/a	2	1	1	1
Maintain or improve abundances of Murray hardyheads and pygmy perch so that 'Relative Abundance Index' values of ≥1 are achieved on an annual basis	Murray hardyhead	1	2	2	2
	Yarra pygmy perch	2	1	1	1

CLLMM Ecological Targets	Species or wetland	CLLMM EWRs[32]			
		CLLMM1 (>650)	CLLMM2 (>3,150)	CLLMM3 (>6,000)	CLLMM4 (>10,000)
Detect recruitment success of Murray hardyheads and pygmy perch at least every second year	Murray hardyhead	1	2	2	2
	Yarra pygmy perch	1	1	1	1
Maintain or improve abundances, distribution and recruitment of black bream and greenback flounder with population condition score ≥3.	Black bream	2	2	1	1
	Greenback flounder	3	2	1	1
Facilitate regular recruitment and a broader distribution of juvenile mulloway	n/a	3	2	1	1
Maintain an average Catch-Per-Unit-Effort (CPUE) of small-mouthed hardyhead sampled in spring/early summer of > 120 for adults, and >790 for juveniles	n/a	3	2	1	1
Maintain the proportional abundance of small-mouthed hardyhead juveniles at >60% in 75% of defined monitoring sites within the CLLMM	n/a	2	1	1	1
Macroinvertebrate taxonomic distinctness falls within the expected ranges of a regional reference.	Lower Lakes	2	2	2	2
	Coorong	2	1	1	2

CLLMM Ecological Targets	Species or wetland	CLLMM EWRs[32]			
		CLLMM1 (>650)	CLLMM2 (>3,150)	CLLMM3 (>6,000)	CLLMM4 (>10,000)
The distribution of macroinvertebrate species remains within or above the species-specific reference level for their index of occurrence.	Lower Lakes	2	2	2	2
	Coorong	2	1	1	2
The area of occupancy where abundance and biomass are at or above the reference level should be >20% of the monitoring sites.	Coorong	2	1	1	1
The macroinvertebrate community has a higher multivariate similarity to the community present in years with than without flow.	Lower Lakes	2	2	2	2
	Coorong	2	1	1	2
Median grain size of sediments in the Coorong and Murray Mouth will remain between 125 – 500 µm	n/a	2	1	1	2
Sediment organic matter content between 1 and 3.5 % dry weight in the Coorong and Murray Mouth.	n/a	1	1	2	2
A continuous distribution of *Ruppia tuberosa* beds along a 50 km section of the southern Coorong (excluding outliers).	n/a	3	2	1	1
Within the abovementioned distribution, 80% of the monitored sites should have *Ruppia tuberosa* plants present in winter and summer	n/a	3	2	2	1
50% of sites with *Ruppia tuberosa* to exceed the local site indicators for a healthy *Ruppia tuberosa* population	n/a	3	3	2	1

CLLMM Ecological Targets	Species or wetland	CLLMM EWRs[32]			
		CLLMM1 (>650)	CLLMM2 (>3,150)	CLLMM3 (>6,000)	CLLMM4 (>10,000)
Support a resilient *Ruppia tuberosa* population with seed densities of 2,000 seeds/m^2 by 2019 and 50% of sites having 60% cover in winter and a seed bank of 10,000 seeds/m^2 by 2029 in the Coorong South Lagoon	n/a	3	2	1	1
Maintain or improve diversity of aquatic and littoral vegetation in the Lower Lakes as quantified using the LLCMM vegetation indices	n/a	1	1	1	1
Barrage outflows sufficient to maintain electrical conductivity in Lake Alexandrina at a long term average of 700 µS/cm, below 1,000 µS/cm 95% of years and below 1,500 µS/cm 100% of the time	n/a	3	1	1	1
To support aquatic habitat: maintain a salinity gradient from 0.5 ppt to 35 ppt between the Barrages and Murray Estuary area, <45 ppt in the North Lagoon, and from 60 ppt to 100 ppt in the South Lagoon	Coorong	2	1	1	1
Maintain an open Murray Mouth, as indicated when the Diurnal Tidal Ratio (DTR) at Goolwa exceeds 0.3, with minimum DTR values of 0.05 and 0.2 at Tauwitchere and Goolwa respectively	Coorong	3	1	1	1
Maintain a minimum annual flow required to keep the Murray Mouth open (730—1,090 GL/year)	Coorong	3	1	1	1

3.7 Priority ecosystem functions

The Basin Plan (Schedule 9) provides the following criteria for identifying ecosystem functions:

- supports the creation and maintenance of vital habitats and populations
- supports the transportation and dilution of nutrients, organic matter and sediment
- provides connections along a watercourse (longitudinal connectivity)
- provides connections across floodplains, adjacent wetlands and billabongs (lateral connections).

Processes or functions consistent with these criteria have been identified as key ecological attributes for each of the PEAs within the SA River Murray WRP Area (the Channel, the Floodplain and the CLLMM), and so ecological objectives relating to ecosystem functions have been included for each asset.

The identification of priority ecosystem functions for the SA River Murray WRP Area as a whole was undertaken through a DEWNR project described in Bonafacio (2015) and the following information has been extracted from this report. Priority ecosystem functions (PEFs) are considered to be those that occur within two or more of the PEAs and rely on connectivity between the PEAs. By aligning the ecological objectives of the PEAs with ecosystem functions identified in the scientific literature, 10 PEFs have been identified. An associated ecological objective has been developed for each PEF (Table 12).

A unique suite of ecological targets and EWRs for the PEFs has not been developed. However, for the purposes of the LTWP it is assumed that the targets and EWRs of the priority environmental assets capture those of the PEFs. This is justified on the basis that the approach aligned the existing objectives of the PEAs and these already have associated EWRs and targets.

Connectivity throughout the WRP Area is implicit to the delivery of the asset EWRs, with the primary mechanism for delivery being the provision of environmental water to the SA border, which then flows onto the CLLMM. This reflects a continuing shift towards more integrated management of the SA River Murray WRP Area as a whole. For example, in recent years proposed multi-site watering actions for the SA River Murray WRP Area have been developed (Department of Environment, Water and Natural Resources, 2014b) that seek to align the desired water delivery pattern for the CLLMM with that of the Channel or Floodplain. This was further investigated through hydrological modeling of the alignment of the asset EWRs (see below).

Table 12. Priority ecosystem functions and associated ecological objectives for the SA River Murray WRP Area

Priority ecosystem functions	Ecological objectives
Flow variability	Improve flow variability throughout the SA River Murray
Lateral hydrological connectivity	Improve the lateral hydrological connectivity between the Channel and Floodplain
Longitudinal hydrological connectivity	Improve the longitudinal hydrological connectivity between the Channel and CLLMM
Mobilisation and transport of salt	Increase the mobilisation, transport and export of salt of through the SA River Murray
Mobilisation and transport of carbon and nutrients	Increase the mobilisation, transport and export of nutrients and carbon through the SA River Murray
Primary productivity	Enhance primary productivity due to increased lateral and longitudinal connectivity
Transport of plant propagules	Facilitate the transport of plant propagules throughout the SA River Murray due to increased lateral and longitudinal connectivity
Dispersal of faunal larvae and juveniles	Facilitate the dispersal of faunal larvae throughout the SA River Murray due to increased lateral and longitudinal connectivity
Faunal recruitment	Enhance the recruitment into faunal populations due to increased lateral and longitudinal connectivity
Secondary productivity	Increase secondary productivity due to increased lateral and longitudinal connectivity

3.7.1 Alignment of environmental water requirements

In order to improve the understanding of the hydrological connectivity between the three assets, to promote integrated management across the SA River Murray WRP Area and to inform the development of future regional multi-site watering actions, a modeling exercise was undertaken that assessed the alignment of the EWRs of the Channel and Floodplain with the EWRs for the CLLMM. The modeling inputs were hypothetical hydrographs of flows at the border that met the discharge, duration, timing, rate of rise and rate of fall metrics of the Channel and the Floodplain EWRs. A second modeling exercise assessed the consistency within the CLLMM EWRs by modeling the daily Coorong water levels produced by the barrage outflow volume and timing metrics. The methods, assumptions and outputs are described in Department of Environment, Water and Natural Resources (in prep (b)) and have been summarised below.

The four key questions were:

1. Does the timing of the Channel and Floodplain EWRs align with the preferred delivery pattern of barrage outflows?
2. What Channel or Floodplain EWR must be met in order to meet the barrage outflow metric of each CLLMM EWR?
3. Where volumes align, is there consistency between the average return frequency metrics of the Channel and Floodplain EWRs with those of the CLLMM?
4. For a given CLLMM EWR, do the barrage outflow metrics (volumes and timing) provide the desired Coorong South Lagoon water levels, timing and duration metrics?

Modeling indicated that there was good alignment between the timing of the Channel/Floodplain EWRs and the preferred annual barrage release pattern.

In terms of volume, the modeled outputs[33] indicate the following:

- the lowest Channel EWR (EWR-IC1) does not deliver sufficient water to meet the minimum required barrage outflow volume (650 GL/year)
- the remainder of the Channel EWRs (EWR-IC2 to EWR-IC7) and all of the floodplain EWRs (EWR-FP1 to EWR-FP5) provide sufficient volume for the lowest CLLMM EWR (EWR-CLLMM1)
- the highest Channel EWR (EWR-IC7), which has a discharge metric of 40,000 ML/day QSA, and all the Floodplain EWRs (EWR-FP1 to EWR-FP5) provide sufficient volume for EWR-CLLMM2, which specifies an annual barrage outflow volume of greater than 3,150 GL/year
- the three largest Floodplain EWRs (EWR-FP3 to EWR-FP5) which have discharges of 70,000 ML/day QSA or above, provide sufficient volume for EWR-CLLMM3, which has an annual barrage outflow metric of greater than 6,000 GL/year
- the two largest Floodplain EWRs (EWR-FP4 and EWR-FP5) which have discharges of 80,000 ML/day QSA, provide sufficient volume for the largest CLLMM EWR (EWR-CLLMM4), which has an annual barrage outflow metric of greater than 10,000 GL/year.

Comparison of the average return interval metrics of the Channel and Floodplain EWRs with those of the CLLMM show that, in general, the CLLMM EWRs require in-channel pulses and small to medium overbank flows to occur more frequently than specified by the Channel and Floodplain EWRs (Table 13**Error! Reference source not found.**). This difference may partly be due to slightly different approaches to describing the ARI metrics, with the

[33] The interpretations presented are based on the median modelled annual barrage outflow volumes for each channel/floodplain EWR only; results may vary in years where losses are lower or higher than median.

CLLMM using whole years, while the Channel and Floodplain used fractions. The alignment of the Channel and Floodplain EWRs with the CLLMM EWRs is summarised in Table 13.

The CLLMM EWRs incorporate metrics for the Coorong South Lagoon (water levels, timing and duration), which were largely based on the conditions needed to support the life-cycle of *Ruppia tuberosa* and derived from Ye, et al. (2014, cited in O'Connor, et al. 2015) and expert opinion (O'Connor, et al., 2015). To strengthen the basis for the values of the South Lagoon metrics, a Coorong 1D hydrodynamic model was used to estimate the alignment of these metrics and the barrage outflow metrics.

The modeling results indicate relatively good alignment between the barrage outflows (volume and delivery pattern) and the Coorong South Lagoon water level metrics for two of the EWRs (EWR-CLLMM1 and EWR-CLLMM3), although for EWR-CLLMM3 there may be some difficulty maintaining water levels throughout January. For EWR-CLLMM2, the barrage outflows may not be sufficient to reach the desired water level range in the South Lagoon. Modeled results for EWR-CLLMM4 indicate Coorong water levels exceed the specified range in late spring/early summer then decline rapidly to below the specified range in late summer. This is a preliminary analysis only and further exploration is required into the ability to optimise Coorong South Lagoon water level conditions through altered barrage operations.

This information will assist with planning for future multi-site watering actions within the SA River Murray WRP Area by providing an understanding of the nature of the flow events required for the Channel and Floodplain PEAs in order to also meet the hydrological requirements of the CLLMM PEA, including the Coorong South Lagoon conditions needed to support the life-cycle of *Ruppia tuberosa*.

Table 13. Alignment of Channel and Floodplain EWRs with CLLMM EWRs

Assessment is based on the median outputs of modelled barrage outflows only. If the minimum volume requirements of the CLLMM EWRs were not met then no assessment of the alignment of average return interval was undertaken

EWR #	EWR-CLLMM1		EWR-CLLMM2		EWR-CLLMM3		EWR-CLLMM4	
	Volume (>650)	ARI (100%)	Volume (>3,150)	ARI (50%)	Volume (>6,000)	ARI (33%)	Volume (>10,000)	ARI (14%)
EWR-IC1 (10,000; ARI 95%)	×	-	×	-	×	-	×	-
EWR-IC2 (15,000; ARI 75%)	✓	×	×	-	×	-	×	-
EWR-IC3 (20,000; ARI 55%)	✓	×	×	-	×	-	×	-
EWR-IC4 (25,000; ARI 59%)	✓	×	×	-	×	-	×	-
EWR-IC5 (30,000; ARI 55%)	✓	×	×	-	×	-	×	-
EWR-IC6 (35,000; ARI 55%)	✓	×	×	-	×	-	×	-
EWR-IC7 (40,000; ARI 48%)	✓	×	✓	×	×	-	×	-
EWR-FP1 (50,000; ARI 63%)	✓	×	✓	✓	×	-	×	-
EWR-FP2 (60,000; ARI 50%)	✓	×	✓	✓	×	-	×	-
EWR-FP3 (70,000; ARI 38%)	✓	×	✓	×	✓	✓	×	-
EWR-FP4 (80,000; ARI 28%)	✓	×	✓	×	✓	×	✓	✓
EWR-FP5 (80,000; ARI 13%)	✓	×	✓	×	✓	×	✓	×

Photo: Lake Merreti © Callie Nickolai

4 Management considerations

4.1 Indigenous values

The River Murray, and its floodplains and wetlands, are central to the life and culture of Indigenous nation groups in the WRP Area. The two nation groups along the South Australian River Murray are the First Peoples of the River Murray and Mallee Region and the Ngarrindjeri. There are close cultural, family and historical connections between Indigenous people from across the SA MDB region (Hemming, et al., 2000).

The strong association between Indigenous people and the environment is reflected in their Creation stories, which pass on important knowledge, cultural values and beliefs and reflect the relationships between land, water, animals and people (Australian Govenment, 2015; Ngarrindjeri Nation, 2006).

4.1.1 Ngarrindjeri cultural values

Note: The information on Ngarrindjeri cultural values and aspirations expressed in this section are those directly provided by the Ngarrindjeri Regional Authority for inclusion in this plan.

The Ngarrindjeri Regional Authority is the peak regional Indigenous body representing the Ngarrindjeri Nation. The Ngarrindjeri are the Traditional Owners and Native Title Claimants of the land and waters of the River, Coorong and Lakes Alexandrina and Albert and adjacent areas, and have cultural authority and responsibility for areas extending up the River to Morgan through their member organisation the Mannum Aboriginal Community Association Incorporated (MACAI). The Ngarrindjeri have occupied, enjoyed, managed and used their inherited lands and waters of the River Murray, Lakes and Coorong since time immemorial.

4.1.1.1 Ngarrindjeri Yarluwar Ruwe (Sea Country)

The River Murray, Lower Lakes, Kurangk (Coorong) and Murray Mouth area are central to Ngarrindjeri cultural and spiritual beliefs. This association is expressed through Kaldowinyeri stories (cultural and spiritual histories) about Yarluwar-Ruwe (Sea Country) which reveals the significance of the relationship between the country and the people, both practically and spiritually. Kaldowinyeri stories and oral traditions explain how the land and water, animals and people came to be, and what and who they are. Creation ancestors such as Ngurunderi and Pondi, the Muntjingga and Thukabi teach Ngarrindjeri how to respect and understand the connection between the lands, the waters and the sky.

The Kaldowinyeri stories also record dramatic changes in the 'ecological character' of the region over millennia and explain the richness of 'natural resources' – especially the wealth of fresh and salt water marine life such as fish, shellfish, eels, waterbirds and water plants. The Ngarrindjeri have always depended on their Yarluwar Ruwe and its resources. Old People's living places (e.g. middens, burial grounds and other sacred places) are evidence of thousands of years of Ngarrindjeri sustainable use of their lands and waters since creation.

The following provides an overview of key parts of the Ngurunderi Kaldowinyeri Story (Ngarrindjeri Nation, 2006, p8):

> *A long, long time ago Ngurunderi our Spiritual Ancestor chased Pondi, the giant Murray Cod, from the junction where the Darling and Murrundi (River Murray) meet. Back then, the River Murray was just a small stream and Pondi had nowhere to go. As Ngurunderi chased him in his bark canoe he went ploughing and crashing through the land and his huge body and tail created the mighty River Murray. When Ngurunderi and his brother-in-law Nepele caught Pondi at the place where the fresh and salt water meet they cut him up into many pieces, which became the fresh and salt water fish for the Ngarrindjeri people. To the last piece Ngurunderi said, "you keep being a Pondi (Murray Cod)". As Ngurunderi travelled throughout our*

Country, he created landforms, waterways and life. He gave to his people the stories, meanings and laws associated with our lands and waters of his creation. He gave each Lakalinyeri (clan) our identity to our Ruwe (country) and our Ngarjtis (animals, birds, fish and plants) - who are our friends. Ngurunderi taught us how to hunt and gather our foods from the lands and waters. He taught us, don't be greedy, don't take any more than what you need, and share with one another. Ngurunderi also warned us that if we don't share we will be punished.

Ngarrindjeri respect the gifts of Creation that Ngurunderi passed down to our Spiritual Ancestors, our Elders and to us. Ngarrindjeri must follow the Traditional Laws; we must respect and honour the lands, waters and all living things. Ngurunderi taught us our Miwi, which is our inner spiritual connection to our lands, waters, each other and all living things, and which is passed down through our mothers since Creation. Our Great Grandmothers, Grandmothers and mothers fought to protect our Spiritual waters from desecration when a bridge to Kumarangk (Hindmarsh Island) was to be built. Ngurunderi taught us how to sustain our lives and our culture from what were our healthy lands and waters. Our lands and waters must be managed according to our Laws to make them healthy once again. As the Ngarrindjeri Nation we must maintain our inherent sovereign rights to our Yarluwar-Ruwe. Ngarrindjeri people have a sovereign right to make our living from the lands and waters in a respectful and sustainable way.

Ngarrindjeri have strong cultural and spiritual connections to particular places, to particular species of animals and plants, and all elements of the environment are part of their kinship system. Particular animal and plant species are the Ngartji (totem or special friend) of Ngarrindjeri people, who have special responsibility to care for their Ngartji. This relationship is described in the following statement made by Ngarrindjeri Rupelli (traditional leader), George Trevorrow (deceased):

> *Ngartji to non- Aboriginal people is like a totem which each one of us has and each group belongs to. It could be the pelican. It could be the swan. It could be the mullet. There are different species of…animal, fish, plant, but each group belongs to that ngartji. A ngartji is something that is more than a close friend. It's more your best friend. It is something that is more closely to you* (George Trevorrow in Bell, 1998, p205).

To care for Ngartji is to care for country – Ngartjis are also important indicators of the health of the lands and waters. Freshwater wetlands are referred to as 'nurseries' by Ngarrindjeri in recognition of the important role these areas play in providing food and shelter for many types of Ngartjis. Submerged plants in these nursery areas are critical for food and shelter for animals and their young. They are understood to be like the lungs of the system – cleansing the land and water.

4.1.1.2 Ngarrindjeri Ruwe/Ruwar (lands, waters, body spirit and all living things)

Ngarrindjeri use the concept of Ruwe/Ruwar to encapsulate the interconnection between country, body and spirit. Ngarrindjeri Ruwe/Ruwar frames Ngarrindjeri rights and responsibilities as traditional owners and is centred on an understanding that all things are connected. This interconnection is fundamental to wellbeing and it is for this reason that healthy lands and waters are critical to healthy Ngarrindjeri people and culture. The Ngarrindjeri 'Vision for Country' encapsulates the Ngarrindjeri philosophy of being (Ruwe/Ruwar) and is outlined below:

> *Our Lands, Our Waters, Our People, All Living Things are connected. We implore people to respect our Ruwe (Country) as it was created in the Kaldowinyeri (the creation). We long for sparkling, clean waters, healthy land and people and all living things. We long for the Yarluwar-Ruwe (Sea Country) of our ancestors. Our vision is all people Caring, Sharing, Knowing and Respecting the lands, the waters and all living things* (Ngarrindjeri Nation, 2006, p5).

Ngarrindjeri perceive the lands and waters as a living body – the River Murray, Coorong, and Lakes Alexandrina and Albert Wetland are part of the Ngarrindjeri living body. Ngarrindjeri Creation ancestors made, and are a part of this living body. This fundamental spiritual connection (Ruwe/Ruwar) is reliant on healthy lands and waters, and the maintenance of connectivity between the River Murray, Coorong, Lower Lakes and Murray Mouth as created by Ngurunderi and other Creation Ancestors. The health of Ruwe/Ruwar relies on maintaining the foundational and ongoing spiritual connection between Ngurunderi (the Creator and Spiritual Ancestor), Ruwe (Country, Lands and Water) and the Ngarrindjeri Nation (Birckhead, et al., 2011, p38).

'Ecological' based descriptions of connectivity and of Ngarrindjeri Yarluwar Ruwe as ecological attributes, assets or critical components, processes and services are based on understandings of the relationship between humans and non-humans - conceived in Western cultural terms as the divide between 'nature' and 'culture'. For Ngarrindjeri the 'environment' cannot be compartmentalised: the lands and waters are a living body and the Ngarrindjeri are part of the living body. All things are connected and interconnected and are an embodiment of Ruwe/Ruwar (land, body, spirit) which extends 'ecological' connectivity to humans and is therefore inherently cultural.

4.1.1.3 Ngarrindjeri and water

Freshwater flows that come down the Murray-Darling system into the lands and water of the Ngarrindjeri are seen by the Ngarrindjeri as the life blood of the living body of the River Murray, Lower Lakes and Coorong. Ngarrindjeri are part of the water. It is life, gives life and is living. The cultural and spiritual relevance for Ngarrindjeri of water as a source of life and as part of the living body is that it flows within, around and through Ngarrindjeri country. The exercise of Ngarrindjeri cultural rights and the fulfilment of Ngarrindjeri responsibilities include being interconnected with and being part of the living water: the flow of water forms part of the interconnectedness of Ngarrindjeri to their country. The NRA (Ngarrindjeri Regional Authority, 2012, p3) have taken the following position regarding *a priori* rights to water in its submission to the MDBA:

> *Ngarrindjeri consider that they have the first right, a right attached to the exercise of our cultural rights, interests and responsibilities, that precede all other rights including but not limited to the legislative function of the MDBA to allocate water for particular uses. The rights and interests of the Ngarrindjeri require that water flows into, through and from our country from up river.*

Ngarrindjeri Ruwe/Ruwar requires connectivity, flow, and mixing to occur between all living things and the lands and waters, and the spirit world. Flows come together and mix and produce life – fish breed in the lakes and Coorong; birds breed in the places where life is being produced; these things are recognised in Ngarrindjeri philosophy. The failure of water to flow into Ngarrindjeri country impacts upon Ngarrindjeri to exercise rights and the fulfilment of responsibilities as custodians of the land, water and sky.

4.1.1.4 The Meeting of the Waters – Murray Mouth

The 'Meeting of the Waters', which includes the Murray Mouth, is significant as a registered Aboriginal 'site' under the Aboriginal Heritage Act 1988 (SA). It includes the waters and the bed of the lakes, river and estuary. Its spiritual and cultural significance is essential to the wellbeing of lands and waters and all living things, including Ngarrindjeri. The cultural health of this area requires adequate fresh water flows from up river to flush out the Murray Mouth and ensure that the Ngarrindjeri are able to continue to exercise their cultural rights in this area, including the flushing of the Murray Mouth. The following statements by Ngarrindjeri Rupelli (traditional leader), George Trevorrow (deceased) illustrates the importance of the area:

> *That's what we're talking about when we call it the meeting of the waters. Those waters, once they start mixing, that is the spiritual waters of this area, and of the Ngarrindjeri. This is where the major connections happen. This is the breeding place for all the ngatji, and everything that goes with the mixing of the water*

underneath the water, so it's very, very important to us spiritually, because those things, as I said, they are closer than a friend to you. They are nearly almost part of you. They speak to you, you speak to them, and this is the place where they all come to (Trevorrow in Bell, 2014, p563).

Ngarrindjeri have long-term knowledge of the impacts of changing flows in the 'Meeting of the Waters' site. This includes Creation stories that incorporate the importance of the mixing of the salt and fresh waters, and the importance of fresh water to the maintenance of the health of the land and the waters. The 'Meeting of the Waters' site has been recognised as significant to natural resource management and water planning in South Australia and the Murray-Darling Basin (Hemming, 2009; Murray-Darling Basin Authority, 2013b).

4.1.1.5 Ngarrindjeri 'Speaking as Country' - Yannarumi

Ngarrindjeri people have a deep obligation and responsibility towards their traditional country based on the Creation. Ngarrindjeri speaking lawfully as country (Yannarumi), i.e. exercising their right and responsibilities to speak for, care for and manage Ngarrindjeri Yarluwar Ruwe, is therefore critical to the health of lands and waters. Ngarrindjeri Yannarumi can be understood as a form of Ngarrindjeri cultural health practice and assessment process, a life giving assessment of lands and waters.

Ngarrindjeri require an improvement to the health of their lands and waters to support Ngarrindjeri wellbeing. The lands and the waters within the CLLMM region have been degraded and further losses of species, water quality, flows and breeding events will have an increased detrimental effect on Ngarrindjeri wellbeing. The NRA takes responsibility for assessing whether something is healthy, lawful and creates wellbeing – based on the concept of Ngarrindjeri Ruwe/Ruwar.

4.1.2 Ngarrindjeri involvement in environmental water planning

Ngarrindjeri have developed an engagement framework that provides well-developed structures and practices to support equitable and effective Ngarrindjeri engagement in water resource research, policy development and management processes within the SA MDB region (Hemming, et al., 2014). Foundational to this new form of engagement is the development of the contract law, Kungun Ngarrindjeri Yunnan Agreement (KNYA), which translates to 'listening to Ngarrindjeri people talking'.

In 2009 a whole-of-government KNYA was entered into between the Ngarrindjeri and the South Australian Government which established a consultation and negotiation framework between parties in relation to natural resource management (NRM) and cultural heritage management (CHM) (see Hemming, et al., 2011). The KNYA established and funded a joint taskforce that creates a formal context for the NRA to negotiate regarding South Australian Government programmes on Ngarrindjeri Ruwe/Ruwar. The KNYA includes recognition of Ngarrindjeri traditional ownership; and recognition of the Ngarrindjeri Regional Authority (established in 2007) as the Ngarrindjeri peak body. This is guided by the KNYA taskforce strategic implementation plan, co-written with DEWNR which outlines a number of objectives for KNYA taskforce to provide guidance on how it can support and implement positive outcomes (Department of Environment Water and Natural Resources, and Ngarrindjeri Regional Authority, 2012a; Department of Environment Water and Natural Resources, and Ngarrindjeri Regional Authority, 2012b).

Underpinning the KNYA strategy is the foundational Ngarrindjeri management planning document - the Ngarrindjeri Nation Yarluwar-Ruwe Plan: Caring for Ngarrindjeri Sea Country and People (Ngarrindjeri Nation, 2006). The plan articulates a broad vision and a set of strategic directions for caring for Ngarrindjeri country. The Ngarrindjeri Yarluwar Ruwe (NYR) Program (established in 2007) has been further developing and implementing the visions of the plan (Hemming, et al., 2007). The NYR Program works with state and local Government, NRM boards and local communities for natural resource management that recognises Ngarrindjeri values and incorporates Ngarrindjeri expertise and capacity. This governance model combined with the KNYA strategy have

been central to Ngarrindjeri engagement in the South Australian and Australian Governments' Murray Futures Program (RRP and CLLMM Recovery Project) and the development of the Ngarrindjeri Partnerships Project (NPP) with the SA Government. These programmes focus on strengthening Ngarrindjeri capacity, skills and experiences into regional NRM and CHM, including water-related research, policy development, planning and management.

This strategy has established a programme of Statement of Commitments (formal terms of reference) and associated working groups that frame and direct Ngarrindjeri/Government projects and programmes and protect Ngarrindjeri cultural knowledge. This creates a framework for more equitable Ngarrindjeri engagement in water planning such as: inputs into annual environmental water planning for the LLCMM, Channel and Floodplain Assets (through The Living Murray Program) ; wetland planning and monitoring (through Natural Resources SA MDB and the Riverine Recovery Project); federal environmental water plans; water quality planning; and engagement in the review of the Coorong, Lakes Alexandrina and Albert Ramsar wetland Ecological Character Description (see Collings, 2012; Department of Environment, Water and Natural Resources, 2013a; Hemming, et al., 2014; Murray-Darling Basin Authority, 2013b).

Ngarrindjeri engagement in State water policy and planning has been strengthened through the signing of a SA MDB water planning statement of commitment (SOC) between NRA, DEWNR, the SA MDB NRM Board and the South-East NRM Board. The SOC recognises and supports Ngarrindjeri interests in water and provides a framework for how the parties will work together in water resource planning, particularly to meet the Indigenous Values and Uses requirements of Chapter 10 Part 14 of the Basin Plan. The SOC and outcomes from its implementation will be used to inform the development process and content of future versions of the SA River Murray LTWP. A second important agreement has been the entering of Ngarrindjeri and the State of South Australia into a formal 'Speaking as Country Deed' 2014.The deed affirms the importance of freshwater flows down the River Murray and an open Murray Mouth, and for the parties to work together to ensure end of system flow objectives support the maintenance of the cultural health of the registered 'Meeting of the Waters' heritage site. The deed acknowledges that Ngarrindjeri speak for, control and care for their country and embodies the concept of Ngarrindjeri Yannarumi. State Government environmental water planning uses a series of decision making tools. It is important that Indigenous interests, knowledge and perspectives are recognised in these tools.

4.1.3 First Peoples of the River Murray and Mallee Region cultural values

Note: This is an interim representation of information relating to FPRMM cultural values and aspirations based on existing documents. This information will be improved in future versions of the LTWP through further engagement of the FPRMM.

The First Peoples of the River Murray and Mallee Region (FPRMM) are the traditional owners of the section of River Murray between the border and Morgan and have interests that extend further down the River. They have maintained a long association with the River Murray and see it as a living body (Murray-Darling Basin Authority, 2012). The river environment provided resources such as water, fish, yabbies and plant material, including the use of bark from River red gums as canoes, while the surrounding floodplain was a place to harvest animals such as possums and kangaroos for food, providing the basis for a rich cultural economy (Murray-Darling Basin Authority, 2012).

The FPRMM are the native title holders of about 260 km^2 of land and waters in the Riverland, South Australia, including areas of the River Murray around Renmark, Berri, Barmera, Waikerie and Morgan (Native Title Research Unit AIATSIS). The South Australian Government and the FPRMM have entered into The River Murray and Crown Lands Indigenous Land Use Agreements (ILUA), which commenced on the same day the Native Title determination was made in favour of the FPRMM. This native title consent determination recognises their non-exclusive rights to access, hunt, fish, camp, gather and use the

natural resources, undertake cultural activities, conduct ceremonies and meetings, and protect places of cultural and religious significance (Native Title Research Unit AIATSIS).

The River Murray and Mallee Aboriginal Corporation (RMMAC) is the Registered Native Title Prescribed Body Corporate for the native title consent determination and administers land on behalf of the FPRMM (Native Title Research Unit AIATSIS). RMMAC have prepared a strategic plan, which sets out objectives and strategies for working with government agencies and other stakeholders to achieve those objectives (River Murray and Mallee Aboriginal Corporation, 2013). This strategic plan provides the following vision '*The People, River and Mallee are at the centre of everything we do. Our driving force is the spirit of our Ancestors. Our vision is to ensure our people achieve economic independence through education and employment while preserving our environment, heritage and cultural and spiritual wellbeing for now and into the future*' (River Murray and Mallee Aboriginal Corporation, 2013). A number of values, aims and priorities are identified within the strategic plan, with a key value being ecological sustainability and a key aim to '*Protect and repair our country, waters, flora, fauna and air*' (River Murray and Mallee Aboriginal Corporation, 2013).

4.1.4 First Peoples of the River Murray and Mallee Region involvement in environmental water planning

The FPRMM have been involved in the planning and management of Chowilla Floodplain for many years (including prior to the construction of the environmental regulator), primarily through the Chowilla TLM Icon Site Program. Further collaboration between the FPRMM, the Wetlands and Floodplains team and the NRM Communities team of Natural Resources SA MDB, and the Aboriginal Partnerships team, has seen the inclusion of FPRMMs perspectives into the management of other wetland and floodplain areas. This engagement has been formalised into the First Peoples NRM Working Group, which meets bimonthly to coordinate First Peoples engagement in DEWNR projects. The First Peoples Coordinator has been employed by DEWNR to coordinate the Working Group and support the engagement of the FPRMM in a range of natural resources management projects, including input into wetland and floodplain management plans (Natural Resources SA Murray-Darling Basin, 2015a). Members of the First Peoples NRM Working Group have indicated support for the environmental water and wetland management programmes, and their objectives, for their role in protecting and maintaining Indigenous cultural and heritage values (Natural Resources SA Murray-Darling Basin, 2015b).

This LTWP does not currently provide Indigenous cultural information that has been endorsed for inclusion by the FPRMM and RMMAC. Preliminary consultation with the FPRMM and RMMAC commenced during the development of this plan, and will continue through the development of the water resource plan for the SA River Murray, which is required under the Basin Plan to identify Indigenous objectives and outcomes (s10.52). This LTWP is therefore seen as interim measure in terms of FPRMM input and will be improved in future versions of the plan.

4.1.5 Integrating Indigenous values

The Government of South Australia recognises the importance of Indigenous culture and values, and is committed to seeking and incorporating these in the development of environmental water plans where possible.

There is a strong alignment between ecological objectives and targets identified in this LTWP and Indigenous values. For Ngarrindjeri, a range of objectives and targets outlined in this plan for restoring the freshwater flows required to sustain healthy functioning 'ecosystems' are also crucial in maintaining interconnectivity of Ruwe/Ruwar which is central to Ngarrindjeri cultural life in the River, Coorong, Lower lakes and Murray Mouth. Further consideration of Indigenous values will continue to occur at smaller spatial and temporal scales e.g. during annual environmental water planning for the region.

The consideration of the values, aspirations and views of Indigenous Nation Groups in decision-making through their participation in the development of water resource and environmental water plans is prescribed under the Basin Plan (2012). The Environmental Watering Plan of the Basin Plan requires that environmental watering is undertaken in a way that maximises its benefits and effectiveness by having regard to Indigenous values (s8.35), with these values being integrated through engagement with relevant Indigenous organisations when identifying the objectives of Indigenous people during water resource planning (s10.52). Ngarrindjeri consider the engagement process with the SA Government provides well-developed structures and practices to support equitable and effective Ngarrindjeri engagement and participation in the implementation of the Murray-Darling Basin Plan and is the preferred approach to engagement with Ngarrindjeri. In particular implementing the SOC will support Basin Plan compliance in Indigenous engagement, as well as progress a number of Ngarrindjeri water related interests.

The SA River Murray Water Resource Plan has not yet been completed, however its adoption will trigger the revision and update of this LTWP (s8.22), at which time any additional, relevant information relating to Indigenous values can be incorporated.

4.2 Possible co-operative arrangements

4.2.1 Cooperative arrangements within the SA River Murray Water Resource Plan Area

Environmental water management within the SA River Murray WRP Area continues to evolve. There is a growing number of environmental managers responsible for managing environmental sites, including multiple areas within the LTWP priority assets, and a variety of mechanisms for delivering environmental water. Asset and site (intra-asset) managers and the areas that they are responsible for managing are described in Section 2.4.6.

This section describes existing cooperative arrangements, which are needed to ensure all environmental asset and site managers, environmental water holders and environmental water managers are working towards the common goal for the SA River Murray WRP Area of a healthy, functioning and resilient ecosystem. These arrangements ensure that decisions are transparent, priorities and trade-offs are understood, and outcomes at the site-scale contribute to desired outcomes at the LTWP asset and WRP Area scale. With a finite volume of environmental water available, it is not always possible to deliver all desired actions; however the benefits of environmental water management can be maximised if a single allocation of environmental water is used efficiently and effectively to achieve multiple outcomes at multiple sites.

For the purposes of the SA River Murray LTWP, cooperative arrangements refer to the policies, processes and forums that should be observed by all relevant parties (DEWNR staff and external to DEWNR) involved in managing environmental water and sites within the WRP Area. These mechanisms may be formal or informal, and participation may be direct or in-direct. For instance, there are many community groups undertaking environmental site management and their involvement in the forums is likely to be via staff from the Natural Resources SA MDB. Interactions between Government and Ngarrindjeri take place through the KNYA taskforce, leader to leader meetings and the NYR Program. FPRMM interactions with Government are occurring through the River Murray and Crown Lands ILUA Liaison Committee and First Peoples NRM Working Group.

There are additional site-specific planning and management mechanisms (e.g. site-specific advisory groups). These are still relevant and are not replaced by the arrangements described within this document. However, their decisions and activities with respect to environmental water management should be consistent with state policies and plans, and fed through to the policy and operational areas of DEWNR to ensure there is strategic oversight of environmental water management across the WRP Area.

Generally, planned environmental water (PEW) is not actively managed and therefore these cooperative arrangements are not directly relevant, unless South Australia is receiving less than Entitlement or water allocations are less than 100%. Under these circumstances, PEW managers and managers of sites that rely on PEW, will need to participate in any additional cooperative arrangements that apply to the WRP Area and across the Southern Connected Basin under dry conditions, e.g. Dry Allocation Framework in the Water Allocation Plan for the River Murray Prescribed Watercourse or arrangements agreed through Southern Connected Basin Environmental Watering Committee (SCBEWC).

There are five key phases in the management of environmental water, each of which can be undertaken at multiple spatial scales (WRP Area, LTWP asset or intra-asset 'site'):

1. Planning and prioritisation
2. Negotiation and allocation
3. Delivery
4. Monitoring
5. Evaluation and reporting

Table 14 below indicates the existing cooperative arrangements for each phase of environmental water management. The cooperative arrangements listed are those that apply to the management of environmental water within the SA River Murray WRP Area only and apply across all assets and sites. The table does not include the arrangements that operate at a smaller scale i.e. planning, management and monitoring mechanisms that are relevant to a single asset or site (e.g. the Barrage Operations Advisory Group or TLM Icon Site monitoring); nor those that operate at a broader scale (e.g. activities overseen by the SCBEWC). The 'cooperative mechanism' column provides the title of the arrangement currently in place; further detail is generally documented through internal DEWNR policies, procedures and Terms of Reference and is available from the administrator. The 'administrator' column indicates the party responsible for overseeing the policy, procedure or forum; it does not list all groups or individuals that should participate in implementation as all parties involved in environmental water management within the SA River Murray WRP Area are expected to participate.

Central to many of the cooperative arrangements are processes for environmental site and water managers to have regard to the flow management targets for a number of key water quality factors (including dissolved oxygen, cyanobacteria or biovolume and salinity) as outlined in Chapter 9 of the Basin Plan. In particular, the asset and water managers should consider potential water quality impacts during annual and real-time planning (including potential cumulative impacts from multi-site actions), manage any risks that may emerge once water is being delivered in real time, and report annually on how they have had regard for flow management targets as part of their obligations under Schedule 12, Matter 14.

The cooperative arrangements currently in place are expected to be expanded over time to improve coordination, minimise risk and optimise the outcomes of environmental watering in the SA River Murray WRP Area.

Table 14. Cooperative arrangements for environmental water management within the SA River Murray WRP Area

Environmental water management phase	Co-operative mechanism	Description	Administrator
Planning and prioritisation			
State annual planning for the WRP Area	Standard Operating Procedure: Develop Annual Watering Plan	Describes process for developing an annual environmental watering plan for the WRP Area for the upcoming water year	DEWNR Policy[34]
	Watering Proposal Template	To be completed by each asset/site manager (including a risk assessment) - key input to annual plan and prioritisation. The template used for the SA River Murray WRP Area is generally based on the template developed by TLM/EWG (now SCBEWC), with minor changes to improve relevance to the region.	DEWNR Operations[35] (TLM sites); DEWNR Policy
State annual prioritisation for the WRP Area	Annual Prioritisation	Agreed prioritisation process and criteria implemented through participatory meeting. The prioritisation process used for the SA River Murray WRP Area is generally based on the process implemented by TLM/EWG (now SCBEWC), with minor changes to improve relevancy to the region. The process is documented in the Annual Environmental Watering Plan for the South Australian River Murray, which is published on the DEWNR website each year.	DEWNR Policy

[34] DEWNR Policy refers to the Environmental Water Trade and River Operations Policy Team within the Water and Climate Change Branch of DEWNR
[35] DEWNR Operations refers to both Water Resource Operations and Environmental Water Operations team within the River Murray Operations and Major Projects Branch of DEWNR

Environmental water management phase	Co-operative mechanism	Description	Administrator
Multi-site planning for the WRP Area	Process yet to be formalised	Undertaken as a component of annual planning to develop a potential delivery pattern for outcomes at multiple assets/sites	DEWNR Operations; DEWNR Policy
Negotiation and allocation			
Negotiate for water allocation	Process yet to be formalised however negotiations should be consistent with the Annual Environmental Watering Plan for the WRP Area	Negotiations are undertaken directly between asset/site managers, river operators and environmental water holders	n/a
Notify allocation approval	Process yet to be formalised	Water holders inform the relevant asset/site managers via letter/email. The CEWO may require a watering 'schedule' to be negotiated and signed, which specifies the agreed watering action and accounting methodologies Managers should then forward a copy of this advice to DEWNR Operations and DEWNR Policy so that there is oversight of all allocations to the WRP Area	DEWNR Operations; DEWNR Policy
Trade environmental water	Standard Operating Procedure: Trade Environmental Water	Environmental water held interstate is generally traded onto a South Australian licence held by the Minister for the River Murray. Some external site managers have their own licence for environmental watering so will not trade onto the Minister's licence	DEWNR Finance[36]

[36] Under Chinese wall arrangements as per Basin Plan s12.52

Environmental water management phase	Co-operative mechanism	Description	Administrator
Report trade activity	Process yet to be formalised	Advice is provided by DEWNR Licensing upon receipt of trades to DEWNR Policy and DEWNR Operations so that there is oversight of all environmental water trade activity within the WRP Area	DEWNR Policy; DEWNR Operations
Delivery			
Real-time planning (including for the use of unregulated flows)	E-flows Reference Group	DEWNR asset/site managers participate in regular meetings when planning the delivery of environmental water to the WRP Area. Each asset/site manager will have their own arrangements in place for operational planning at a site scale but this information should be fed through to the E-flows Reference Group and River Murray Operations Working Group (RMOWG).	DEWNR Operations
	Policy on the use of River Murray Unregulated Flows within the SA River Murray WRP Area	A policy and standard operating procedure is currently under development to guide decision-making on the use of unregulated flows at specific sites	DEWNR Policy
Assessment of potential water quality impacts	Guidelines for Having Regard to Targets for Managing Water Flows	Potential cumulative impacts in the context of current conditions are assessed through the RMOWG as per the Guidelines	DEWNR Operations
Approve extraction/use from River	River Murray Action Request Form	To be completed by asset/site managers and submitted to the DEWNR Operations, where an assessment will be undertaken and referred to the RMOWG as necessary	DEWNR Operations
Deliver water to SA border	Water order to MDBA and liaison with SA Water	Requires knowledge of all environmental water allocations and trades, and ensures water is available for environmental watering actions at the appropriate time	DEWNR Operations

Environmental water management phase	Co-operative mechanism	Description	Administrator
Deliver water to asset/site	Standard Operating Procedure: Deliver Environmental Water	The mechanism for delivering water varies widely and each asset/site manager will have their own arrangements in place for water delivery. Water delivery must be undertaken consistent with the approved action.	Asset/site manager
Report watering activity	Standard Operating Procedure: Record Environmental Use Spreadsheet template for environmental water accounting	Asset/site managers should provide regular written updates to DEWNR Operations and DEWNR Policy to ensure there is oversight of all watering activities underway	DEWNR Operations; DEWNR Policy
Monitoring and evaluation			
Measure site-specific water use	The mechanism for measuring the volume of water used will depend on the type of watering action as follows: • Pumping/drip irrigation - metered[37] • Gravity fed wetland basins - modelled • Large scale actions - modelled using DEWNR-approved models, and measurements to calculate discharge over structures and area inundated	Asset/site managers are responsible for ensuring that water use complies with the allocated/approved volume.	Asset/site manager

[37] Refer South Australian Licensed Water Use Metering Policy

Environmental water management phase	Co-operative mechanism	Description	Administrator
Report water use	Standard Operating Procedure: Record Environmental Water Use	Describes process for site managers to report volumes of water use. This data is needed to enable the State to meet legislated reporting requirements under the Basin Plan (Matter 9 - Identification of environmental water and the monitoring of its use)	DEWNR Policy
	Spreadsheet template for environmental water accounting	Standard template to be used by asset and site managers to report volumes	DEWNR Policy; DEWNR Operations
	Standard Operating Procedure: Produce Annual Report on Environmental Watering	Each year a report is published summarising environmental water use and key ecological outcomes	DEWNR Policy
Reconcile environmental water licenses (water volumes and cost)	Standard Operating Procedure: Reconcile Environmental Water Accounts	For licenses held by the Minister, reconciliation is completed by DEWNR Policy. If an externally-held licence is used for environmental watering then the environmental water manager is responsible for providing a reconciliation to DEWNR Licensing.	DEWNR Policy; external site managers; DEWNR Licensing[38]
Monitor ecological outcomes	A detailed monitoring and evaluation plan will be developed for the SA River Murray LTWP to enable the State to meet legislated reporting requirements under the Basin Plan (Matter 8 - the achievement of outcomes at an asset scale), including through the collation of information relating to site-specific outcomes, which is recorded through various existing programmes (e.g. TLM icon site monitoring, CLLMM Ramsar, wetland monitoring through Natural Resources SA MDB and RRP, and monitoring associated with weir manipulations) . The SA River Murray LTWP monitoring and evaluation plan will not replace site-specific monitoring and evaluation plans, which are vital for the continued adaptive management of these sites.		
Evaluate and report ecological outcomes			

[38] DEWNR Licensing refers to Water Licensing, Customer and Commercial Services Branch of DEWNR

4.2.2 Cooperative arrangements with upstream water resource plan areas

The SA River Murray WRP Area is strongly influenced by environmental watering activities that take place in upstream water resource plan areas, particularly the Victorian Murray WRP Area, the Northern Victoria WRP Area, the New South Wales Murray and Lower Darling WRP Area, and the Murrumbidgee WRP Area. Collectively these four interstate water resource plan areas, together with the SA River Murray WRP Area, represent the Southern Connected Basin of the Murray-Darling Basin. There are mechanisms in place to maintain and improve cooperative arrangements for the planning and delivery of environmental water in the Southern Connected Basin.

There are a number of cross-jurisdictional committees to facilitate the management of environmental water and South Australian representatives participate on these committees. Some of the key committees include:

- the Southern Connected Basin Environmental Watering Committee (SCBEWC), which coordinates the planning and delivery of environmental water to maximise ecological outcomes each year through cooperative watering regimes. SCBEWC also considers management of potential water quality risks associated with multi-site watering such as black water events and cumulative salinity impacts. Membership includes holders of environmental water as well as managers of held and planned water, managers of environmental assets, planners and operators responsible for environmental water delivery
- the Environmental Water Working Group (EWWG), which coordinates the development of policy and plans
- the Water Liaison Working Group (WLWG), which assesses the deliverability of environmental water, implications for the Barmah Choke and overall River Murray system operations and coordination.

There are also groups for the coordination, development and real time management of large scale multi-site environmental watering events (e.g. Operational Advisory Group); implementation of the Constraints Management Strategy (CMS) and the oversight of Basin-wide monitoring. In addition to these cross-jurisdictional arrangements, representatives from South Australia participate in regular bi-lateral teleconferences with the Commonwealth Environmental Water Office.

Further documentation of these cooperative arrangements will be progressed through the development of an integrated plan for environmental watering in the Southern Connected Basin.

4.2.3 Cooperative arrangements between water resource plan areas within SA

There are two other water resource plan areas in South Australia – the Eastern Mount Lofty Ranges (EMLR) WRP Area and the SA Murray Region WRP Area. There are some cooperative environmental watering arrangements with both of these areas.

4.2.3.1 Eastern Mount Lofty Ranges Water Resource Plan Area

The EMLR WRP Area has two prescribed water resource areas within its boundary: EMLR and Marne Saunders.

1. Eastern Mount Lofty Ranges

The Water Allocation Plan (WAP) development process for the EMLR assessed whether taking or using water from the prescribed resource of the EMLR has an impact on adjacent water resource areas. It was concluded that the EMLR contributes small volumes to the lower River Murray and Lake Alexandrina and ultimately to Lake Albert, the Murray Mouth and the Coorong. The consumptive use limits for the EMLR (Section 3.4 of the EMLR WAP) have been set to provide water to the local environment, including the terminal wetlands where the EMLR streams meet the River Murray and Lake Alexandrina (Natural Resources SA Murray-Darling Basin, 2013). The monitoring and reporting arrangements for WAP policies are still being developed.

The EMLR WAP notes that conditions in the River Murray and Lake Alexandrina can also directly affect the environmental condition of the lower reaches of the EMLR streams as occurred during the millennium drought. Currently there are no formal rules in the Water Allocation Plan for the River Murray Prescribed Watercourse to minimise this impact (South Australian Murray-Darling Basin Natural Resources Management Board, 2002), however the revised draft of the River Murray WAP incorporates principles that prevent increased extractions from the tributaries of Lake Alexandrina, (Natural Resources SA Murray-Darling Basin, 2014).

There are two additional mechanisms that will assist with minimising the impacts of low water levels in Lake Alexandrina on the lower reaches of the EMLR streams. The first is the inclusion of a particular objective in the Basin Plan (s8.06) to maintain water levels in the Lower Lakes above 0.4 m AHD for 95% of the time and above 0.0 m AHD all of the time. The second is a documented decision making processes for the management of the Lower Lakes during extreme drought (Murray-Darling Basin Authority, 2014c).

2. Marne Saunders

Reductions in spring flow from the Marne River have reduced discharge to the Marne Mouth Wetland located at the junction of the Marne River with the River Murray. The WAP for the Marne Saunders PWRA includes policies to protect the spring flow for the Marne Mouth Wetland.

4.2.3.2 SA Murray Region Water Resource Plan Area

The DEWNR South East Flows Restoration Project has been established to manage water release from Morella Basin via Salt Creek, improve outcomes for South East wetlands and increase flows to the Coorong when required for salinity management. The management of Morella Basin and Salt Creek releases are currently driven by the needs and potential outcomes at Morella Basin, and the need to pass water to avoid flooding of neighbouring properties. However, the pattern of releases can be altered in consideration of potential outcomes and impacts within the South Lagoon of the Coorong, including salinity, nutrients and biotic responses (particularly *Ruppia tuberosa*). The potential to alter release patterns will be enhanced through the future implementation of the South East Flows Restoration Project (provided the design scenario incorporates additional storage).

Decisions on the release volume, flow rate and timing of releases are made each year by the South Eastern Water Conservation and Drainage Board (SEWCDB) following advice from DEWNR and SEWCDB staff. The SEWCDB consists of an eight member statutory body established under the *South Eastern Water Conservation and Drainage Act 1992*. The SEWCDB staff use a digital elevation model and seasonal weather conditions to provide advice to the Board. DEWNR staff seek advice from the Lower Lakes, Coorong and Murray Mouth Scientific Advisory Group on the potential risks and benefits to the Coorong of the proposed release patterns.

4.3 Operational constraints

Constraints have a significant impact on the feasibility of delivering environmental water to and within the SA River Murray WRP Area. It is important for environmental asset and site managers in this area to have a good understanding of these constraints so that they can be factored into their annual and real-time planning for environmental water delivery. There are several types of constraints that may affect the volume of environmental water that can be delivered.

4.3.1 Definitions

The Basin Plan defines a ***physical constraint*** as a natural formation or a physical structure (for example, a pipe or channel) that limits the volume of water that can pass a given location. It does not provide a definition for ***operational constraint.***

The *Preliminary Overview of Constraints to Environmental Water Delivery in the Murray–Darling Basin* (Murray-Darling Basin Authority, 2013c) provides a broad definition for flow constraints and further defines three types of constraints, as follows:

Flow constraints limit how water can be actively delivered through the river system to deliver EWRs, and include:

- ***physical constraints***, such as the rate at which water can be released from a storage (release capacities) or the level to which water can rise before passing over the river bank onto adjacent land (channel capacities)
- ***operational constraints***, relating to the effective management of water resources through a range of operating protocols (for instance, the requirement to maximise reliability of supply for consumptive use, or to protect infrastructure and private property from inundation)
- ***management or policy constraints***, such as the lack of protection for environmental flows as they travel downstream.

The Basin Plan (s8.19 (6)) requires that a long-term watering plan identify ***operational constraints,*** but it is difficult to clearly distinguish one type of constraint from another. For example, due to the risk of exceeding a flow threshold at which point water inundates private land (a physical constraint), river operating rules may set maximum flow rates for a given location in-line with the physical constraint (an operational constraint). A policy may then be established to ensure environmental water delivery causes no or minimal third party impacts (a policy constraint).

Rather than differentiating between the specific categories of constraints, this plan will refer to the key ***flow constraints*** that influence the ability to manage and deliver environmental water to and within the SA River Murray WRP Area, where the flow constraint may be a physical, operational or policy constraint.

4.3.2 Existing work on flow constraints

The MDBA and Basin States are undertaking considerable work on constraints through the SDL adjustment mechanism and implementation of the Constraints Management Strategy: 2013-2024 (CMS), which was published by the MDBA in November 2013 (Murray-Darling Basin Authority, 2013a). A summary of this work is provided below.

4.3.2.1 Constraints Management Strategy key focus areas

The CMS identifies seven key focus areas where physical constraints are to be further investigated:

1. Gwydir (Northern Basin)
2. Hume Dam to Yarrawonga Weir
3. Yarrawonga Weir to Wakool Junction
4. Murrumbidgee River
5. Goulburn River
6. Lower Darling
7. River Murray in South Australia

Six of these key focus areas are located upstream of South Australia and, of these, five represent key physical constraints that restrict the capacity to manage the delivery of environmental water to South Australia under high flow conditions. In each key focus area, work has been undertaken regarding relaxation of constraints which has involved investigation and modelling of the extent that flow rates can be periodically increased or supplemented to deliver environmental water through the Basin, while simultaneously addressing and minimising impacts to third parties.

Basin States will agree to a final package of constraint measures for some or all of the key focus areas by June 2016 as part of the Basin Plan SDL adjustment mechanism. The agreed package of works will be implemented between 2016 and 2024, which is beyond the timeframe of this first LTWP. There are other constraints that impact on the delivery of water to South Australia under low flow conditions however these are not currently being considered through the CMS. These low flow constraints are described later in this section.

4.3.2.2 River Murray in South Australia key focus area

Constraint measures to be investigated in the SA River Murray key focus area relate to the ability to manage flows up to 80,000 ML/day QSA. Overbank flows and floodplain inundation are natural occurrences that were experienced at a much greater frequency in the past. They are essential for supporting floodplain and in-channel health, and providing water to the Lower Lakes, Murray Mouth and Coorong. It is anticipated that, at times, augmented water delivery such as the addition of environmental water or operational changes may contribute to delivering high flow events. As part of investigating the practical delivery of augmented high flows, the CMS work includes consideration of potential impacts to, and future planning for, private property owners (e.g. shacks), councils and infrastructure operators (e.g. operators of boat ramps or unsealed roads along the floodplain).

The upper threshold of 80,000 ML/day QSA is based on MDBA modelling that indicates this is the maximum flow at which active management of environmental water can be undertaken either through releases of held environmental water from storages or changes in dam storage operations. However, realising this threshold is dependent on the implementation of constraint measures in the upstream key focus areas (see above).

4.3.2.3 Constraints Management Strategy operational and management constraints

The CMS identifies nine broad operational and management constraints (expressed as outcomes) that require redress by Basin States (primarily) and the MDBA (to the extent that it is responsible for river operations). Of the nine constraints, the following four have been identified as priorities (Murray-Darling Basin Authority, 2014b):

- protection of environmental flows from extraction and re-regulation
- delivery of water on top of other in-stream flows
- environmental water to be used throughout the length of a river
- channel capacity sharing.

The first three of these priority operational and management constraints coincide with the pre-requisite policy measures (PPMs) (s7.15 of the Basin Plan) to be addressed by Basin States in carrying out the Basin Plan SDL adjustment mechanism. Basin States will develop PPM Implementation Plans by June 2016 detailing how they will implement the PPMs in each valley within their jurisdictions by June 2019 (the time when the Basin Plan SDL is enacted). The MDBA is leading the development of the PPM Implementation Plan for the River Murray on behalf of the States. The MDBA will also work with Basin States to undertake further scoping and analysis of the other operational and management constraints identified in the CMS (Murray-Darling Basin Authority, 2014b).

A summary is provided in Table 15 of the constraints that are currently being addressed through the CMS and PPMs, and are considered to be having the greatest impact on environmental water management in the SA River Murray WRP Area. Addressing these constraints is critical to achieving many environmental outcomes along the Lower River Murray, particularly the Floodplain and CLLMM where significant volumes are required to achieve inundation and flow requirements.

Table 15. Key flow constraints for the SA River Murray WRP Area being addressed through the CMS and PPMs

Constraint	Implication for environmental watering in the SA River Murray WRP Area	Constraint management
Public and private infrastructure, and access routes affected during higher flows	Potential reluctance to allocate or deliver environmental water that may contribute to a total flow to South Australia in excess of 60,000 ML/day QSA without addressing known impacts to infrastructure and private property, including, but not limited to, dwellings, shacks and council infrastructure located close the river's edge.	Current focus of CMS business case in South Australia (see above).
Protection of environmental flows from extraction and re-regulation; Environmental water to be used throughout the length of a river	The protection of environmental flows from extraction and re-regulation once they pass the point of extraction relies on trading mechanism and goodwill of environmental water holders and river operators. This limits the capacity for South Australia to receive adequate volumes of environmental water used at upstream locations.	Current focus of PPM Implementation Plans under development (see above).
Delivery of water on top of other in-stream flows	River operating and accounting rules are not conducive for environmental water holders to release water on top of unregulated flows. This prevents the ability to increase flow peaks and their duration through the use of environmental water.	Current focus of PPM Implementation Plans under development (see above).
Physical constraints in upstream locations	Low managed delivery flow thresholds in many upstream locations limit the timing and volume of environmental water that can be released from storages for delivery at the South Australian border. This limits the ability to boost flow peaks.	Current focus of CMS business cases for upstream locations (see above).

4.3.3 Other constraints and management strategies

In addition to the constraints that are being addressed through the CMS or the SDL adjustment mechanism, there are many challenges to environmental water delivery in the SA River Murray WRP Area. Some of these are not constraints *per se* but challenge the ability to achieve a certain flow delivery pattern or water level at specific times of the year. For instance, flow to South Australia consists of water sourced from storages in multiple valleys (e.g. Murray River, Goulburn River, Darling River, Murrumbidgee River) and the coordination of water provisions from these multiple sources to achieve a particular flow event at the South Australian border can be logistically difficult. The associated large distances and long travel times for water delivery, also make it difficult to respond to rapid changes in flow conditions. This is compounded by uncertainty around travel times for water releases, as well as natural flow peaks, due to differences between events as a result of the influence of antecedent conditions. Knowledge and experience in the coordination of environmental watering actions across multiple catchments is growing and mechanisms such as the establishment of the SCBEWC will assist in managing water in consideration of these challenges.

The flow constraints and the current understanding of the implications for environmental watering in the SA River Murray WRP Area are provided in Table 16. This list is not limited to constraints that occur within the SA River Murray WRP Area, but also includes those that occur upstream of the WRP Area and have a major impact on environmental water delivery to the South Australian border. For each flow constraint identified, Table 16 indicates how the constraint is currently being, or in the future may be, managed. The constraints and management strategies may change in the future as managers and River operators gain greater experience in managing environmental water.

One of the major flow constraints that can significantly impact on the delivery of environmental water to South Australia at critical times (particularly summer and autumn) is the Barmah Choke channel capacity constraint. The Barmah Choke has the lowest capacity of any stretch of the River Murray (Murray-Darling Basin Authority, 2013a), and once channel capacity is exceeded overbank flows into the Barmah-Millewa Forest occur. At certain times of the year it is not desirable to flood the Forest as it may result in negative environmental outcomes and high water losses; therefore flows downstream of Yarrawonga Weir are kept below about 10,600 ML/day (Murray-Darling Basin Authority, 2013a). This timing coincides with high irrigation demands, which occupy most of the available channel capacity, and therefore limits the volume of environmental water that can be passed downstream of Hume Dam.

Historically it has not been desirable to inundate the Forest from mid-December through to the end of April (Murray-Darling Basin Authority, 2013a). Travel time from Yarrawonga to the CLLMM is approximately five to six weeks, therefore this constraint may impact on environmental water delivery to the CLLMM from January to May. Environmental water delivery to the CLLMM is critical in summer and autumn in order to prevent the likelihood of low water levels in the Lower Lakes, maintain barrage outflows for Murray Mouth maintenance and prevent Coorong South Lagoon salinity thresholds from being exceeded.

Despite being within one of the key focus areas of the CMS, there are no plans to modify or enlarge the Choke as it is believed that this would have severe negative impacts on the Barmah-Millewa Forest and so would be inconsistent with the CMS principles of improving environmental outcomes (Murray-Darling Basin Authority, 2013a) . However, the potential negative impacts to the CLLMM due to the inability to deliver environmental water from Hume in summer and autumn should also be considered. The Barmah Choke channel capacity constraint poses a significant long-term risk to the delivery of the EWRs for the CLLMM PEA, and further investigations into options for overcoming this constraint are required.

The constraints currently having the greatest impact on environmental water management in the SA River Murray WRP Area are being addressed through the CMS or the SDL adjustment mechanism PPMs (apart from the Barmah Choke channel capacity constraint - see above). The proposed timeframes for CMS and PPM implementation are shown in Figure 11. The indicative timeframe for this LTWP is November-2015 to November-2020 by which time PPM implementation is to be complete. Work through the CMS is also expected to progress significantly over these years, although full implementation of the CMS will be over a longer timeframe. The revision and update of the SA River Murray LTWP in November 2020 will therefore enable an assessment of the need for further work in this area based on the extent to which flow constraints have been successfully addressed.

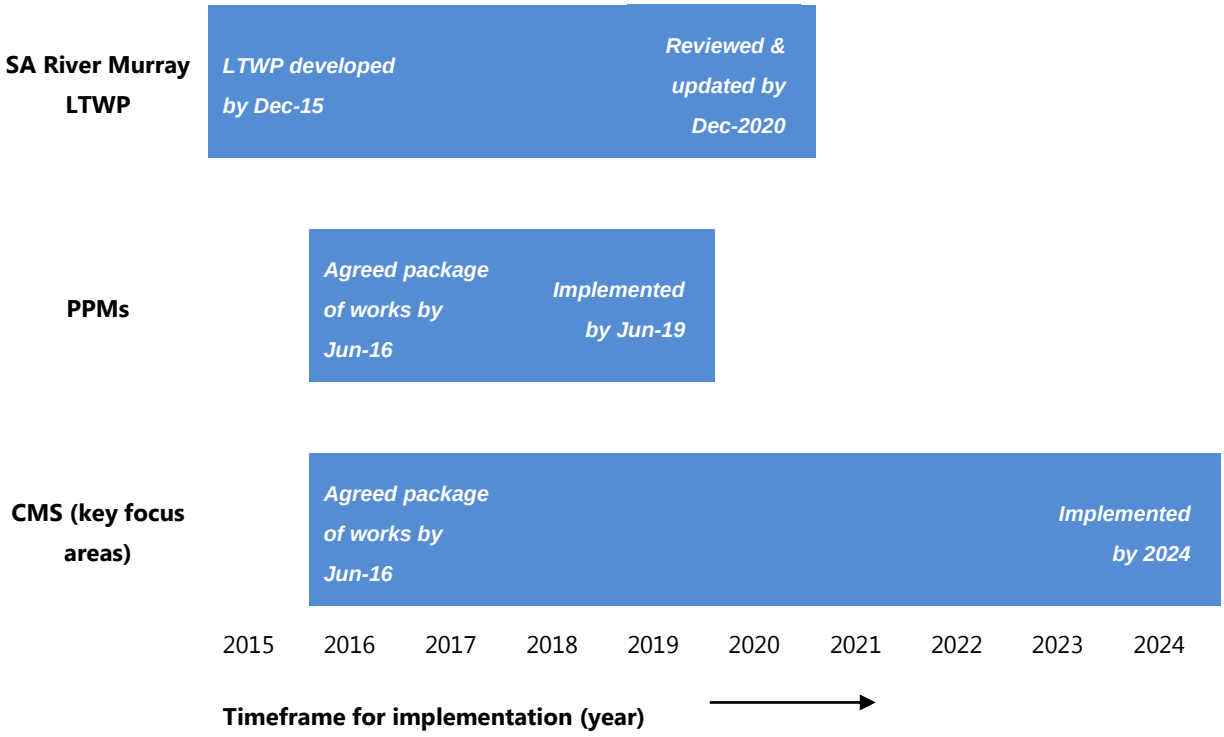

Figure 11. Timeframes for SA River Murray LTWP, PPMs and CMS implementation

Table 16. Flow constraints that influence environmental water management along the Lower Murray in South Australia

Constraint	Implication for environmental watering in the SA River Murray WRP Area	Constraint management
Physical capacity to release water from storages during high flows limits quantity of water that can be delivered to South Australia.	The current understanding is that flows to South Australia can only be boosted by approximately 10,000 ML/day, depending on flows conditions at the time (Murray-Darling Basin Authority, 2014d). This limits the flow rates that can be achieved through enhancing unregulated flows.	This constraint is factored into environmental water planning. The learnings gained over time will provide a more accurate understanding of the volume of environmental water that can be added including under certain unregulated flow conditions.
Channel capacity through the Barmah Choke and operational/policy decisions to minimise summer inundation of the Barmah-Millewa Forest to avoid potential adverse environmental impacts.	Limits the volume of environmental water that can be passed downstream of Hume Dam in summer, particularly during periods of low flow when consumptive demands are high. As a result, at times insufficient water can be delivered to South Australia to maintain water levels in the Lower Lakes, prevent disconnection of the North and South Lagoons of the Coorong, and maintain an open Murray Mouth.	Investigate options to deliver more water to South Australia in summer, e.g. through channel capacity sharing arrangements, bypassing the Choke or delivery from tributaries downstream of the Choke.
Various factors may constrain the use of Lake Victoria in managing environmental water delivery, including: operating rules (Lake Victoria Operating Strategy) specific objective and outcome for improving water quality using Lake Victoria (Murray-Darling Basin Authority, 2015) channel capacity constraints at both the inlet and outlet.	These constraints can limit the potential to operate Lake Victoria to: provide a source of environmental water store environmental water for release at an alternative time be bypassed and allow longitudinal connectivity and ensure flow peaks move into South Australia.	There have been small trials in the flexible operation of Lake Victoria to facilitate environmental watering actions, including a pre-release of environmental water to prevent a short-term drop in flow rates at the South Australian border. Opportunities to trial these types of operations should continue.

Constraint	Implication for environmental watering in the SA River Murray WRP Area	Constraint management
Weir pools are currently managed within a given operating range to advantage extraction for consumptive use, recreation and other riparian uses.	Weir manipulations are constrained due to operational limitations, which limits the delivery of water and achievement of ecological outcomes through the raising and lowering of weir pools.	A transition to establishing variable weir pool levels will require a change to standard practice in South Australia and will need to be implemented over time. This is likely to be addressed through revisions in the Water Allocation Plan for the River Murray Prescribed Watercourse, development of operating procedures for weir pool level manipulation and through the CMS.
Weir manipulation, the operation of environmental regulators and boosting unregulated flows will affect certain private and public infrastructure and access.	Operating infrastructure and augmenting flows needs to consider known likely impacts.	Trial weir pool raisings have been undertaken to test communication protocols and approval processes, and will continue across most reaches. CMS projects are investigating impacts and seeking funding to address.
Works and construction activity on the floodplain, including environmental works at selected wetlands, and on the Pike and Katarapko floodplains.	Reluctance to enhance flow peaks through the addition of environmental water if it may impact on construction works and incur additional expenses. Flow peaks may also be managed, where required, so as to avoid impacting on construction activity.	Contractual arrangements with constructing bodies should consider potential impacts of peaks in flow, including through the addition of environmental water, so as to limit financial penalties where possible. Watering decisions should also consider the likely benefit of watering and the impact on construction, including the delay in future site operation for environmental outcomes.
Distance to permanent water limits the feasibility of pumping to some temporary wetland and floodplain habitats.	Physical limitations of pumping infrastructure and the costs of delivery limit the wetlands/floodplain areas that can be actively watered through pumping.	In some circumstances, alternative watering techniques, such as drip irrigation, may provide a more efficient or cost-effective method of delivering water to priority areas in need. There have been some trials into alternative watering techniques and these should continue to be explored in the future.

Constraint	Implication for environmental watering in the SA River Murray WRP Area	Constraint management
Target minimum water level requirement in the Lower Lakes.	Low water levels in the Lower Lakes limit the ability to release water through the barrages. Water levels also need to be above 0.50 mAHD to enable water access by some consumptive users.	Investigations into managing variable lake levels to be undertaken.
Logistics of barrage operations.	Physical operation of barrages is time consuming and can limit opportunities to rapidly open or close gates, particularly under low lake level conditions where there is an increased risk of salt water ingress. This can impact on the ability to deliver water to the Coorong, and meet Basin Plan salinity targets for the Coorong, under certain conditions.	Investigate options for installing additional automated barrage gates.

4.4 Long-term risks to providing environmental water

4.4.1 Identification of risks

The Basin Plan identifies three risks to the condition and availability of Basin water resources (s4.02), which are:

a) insufficient water available for the environment

b) water being of a quality unsuitable for use

c) poor health of water dependent ecosystems

The first two (Basin Plan risk a and b) pose a direct risk to providing the EWRs of the priority environmental assets and priority ecosystem functions, and if they were to continue over long timeframes, then ultimately the ecosystem will decline to the point where it is no longer able to respond to watering (Basin Plan risk c). For the SA River Murray WRP Area, there are two additional risks where there may be a sufficient volume of environmental water available, but either the water is not delivered in the appropriate way to achieve ecological outcomes, or it is not possible to deliver the water to the assets or functions when it is needed. For the purposes of this LTWP, these are summarised into four consequences, as follows:

1. insufficient water available for SA River Murray WRP Area priority assets/functions[39]
2. water delivery is not appropriate for outcomes at SA River Murray WRP Area priority assets/functions
3. water cannot be delivered to SA River Murray WRP Area priority assets/functions
4. water quality is unsuitable for use at SA River Murray WRP Area priority assets/functions.

A number of potential risks that could give rise to these consequences have been identified. These have been placed into three categories (Table 17), as follows:

[39] Water availability includes held environmental water, planned environmental water and unregulated flows

1. climate change and/or extreme events
2. risks associated with policy and decision-making (including constraints)
3. lack of supporting evidence.

The matrix within Table 17 provides examples of the types of risk that fall within each category and how these align with the consequences identified above. For example, climate change may result in hotter, drier conditions which in turn result in reduced inflows and increased losses, with a consequence of insufficient water being available for environmental assets. Climate change may also result in heavy, unseasonal rainfall events that cause unregulated flows, with a consequence of sufficient volume but an inappropriate delivery pattern for ecological outcomes to occur.

4.4.2 Potential risk mitigation strategies

The matrix (Table 17) also identifies potential mitigation strategies for each risk. Three of the key mechanisms for preventing the realisation of long-term risks are: 1) effective decision-making frameworks; 2) addressing flow constraints, and 3) rigorous monitoring and evaluation programmes.

4.4.2.1 Effective decision-making frameworks

The co-operative arrangements section of this LTWP describes the processes in place within the WRP Area to facilitate the coordination of environmental water management and guide decision-making across the region. DEWNR will continue to strengthen these arrangements into the future. DEWNR will continue to participate in the formalising of arrangements to coordinate environmental watering across the Southern Connected Basin (SCB), which is likely to occur primarily through the SCBEWC and the development of a 'coordination plan' for the SCB (see Section 4.2.2).

4.4.2.2 Addressing flow constraints

Flow constraints pose a major risk to providing the EWRs of the priority environmental assets of the SA River Murray WRP Area, and modelling indicates that relaxation of constraints can improve the delivery of environmental watering events (Gibbs, et al., 2012). Further details of the constraints that influence environmental water delivery to and within the SA River Murray WRP Area are provided in the Operational Constraints section of this LTWP (Section 4.3). Many of these flow constraints should be addressed through the implementation of the PPMs identified in the Basin Plan (s7.15) and the business cases for the key focus area under the CMS.

A major flow constraint that is not being addressed through the PPMs or the CMS business cases but can significantly impact on the delivery of environmental water to South Australia at critical times (particularly summer and autumn) is the Barmah Choke channel capacity constraint (see Section 4.3.3).

4.4.2.3 Rigorous monitoring and evaluation programmes

DEWNR will develop an integrated monitoring and evaluation plan to inform the assessment of ecological outcomes at the priority environmental assets within the SA River Murray WRP Area (see Section 0). The information gathered through the implementation of this monitoring and evaluation plan will be critical for ongoing management and to support the recognition of the environmental assets within the SA River Murray WRP Area as priorities for the Basin.

The Draft River Murray WAP recognises the need for monitoring and evaluation of water demand and water availability to inform adaptive management for climate change (Natural Resources SA Murray-Darling Basin, 2014). Climate change is likely to result in hotter, drier conditions, which will have the combined effect on water resource availability of reduced inflows and increased demand for water, as well as potentially lower quality of

water. Ecosystems within the SA River Murray WRP Area are already suffering from the reduced frequency of high flow events due to river regulation and over-extraction. The environmental 'demands' (represented by the EWRs) cannot be reduced as a strategy for managing climate change risks. Instead, if the EWRs continue to be unmet, then they may need to be altered to increase the desired frequency and duration of inundation in order to restore degraded ecosystems.

Further research and monitoring are needed to better quantify the impacts (forecast and actual) of climate change on water availability and water demand. This information will assist with the identification of specific mitigation strategies which may include altering water resource plans to manage resources differently (s10.51) and a review of the Basin Plan (s6.06).

Table 17. Matrix of risks and consequences that impact on providing the EWRs of the SA River Murray WRP Area

CONSEQUENCES			
Insufficient water available for SA River Murray WRP Area assets/functions [40]	**Sufficient water but not delivered appropriately for SA River Murray WRP Area priority assets/functions**	**Sufficient water but cannot be delivered to SA River Murray WRP Area priority assets/functions**	**Water quality is unsuitable for use at SA River Murray WRP Area priority assets/functions**
RISK CATEGORY: CLIMATE CHANGE OR EXTREME EVENTS (E.G. DROUGHTS)			
Potential risk: • high losses (evaporation/infiltration) • low inflows • sea-level rise	*Potential risk:* • change in the timing/occurrence of unregulated flow events due to a shift in weather patterns	*Potential risk:* • physical constraints limit water delivery	*Potential risk:* • increased accumulation of carbon, nutrients and salt • increased run-off and erosion due to extreme rainfall events • exposure and re-inundation of acid-sulfate soils
Mitigation strategies: • ensure effective and transparent frameworks are in place to guide water management during extreme events (e.g. Dry Allocation Framework in Water Allocation Plan) • review of Basin Plan (see s6.06), SDL and water sharing arrangements • barrage modification (Siebentritt, et al., 2014)	*Mitigation strategies:* changed management of storages	*Mitigation strategies:* • CMS business case implemented to address priority physical constraints other key physical constraints not being addressed through CMS are identified and addressed	*Mitigation strategies:* • ensure effective and transparent frameworks are in place to guide water management during extreme events

[40] Water availability includes held environmental water, planned environmental water and unregulated flows

CONSEQUENCES			
Insufficient water available for SA River Murray WRP Area assets/functions [40]	**Sufficient water but not delivered appropriately for SA River Murray WRP Area priority assets/functions**	**Sufficient water but cannot be delivered to SA River Murray WRP Area priority assets/functions**	**Water quality is unsuitable for use at SA River Murray WRP Area priority assets/functions**
RISK CATEGORY: POLICY/WATER MANAGEMENT DECISIONS			
Potential risk: • environmental water releases reduce levels in storages and therefore reduce spills/unregulated flows • not enough water recovered to meet environmental watering demands	*Potential risk:* • upstream EWRs are drivers for multi-site watering actions and return flows arrive at wrong time leading to failed breeding events, depletion of seed banks etc.	*Potential risk:* • operational and policy constraints, including potential third party impacts and use of return flows	*Potential risk:* • cumulative impacts of watering actions (including infrastructure operations) reduce the quality of water reaching downstream areas and limit the opportunity to implement environmental watering actions • water is unsuitable for consumptive users and therefore not available for environmental watering actions due to the risk of further impacting on water quality
Mitigation strategies: • ensure effective and transparent frameworks are in place to guide prioritisation of watering actions • PPMs implemented to enable effective multi-site watering actions • Basin Plan and SDL Review (see s6.06)	*Mitigation strategies:* • coordination across the Southern Connected Basin (SCB) with transparent, science-based decision-making	*Mitigation strategies:* • PPMs implemented to address priority policy constraints • other key policy/operational constraints that are not being addressed through PPMs are identified and addressed	*Mitigation strategies:* • develop and implement agreed frameworks and guidelines for managing potential cumulative water quality impacts across the SCB and within SA

CONSEQUENCES			
Insufficient water available for SA River Murray WRP Area assets/functions [40]	**Sufficient water but not delivered appropriately for SA River Murray WRP Area priority assets/functions**	**Sufficient water but cannot be delivered to SA River Murray WRP Area priority assets/functions**	**Water quality is unsuitable for use at SA River Murray WRP Area priority assets/functions**
RISK CATEGORY: LACK OF SUPPORTING EVIDENCE			
• assets not prioritised for environmental water delivery	• poor understanding of, or limited ability to demonstrate, the significance of delivery pattern	• poor understanding of, or limited ability to demonstrate, the risks of not watering	• poor understanding of site-specific and cumulative water impacts
Mitigation strategies: • secure investment in expanding supporting evidence • design and implement an efficient and effective monitoring and evaluation programme • improve modelling tools • further investigations and research	*Mitigation strategies:* • secure investment in expanding supporting evidence • design and implement an efficient and effective monitoring and evaluation programme • improve modelling tools • further investigations and research	*Mitigation strategies:* • secure investment in expanding supporting evidence • design and implement an efficient and effective monitoring and evaluation programme • improve modelling tools • further investigations and research	*Mitigation strategies:* • secure investment in expanding supporting evidence • design and implement an efficient and effective monitoring and evaluation programme • improve modelling tools • further investigations and research

Photo: White-faced heron

5 Monitoring, evaluation, reporting and improvement

5.1 Environmental water reporting requirements

Below is a brief summary of the main reporting requirements associated specifically with environmental watering activity in the SA River Murray WRP Area. There are many other broader natural resource management reports produced that incorporate information relating to the condition of the SA River Murray and environmental watering but these have not been included here (e.g. state and regional NRM reporting). Additional requirements may also include reporting to funding bodies that have supported investigations and works for environmental outcomes such as the installation of flow regulators, and reporting requirements for Ramsar-listed wetlands.

5.1.1 Basin Plan reporting requirements

Schedule 12 of the Basin Plan lists four 'Matters' that relate to reporting against the implementation of the Environmental Watering Plan (Basin Plan Chapter 8), three of which South Australia is required to report on (Table 18). The MDBA and CEWH are responsible for reporting against the fourth Matter (Matter 7 - the achievement of environmental outcomes at a Basin-scale) and information provided by the Basin States will contribute to Matter 7 reporting.

Annual reporting against Matters 9 and 10 commenced for the 2013-14 water year and the first report was submitted to the MDBA before 31 October 2014. The first report against Matter 8 is due 31 October 2017, with the reporting period ceasing on 30 June 2017 which is only approximately one and a half water-years after the completion of the LTWP in November 2015. Matter 8 reporting requirements will be the focus of a proposed integrated monitoring and evaluation plan for the SA River Murray WRP Area (see below).

Table 18. Reporting requirements for Basin States relating to Basin Plan Chapter 8 Environmental Watering Plan

Item	Matter	Reporting frequency	Due
8	The achievement of environmental outcomes at an asset scale	Five-yearly	First report due 31 October 2017
9	The identification of environmental water and the monitoring of its use	Annual	31 October each year
10	The implementation of the environmental management framework (Part 4 of Chapter 8)	Annual	31 October each year

5.1.2 Other reporting requirements

Additional reporting of environmental watering activity within the SA River Murray WRP Area is summarised below.

5.1.2.1 Water use reporting

Reconciliation of environmental water licences and accounts is reported to DEWNR Licensing and is due at the end of each water year.

Reporting environmental water use to environmental water holders (CEWO and TLM) is required at the end of each water year (or during the year, as requested by water holders).

5.1.2.2 Ecological and operational reporting to water holders

For TLM, long-term environmental monitoring programmes are in place at Chowilla and the LLCMM Icon Sites, including intervention and condition monitoring. Information generated through these programmes is used to report on responses to environmental watering, and the environmental condition of the sites.

For CEWO, reporting requirements vary depending on the site and watering action, and is agreed between the CEWO and the site manager prior to water delivery. Ecological outcomes arising from the delivery of Commonwealth environmental water to the Channel PEA and areas of the Floodplain PEA that are inundated by flows of less than 60,000 ML/day QSA (excluding Chowilla) will be monitored and evaluated through the CEWH's Long-Term Intervention Monitoring Project (LTIM Project).

For the South Australian Minister for Water and the River Murray, formal reporting requirements have not yet been established, however information is gathered through the drafting of DEWNR's annual environmental watering report (see below).

5.1.2.3 Public reporting of environmental watering activity

An annual environmental watering report is produced by DEWNR at the end of each water year. This report summarises the volumes and timing of environmental water delivered within the SA River Murray WRP Area, provides an evaluation of actual against planned actions and highlights some of the key environmental outcomes achieved through environmental water delivery. The report is published on DEWNR's website and meets the South Australian Government's commitment to the Council of Australian Governments (COAG) to provide transparency and accountability for public information sharing of River Murray environmental water use in South Australia (Council of Australian Governments, 2010).

5.2 Integrated monitoring and evaluation plan

An integrated monitoring and evaluation plan for the SA River Murray WRP Area is proposed, with a particular focus on meeting the state's requirement to report against Matter 8 of the Basin Plan (the achievement of environmental outcomes at an asset scale).

This LTWP identifies three priority environmental assets - the Channel, the Floodplain and the CLLMM, which have a combined total of 46 ecological objectives and 101 ecological targets Monitoring progress against all of these targets is not feasible so development of an integrated monitoring and evaluation plan will involve the prioritisation of asset-scale indicators.

There are many existing managed sites within the SA River Murray WRP Area that are managed for ecological outcomes through the delivery of environmental water (see Section 2.4.6). Many of these sites have their own long-term environmental management plan that includes site-specific management objectives, targets and actions. They also have established monitoring programmes that have been specifically designed to enable adaptive management of the site, and to fulfil any reporting requirements to funding providers. The objectives, targets and monitoring needs of these site-specific projects are not replaced by this LTWP.

These managed sites operate at various scales and use different types of management levers, a number of which are conducted external to DEWNR. The integrated monitoring and evaluation plan will consider how data gathered through these existing projects can be consolidated and re-evaluated at a whole-of-asset scale, as well as identifying any monitoring gaps. Ongoing resourcing of many of the existing monitoring programmes is uncertain and this will need to be considered during the development of the integrated monitoring and evaluation plan.

The objectives, targets and EWRs identified for the priority environmental assets were not constrained to those considered to be achievable under the current stage of implementation of all Basin Plan related reform. Further work is required to assess to what extent they are likely to be met through water recovery and constraints management. The immediate goal is to see progress towards the targets in this LTWP, which represent a healthy, functioning ecosystem.

The identification of expected outcomes can assist with evaluation and, in the future, outcomes that are achievable within the SA River Murray WRP Area under the Basin Plan may be identified. However, this will be difficult until the outcomes of the SDL adjustment mechanism are known, including the extent to which constraints and PPMs are addressed and the subsequent impact on the final water recovery volume held by the environment.

The PPMs are not expected to be fully implemented until June 2019 and during this time the use of environmental water to enhance unregulated flows will be largely limited to extending the duration, rather than boosting the magnitude, of flow peaks. Implementation of the CMS in the key focus areas is not expected to be complete until 2024, therefore these physical constraints are likely to continue to impact on the delivery of environmental water under high flow conditions. Even then, uncertainty around expected outcomes will exist due to the influence of climate variability and decisions on how and when environmental water is delivered.

5.3 Review of this plan

The triggers and timeframes for reviewing and updating this LTWP are provided in Section 2.2. Information generated through the implementation of an integrated monitoring and evaluation plan, together with the learnings from site-specific monitoring programmes that provide the majority of the data, will be instrumental in updating and improving future version of the LTWP.

Photo: Murray Mouth © Kirsty Wedge

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Appendix 1. Alignment of BWEWS expected outcomes with ecological objectives of the SA River Murray WRP Area priority environmental assets

Theme	BWEWS Expected Outcome	Code[41]	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
Longitudinal connectivity	To keep base flows at least 60% of the natural level	**RFC_1**	Provide diverse hydraulic conditions over the range of velocity classes in the lower third of weir pools so that habitat and processes for dispersal of organic and inorganic material between reaches are maintained; Maintain a diurnally-mixed water column to ensure diverse phytoplankton and avoid negative water quality outcomes	Provide diverse hydraulic conditions and complex habitat for flow dependent biota and processes; Maintain water quality to support water dependent biota and normal biogeochemical processes	
	30% overall increase in flows in the River Murray: from increased tributary contributions from the Murrumbidgee, Goulburn, Campaspe, Loddon and Lower Darling catchments collectively	**RFC_3**			
	30 to 40% increase in flows to the Murray mouth.	**RFC_4**	Ensure adequate flushing of salt from the Murray to the Southern Ocean		Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity between the Coorong and the sea

[41] The code for each BWEWS expected outcome has been taken from the 2015-16 Southern Connected Basin Environmental Watering Proposal Template

Theme	BWEWS Expected Outcome	Code[41]	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
Lateral connectivity	30 to 60% increase in the frequency of freshes, bank-full and lowland floodplain flows in the Murray, Murrumbidgee, Goulburn–Broken and Condamine–Balonne catchments	**RFC_5**	Provide for the mobilisation of carbon and nutrients from the floodplain to the river to reduce the reliance of in-stream foodwebs on autochthonous productivity; Maintain habitats and provide for dispersal of organic and inorganic material and organisms between river and wetlands; Throughout the length of the Channel asset, establish and maintain groundwater and soil moisture conditions conducive to improving riparian vegetation	Provide for the mobilisation of carbon and nutrients from the floodplain to the river; Establish groundwater conditions conducive to maintaining diverse native vegetation across the Floodplain PEA; Establish soil conditions conducive to maintaining diverse native vegetation across the Floodplain PEA	

Theme	BWEWS Expected Outcome	Code[42]	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
End-of-basin flows	Barrage flows are greater than 2000 GL/year on a three-year rolling average basis for 95% of the time, with a two year minimum of 600 GL at any time	**RFC_8**			Establish and maintain stable salinities in the Lakes and a variable salinity regime in the Murray estuary and Coorong
	Water levels in the Lower Lakes are maintained above: sea level (0m AHD) and; 0.4 metres AHD, for 95% of the time, as far as practicable, to allow for barrage releases	**RFC_9**			See CLLMM EWRs
	Salinity in the Coorong and Lower Lakes remains below critical thresholds for key flora and fauna including: salinity in Lake Alexandrina is lower than 1,000 EC 95% of the time and less than 1,500 EC all the time; salinity in the Coorong's south lagoon is less than 100 grams per litre 95% of the time	**RFC_10**			Establish and maintain stable salinities in the Lakes and a variable salinity regime in the Murray estuary and Coorong
	Murray mouth is open 90% of the time to an average annual depth of one metre.	**RFC_11**			Maintain a permanent Murray Mouth opening through freshwater outflows with adequate tidal variations to improve water quality and maximise connectivity between the Coorong and the sea

[42] The code for each BWEWS expected outcome has been taken from the 2015-16 Southern Connected Basin Environmental Watering Proposal Template

Theme	BWEWS Expected Outcome	Code[43]	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
Vegetation - Forests and woodlands	Maintain the current extent of forest and woodland vegetation including approximately: 360,000 hectares of river red gum; 409,000 hectares of black box; 310,000 hectares of cooibah	**WDV_1**	Throughout the length of the Channel asset, establish and maintain a diverse native flood-dependent plant community in areas inundated by flows of 10,000 - 40,000 ML/day QSA	Maintain a viable, functioning River red gum population within the Floodplain PEA; Maintain a viable, functioning black box population within the Floodplain PEA; Maintain a viable, functioning River cooba population within the Floodplain PEA	
	No decline in the condition of river red gum, black box and coobah across the Basin	**WDV_2**			
	By 2024, improved condition of river red gum in the Lachlan, Murrumbidgee, Lower Darling, Murray, Goulburn–Broken and Wimmera–Avoca	**WDV_3**			
	By 2024, improved recruitment of trees within river red gum, black box and coobah communities—in the long term achieving a greater range of tree ages.	**WDV_4**			

[43] The code for each BWEWS expected outcome has been taken from the 2015-16 Southern Connected Basin Environmental Watering Proposal Template

Theme	BWEWS Expected Outcome	Code[44]	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
Vegetation - Shrublands	Outcomes for shrubland vegetation: maintain the current extent of extensive lignum shrubland areas within the Basin; by 2024, improvement in the condition of lignum shrublands.	**WDV_5**		Maintain a viable, functioning lignum population within the Floodplain PEA	
Vegetation - non-woody	Outcomes for non-woody vegetation: to maintain the current extent of non-woody vegetation; by 2024, increased periods of growth for communities that: closely fringe or occur within the main river corridors; form extensive stands within wetlands and low-lying floodplains; a sustained and adequate population of *Ruppia tuberosa* in the south lagoon of the Coorong, including by 2019, *R. tuberosa* to occur in at least 80% of sites across at least a 50 km extent, and by 2029, the seed bank to be sufficient for the population to be resilient to major disturbances.	**WDV_6**	Throughout the length of the Channel asset, establish and maintain a diverse native flood-dependent plant community in areas inundated by flows of 10,000 - 40,000 ML/day QSA; Throughout the length of the Channel asset, establish and maintain a diverse macrophyte community in wetlands inundated by flows up to 40,000 ML/day QSA	Establish and maintain diverse water dependent vegetation within aquatic zones across the Floodplain PEA; Establish and maintain diverse native vegetation comprising native flood dependent and amphibious species within the shedding floodplain zones across the Floodplain PEA	Restore *Ruppia tuberosa* colonisation and reproduction in the Coorong at a regional scale; Maintain or improve aquatic and littoral vegetation in the Lower Lakes

[44] The code for each BWEWS expected outcome has been taken from the 2015-16 Southern Connected Basin Environmental Watering Proposal Template

Theme	BWEWS Expected Outcome	Code[45]	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
Waterbirds	The number and type of waterbird species present in the Basin will not fall below current observations	**WB_1**		Provide refuge for the maintenance of adult populations of waterbirds across the Floodplain PEA	Maintain or improve waterbird populations in the Coorong and Lower Lakes
	Significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups	**WB_2**		Create conditions conducive to successful, small-scale breeding events for waterbirds across the Floodplain PEA	
	Breeding events (the opportunities to breed rather than the magnitude of breeding *per se*) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario	**WB_3**			
	Breeding abundance (nests and broods) for all of the other functional groups to increase by 30–40% compared to the baseline scenario, especially in locations where the Basin Plan improves over-bank flows.	**WB_4**			

[45] The code for each BWEWS expected outcome has been taken from the 2015-16 Southern Connected Basin Environmental Watering Proposal Template

Theme	BWEWS Expected Outcome	Code	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
Fish - Broad outcomes	No loss of native species currently present within the Basin	**F_1**	Restore the distribution of native fish; Restore and maintain resilient populations of foraging generalists		
	Improved population structure of key species through regular recruitment	**F_2**	Restore the distribution of native fish	Restore resilient populations of wetland/floodplain specialists within aquatic zones across the Floodplain PEA during floodplain flow events	Maintain a spatio-temporally diverse fish community and resilient populations of key native fish species in the Lower Lakes and Coorong
	Increased movement of key species	**F_3**			
Fish - Short-lived species[46]	Restored distribution and abundance to levels recorded pre-2007 (prior to major losses caused by extreme drought). This will require annual or biennial recruitment events depending on the species	**F_4**	Restore the distribution of native fish; Restore and maintain resilient populations of foraing generalists	Restore resilient populations of wetland/floodplain specialists within aquatic zones across the Floodplain PEA during floodplain flow events	Maintain a spatio-temporally diverse fish community and resilient populations of key native fish species in the Lower Lakes and Coorong
Fish - Moderate to long-lived species[47]	Improved population structure (i.e. a range of size/age classes for all species and stable sex ratios where relevant) in key sites. This will require annual recruitment events in at least eight out of 10 years at 80% of key sites, with at least four of these being 'strong' recruitment events	**F_5**	Restore resilient populations of Murray cod; Restore resilient populations of golden perch and silver perch; Restore resilient populations of freshwater catfish; Minimise the risk of carp recruitment	Restore resilient populations of circa-annual nester-spawners; Restore resilient populations of flow-dependent specialists; A low proportion of total fish community, measured as abundance and biomass, is comprised of non-native species	

[46] Based on Appendix 6 of the BWEWS short-lived species relevant to the SA River Murray WRP Area = Murray hardyhead, southern pygmy perch, Yarra pygmy perch, southern purple-spotted gudgeon
[47] Based on Appendix 6 of the BWEWS moderate to long-lived species relevant to the SA River Murray WRP Area = silver perch, golden perch, Murray cod, freshwater catfish

Theme	BWEWS Expected Outcome	Code	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
	10–15% increase of mature fish (of legal take size) for recreational target species (Murray cod and golden perch) in key populations	**F_6**	Restore resilient populations of Murray cod; Restore resilient populations of golden perch and silver perch	Restore resilient populations of circa-annual nester-spawners within the SA River Murray; Restore resilient populations of flow-dependent specialists within the SA River Murray	
	Annual detection of species and life stages representative of the whole fish community through key fish passages; with an increase in passage of through key fish passages to be detected in 2019–2024; compared to passage rates detected in 2014–2019.	**F_7**			
Fish - Estuarine species[48]	Detection of all estuarine-dependent fish families throughout 2014–2024	**F_8**			Maintain a spatio-temporally diverse fish community and resilient populations of key native fish species in the Lower Lakes and Coorong (*note, includes nested targets for congolli, common galaxias, short-headed lamprey, pouched lamprey, Murray hardyhead, pygmy perch, black bream, greenback flounder, mulloway and small-mouthed hardyhead*)
	Maintenance of annual population abundance (Catch Per Unit Effort – CPUE) of key estuarine prey species (sandy sprat and small-mouthed hardyhead) throughout the Coorong	**F_9**			
	Detection of a broad spatial distribution of black bream and greenback flounder; with adult black bream and all life stages of greenback flounder present across >50% of the Coorong in eight out of 10 years	**F_10**			

[48] Based on Appendix 6 of the BWEWS estuarine species = mulloway, black bream, greenback flounder, sandy sprat, small-mouthed hardyhead; and four diadromous species (congolli, common galaxias, short-headed lamprey, pouched lamprey)

Theme	BWEWS Expected Outcome	Code	Channel PEA Objective	Floodplain PEA Objective	CLLMM PEA Objective
	Detection in nine out of 10 years of bi-directional seasonal movements of diadromous species through the barrages and fishways between the Lower Lakes and Coorong	**F_11**			
	Increased rates of native fish passage in 2019–2024 compared to 2014–2019	**F_12**			
	Improved population structure of mulloway, including spawning aggregations at the Murray mouth in six out of 10 years and recruitment in at least five out of 10 years.	**F_13**			
Fish - key species [49]	Significant increases in the distributions of key species in the southern Basin.	**F_15**		Restore resilient populations of wetland/floodplain specialists within aquatic zones across the Floodplain PEA during floodplain flow events	

[49] Based on Appendix 6 of the BWEWS key species relevant to the SA River Murray WRP Area = southern pygmy perch, southern purple-spotted gudgeon, Yarra pygmy perch, Murray hardyhead, diadromous species (Congolli, short-headed and pouched lamprey)

Appendix 2. Definitions of held and planned environmental water

The following definitions of held and planned environmental water are taken from Sections 4 and 6 of the *Water Act 2007*.

Held environmental water means water available under:

(a) a water access right; or

(b) a water delivery right; or

(c) an irrigation right;

for the purposes of achieving environmental outcomes (including water that is specified in a water access right to be for environmental use).

Planned environmental water

(1) For the purposes of this Act, ***planned environmental water*** is water that:

(a) is committed by:

(i) the Basin Plan or a water resource plan for a water resource plan area; or

(ii) a plan made under a State water management law; or

(iii) any other instrument made under a law of a State;

to either or both of the following purposes:

(iv) achieving environmental outcomes;

(v) other environmental purposes that are specified in the plan or the instrument; and

(b) cannot, to the extent to which it is committed by that instrument to that purpose or those purposes, be taken or used for any other purpose.

(2) For the purposes of this Act, ***planned environmental water*** is water that:

(a) is preserved, by a law of a State or an instrument made under a law of a State, for the purposes of achieving environmental outcomes by any other means (for example, by means of the setting of water flow or pressure targets or establishing zones within which water may not be taken from a water resource); and

(b) cannot, to the extent to which it is preserved by that instrument for that purpose or those purposes, be taken or used for any other purpose.

(3) The water may be committed to, or preserved for, the purpose or purposes referred to in paragraph (1)(a) or (2)(a) either generally or only at specified times or in specified circumstances.

(4) Without limiting paragraph (1)(b) or (2)(b), the requirements of paragraph (1)(b) or (2)(b) are taken to have been met even if the water is taken or used for another purpose in emergency circumstances in accordance with:

(a) the instrument referred to in that paragraph; or

(b) the law under which the instrument is made; or

(c) another law.

Appendix 3. Species of conservation significance recorded within SA River Murray WRP Area Priority Environmental Assets

Table 19. Threatened plant species[50]

Scientific Name	Common Name	EPBC Status	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Acacia lineata	Streaked Wattle	n/a	Rare	Y	Y		2
Acacia menzelii	Menzel's Wattle	Vulnerable	Vulnerable		Y		1
Acacia montana	Mallee Wattle	n/a	Rare		Y		1
Acacia pinguifolia	Fat-leaf Wattle	Endangered	Endangered			Y	1
Acacia rhetinocarpa	Resin Wattle	Vulnerable	Vulnerable			Y	1
Acanthocladium dockeri	Spiny Everlasting	Critically Endangered	Endangered		Y		1
Adiantum capillus-veneris	Dainty Maiden-hair	n/a	Vulnerable	Y			1
Atriplex morrisii	n/a	n/a	Vulnerable	Y			1
Austrostipa echinata	Spiny Spear-grass	n/a	Rare			Y	1
Bothriochloa macra	Red-leg Grass	n/a	Rare	Y			1
Brachyscome eriogona	n/a	n/a	Rare		Y		1
Brachyscome graminea	Grass Daisy	n/a	Rare	Y	Y		2
Brachyscome paludicola	Swamp Daisy	n/a	Rare*	Y	Y		2

[50] Presence/absence records from DEWNR's biological database have been provided as an indication of the number of threatened species that have been found within each PEA only. Currently there are very few fish records and no invertebrate records entered into the dataset. This is not a comprehensive list and does not reflect species records that have not been provided to DEWNR for input to the database.

Scientific Name	Common Name	EPBC Status	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Caladenia colorata	Coloured Spider-orchid	Endangered	Endangered			Y	1
Caladenia flaccida	Drooping Spider-orchid	n/a	Vulnerable			Y	1
Caladenia tensa	Inland Green-comb Spider-orchid	Endangered	n/a			Y	1
Callistemon brachyandrus	Prickly Bottlebrush	n/a	Rare	Y	Y		2
Callitriche sonderi	Matted Water Starwort	n/a	Rare	Y	Y		2
Callitriche umbonata	Water Starwort	n/a	Vulnerable	Y	Y		2
Calocephalus sonderi	Pale Beauty-heads	n/a	Rare	Y	Y		2
Calotis scapigera	Tufted Burr-daisy	n/a	Rare	Y	Y		2
Centrolepis cephaloformis ssp. cephaloformis	Cushion Centrolepis	n/a	Rare			Y	1
Ceratophyllum demersum	Hornwort	n/a	Rare	Y		Y	2
Christella dentata	Soft Shield-fern	n/a	Rare	Y		Y	2
Cladium procerum	Leafy Twig-rush	n/a	Rare			Y	1
Correa aemula	Hairy Correa	n/a	Rare	Y			1
Correa alba var. pannosa	White Correa	n/a	Rare			Y	1
Corynotheca licrota	Sand Lily	n/a	Rare	Y			1
Crassula peduncularis	Purple Crassula	n/a	Rare		Y		1
Cyperus flaccidus	Flaccid Flat-sedge	n/a	Rare	Y	Y		2

Scientific Name	Common Name	EPBC Status	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Cyperus sphaeroideus	n/a	n/a	Rare			Y	1
Dianella porracea	Pale Flax-lily	n/a	Vulnerable		Y		1
Diplachne parviflora (NC)	Small-flower Beetle-grass	n/a	Rare		Y		1
Duma horrida ssp. horrida	Spiny Lignum	n/a	Rare	Y	Y		2
Elacholoma prostrata	Small Monkey-flower	n/a	Rare	Y			1
Elatine gratioloides	Waterwort	n/a	Rare	Y	Y	Y	3
Eragrostis infecunda	Barren Cane-grass	n/a	Rare	Y	Y		2
Eragrostis lacunaria	Purple Love-grass	n/a	Rare	Y	Y		2
Eremophila gibbifolia	Coccid Emubush	n/a	Rare	Y			1
Eremophila polyclada	Twiggy Emubush	n/a	Rare	Y			1
Eucalyptus fasciculosa	Pink Gum	n/a	Rare			Y	1
Eucalyptus leucoxylon ssp. megalocarpa	Large-fruit Blue Gum	n/a	Rare			Y	1
Euphrasia collina ssp. osbornii	Osborn's Eyebright	Endangered	Endangered			Y	1
Exocarpos strictus	Pale-fruit Cherry	n/a	Rare	Y	Y		2
Fimbristylis aestivalis	Summer Fringe-rush	n/a	Rare	Y		Y	2
Geijera parviflora	Wilga	n/a	Rare	Y			1
Goodenia heteromera	Spreading Goodenia	n/a	Rare	Y	Y		2
Gratiola pedunculata	Stalked Brooklime	n/a	Rare	Y	Y		2

Scientific Name	Common Name	EPBC Status	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Gratiola pumilo	Dwarf Brooklime	n/a	Rare	Y	Y		2
Haegiela tatei	Small Nut-heads	n/a	Rare			Y	1
Hakea tephrosperma	Hooked Needlewood	n/a	Rare	Y			1
Hydrilla verticillata	Waterthyme	n/a	Rare	Y			1
Juncus prismatocarpus	Branching Rush	n/a	Endangered	Y			1
Lachnagrostis robusta	Tall Blown-grass	n/a	Rare	Y			1
Lawrencia berthae	Showy Lawrencia	n/a	Rare	Y			1
Leionema microphyllum	Limestone Phebalium	n/a	Rare			Y	1
Lepidium pseudotasmanicum	Shade Peppercress	n/a	Vulnerable	Y	Y		2
Leucopogon clelandii	Cleland's Beard-heath	n/a	Rare			Y	1
Lobelia concolor	Poison Pratia	n/a	Rare	Y	Y	Y	3
Lycopodiella serpentina	Bog Clubmoss	n/a	Endangered			Y	1
Lythrum salicaria	Purple Loosestrife	n/a	Rare	Y	Y		2
Maireana decalvans	Black Cotton-bush	n/a	Endangered		Y		1
Maireana pentagona	Slender Fissure-plant	n/a	Rare	Y	Y		2
Maireana rohrlachii	Rohrlach's Bluebush	n/a	Rare		Y		1
Melaleuca squamea	Swamp Honey-myrtle	n/a	Rare			Y	1
Mentha diemenica	Slender Mint	n/a	Rare	Y			1

Scientific Name	Common Name	EPBC Status	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Micromyrtus ciliata	Fringed Heath-myrtle	n/a	Rare			Y	1
Myoporum parvifolium	Creeping Boobialla	n/a	Rare	Y	Y	Y	3
Myriophyllum crispatum	Upright Milfoil	n/a	Vulnerable		Y		1
Myriophyllum papillosum	Robust Milfoil	n/a	Rare	Y	Y		2
Najas tenuifolia	Water Nymph	n/a	Endangered	Y			1
Nymphoides crenata	Wavy Marshwort	n/a	Rare	Y	Y		2
Olearia passerinoides ssp. glutescens	Sticky Daisy-bush	n/a	Rare			Y	1
Orobanche cernua var. australiana	Australian Broomrape	n/a	Rare	Y	Y		2
Ottelia ovalifolia ssp. ovalifolia	Swamp Lily	n/a	Rare	Y	Y		2
Philotheca angustifolia ssp. angustifolia	Narrow-leaf Wax-flower	n/a	Rare	Y			1
Picris squarrosa	Squat Picris	n/a	Rare	Y	Y	Y	3
Pilularia novae-hollandiae	Austral Pillwort	n/a	Rare	Y			1
Prostanthera eurybioides	Monarto Mintbush	Endangered	Endangered		Y		1
Pteris tremula	Tender Brake	n/a	Rare	Y			1
Pterostylis arenicola	Sandhill Greenhood	Vulnerable	Vulnerable			Y	1
Ranunculus inundatus	River Buttercup	n/a	Rare			Y	1

Scientific Name	Common Name	EPBC Status	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Ranunculus papulentus	Large River Buttercup	n/a	Vulnerable			Y	1
Rorippa laciniata	Jagged Bitter-cress	n/a	Rare	Y	Y		2
Sclerolaena muricata var. villosa	Five-spine Bindyi	n/a	Rare	Y		Y	2
Spiranthes australis	Austral Lady's Tresses	n/a	Rare			Y	1
Stellaria palustris var. tenella	Swamp Starwort	n/a	Rare	Y			1
Thelymitra epipactoides	Metallic Sun-orchid	Endangered	Endangered			Y	1
Veronica decorosa	Showy Speedwell	n/a	Rare	Y			1
Wurmbea latifolia ssp. vanessae	Broad-leaf Nancy	n/a	Rare			Y	1
Zannichellia palustris	n/a	n/a	Rare	Y	Y		2
Total number of threatened species recorded in each Priority Environmental Asset				**54**	**40**	**34**	
Total number of threatened species recorded in the SA River Murray WRP Area			**91**				

Table 20. Threatened fauna species[51]

Scientific Name	Common Name	EPBC Status[52]	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Acanthiza iredalei	Slender-billed Thornbill	ssp	ssp			Y	1
Acrobates pygmaeus	Feathertail Glider	n/a	Endangered	Y			1
Actitis hypoleucos	Common Sandpiper	Migratory	Rare	Y		Y	2
Anas rhynchotis	Australasian Shoveler	n/a	Rare	Y	Y	Y	3
Anhinga novaehollandiae	Australasian Darter	n/a	Rare	Y	Y	Y	3
Anseranas semipalmata	Magpie Goose	n/a	Endangered		Y		1
Arctocephalus pusillus	Australian Fur Seal (Brown Fur Seal)	n/a	Rare			Y	1
Arctocephalus tropicalis	Subantarctic Fur Seal	Vulnerable	Endangered			Y	1
Ardea ibis	Cattle Egret	Migratory	Rare	Y		Y	2
Ardea intermedia	Intermediate Egret	n/a	Rare	Y	Y	Y	3
Ardeotis australis	Australian Bustard	n/a	Vulnerable	Y	Y		2
Arenaria interpres	Ruddy Turnstone	Migratory	Rare		Y	Y	2
Balaenoptera acutorostrata	Dwarf Minke Whale	n/a	Rare			Y	1

[51] Presence/absence records from DEWNR's biological database have been provided as an indication of the number of threatened species that have been found within each PEA only. Currently there are very few fish records and no invertebrate records entered into the dataset. This is not a comprehensive list and does not reflect species records that have not been provided to DEWNR for input to the database.
[52] Migratory indicates species that are listed under one or more International Agreements (Bonn/CAMBA/JAMBA/ROKAMBA)

Scientific Name	Common Name	EPBC Status[52]	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Biziura lobata	Musk Duck	n/a	Rare	Y	Y	Y	3
Botaurus poiciloptilus	Australasian Bittern	Endangered	Vulnerable	Y		Y	2
Burhinus grallarius	Bush Stonecurlew	n/a	Rare	Y	Y	Y	3
Cacatua leadbeateri	Major Mitchell's Cockatoo	n/a	Rare		Y		1
Calamanthus (Hylacola) cautus	Shy Heathwren	n/a	Rare	Y		Y	2
Calidris alba	Sanderling	Migratory	Rare			Y	1
Calidris melanotos	Pectoral Sandpiper	Migratory	Rare	Y		Y	2
Calidris subminuta	Long-toed Stint	Migratory	Rare	Y		Y	2
Calidris tenuirostris	Great Knot	Migratory	Rare			Y	1
Calyptorhynchus funereus	Yellow-tailed Black Cockatoo	n/a	Vulnerable			Y	1
Caperea marginata	Pygmy Right Whale	n/a	Rare			Y	1
Cereopsis novaehollandiae	Cape Barren Goose	n/a	Rare			Y	1
Charadrius leschenaultii	Greater Sand Plover	Migratory	Rare	Y			1
Charadrius mongolus	Lesser Sand Plover	Migratory	Rare			Y	1
Chelodina expansa	Broad-shelled Tortoise	n/a	Vulnerable	Y	Y		2
Cinclosoma castanotum	Chestnut-backed Quailthrush (Chestnut Quailthrush)	n/a	ssp	Y	Y		2
Cladorhynchus leucocephalus	Banded Stilt	n/a	Vulnerable	Y		Y	2
Climacteris affinis	White-browed Treecreeper	n/a	Rare	Y	Y		2

Scientific Name	Common Name	EPBC Status[52]	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Coracina papuensis	White-bellied Cuckooshrike	n/a	Rare	Y	Y		2
Corcorax melanorhamphos	White-winged Chough	n/a	Rare	Y	Y	Y	3
Coturnix ypsilophora	Brown Quail	n/a	Vulnerable		Y		1
Craterocephalus fluviatilis	Murray Hardyhead	Endangered	n/a	Y	Y	Y	3
Dasyornis broadbenti	Rufous Bristlebird	n/a	Rare			Y	1
Dasyurus viverrinus	Eastern Quoll	n/a	Endangered			Y	1
Egretta garzetta	Little Egret	n/a	Rare	Y	Y	Y	3
Elanus scriptus	Letter-winged Kite	n/a	Rare			Y	1
Emydura macquarii	Macquarie Tortoise	n/a	Vulnerable	Y	Y		2
Entomyzon cyanotis	Blue-faced Honeyeater	n/a	Rare	Y	Y		2
Epthianura crocea	Yellow Chat	n/a	Endangered			Y	1
Eubalaena australis	Southern Right Whale	Endangered	Vulnerable			Y	1
Eulamprus heatwolei	Yellow-bellied Water Skink	n/a	Vulnerable			Y	1
Falco peregrinus	Peregrine Falcon	n/a	Rare	Y	Y	Y	3
Falcunculus frontatus	Crested Shriketit	n/a	Rare	Y			1
Gallinago hardwickii	Latham's Snipe	Migratory	Rare	Y	Y	Y	3
Grus rubicunda	Brolga	n/a	Vulnerable	Y	Y		2
Haematopus fuliginosus	Sooty Oystercatcher	n/a	Rare			Y	1

Scientific Name	Common Name	EPBC Status[52]	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Haematopus longirostris	(Australian) Pied Oystercatcher	n/a	Rare			Y	1
Haliaeetus leucogaster	White-bellied Sea-Eagle	Migratory	Endangered	Y	Y	Y	3
Hydrurga leptonyx	Leopard Seal	n/a	Rare			Y	1
Ixobrychus dubius	Australian Little Bittern (Black-backed Bittern)	n/a	Endangered			Y	1
Kogia breviceps	Pygmy Sperm Whale	n/a	Rare			Y	1
Larus dominicanus	Kelp Gull	n/a	Rare			Y	1
Leipoa ocellata	Malleefowl	Vulnerable; Migratory	Vulnerable	Y	Y	Y	3
Lewinia pectoralis	Lewin's Rail	n/a	Vulnerable			Y	1
Lichenostomus cratitius	Purple-gaped Honeyeater	n/a	ssp	Y		Y	2
Limosa lapponica	Bar-tailed Godwit	Migratory	Rare			Y	1
Limosa limosa	Black-tailed Godwit	Migratory	Rare	Y		Y	2
Litoria raniformis	Southern Bell Frog	Vulnerable	Vulnerable	Y	Y	Y	3
Macropus rufogriseus	Red-necked Wallaby	n/a	Rare			Y	1
Melanodryas cucullata	Hooded Robin	n/a	ssp	Y	Y		2
Melithreptus gularis	Black-chinned Honeyeater	n/a	ssp			Y	1
Mesoplodon grayi	Gray's Beaked Whale (Scamperdown Whale)	n/a	Rare			Y	1

Scientific Name	Common Name	EPBC Status[52]	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Microeca fascinans	Jacky Winter	n/a	ssp	Y	Y	Y	3
Mirounga leonina	Southern Elephant Seal	Vulnerable	Rare			Y	1
Morelia spilota	Carpet Python	n/a	Rare	Y	Y		2
Myiagra inquieta	Restless Flycatcher	n/a	Rare	Y	Y		2
Myotis macropus	Large-footed Myotis	n/a	Endangered	Y			1
Neophema chrysogaster	Orange-bellied Parrot	Critically endangered; Migratory	Endangered			Y	1
Neophema chrysostoma	Blue-winged Parrot	n/a	Vulnerable	Y		Y	2
Neophema elegans	Elegant Parrot	n/a	Rare	Y		Y	2
Neophema petrophila	Rock Parrot	n/a	Rare			Y	1
Neophema splendida	Scarlet-chested Parrot	n/a	Rare		Y		1
Neophoca cinerea	Australian Sea Lion	Vulnerable	Vulnerable			Y	1
Ninox connivens	Barking Owl	n/a	Rare		Y		1
Northiella haematogaster	Bluebonnet	n/a	ssp	Y	Y	Y	3
Notechis scutatus	Eastern Tiger Snake	ssp	n/a	Y	Y	Y	3
Numenius madagascariensis	Far Eastern Curlew	Migratory	Vulnerable			Y	1
Oriolus sagittatus	Olive-backed Oriole	n/a	Rare	Y	Y		2
Oxyura australis	Blue-billed Duck	n/a	Rare	Y	Y	Y	3
Pachycephala inornata	Gilbert's Whistler	n/a	Rare	Y	Y		2

Scientific Name	Common Name	EPBC Status[52]	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Pachycephala rufogularis	Red-lored Whistler	Vulnerable	Rare			Y	1
Pandion haliaetus	Osprey	Migratory	Endangered	Y			1
Petroica boodang	Scarlet Robin	n/a	ssp	Y	Y		2
Philemon citreogularis	Little Friarbird	n/a	Rare	Y	Y		2
Philomachus pugnax	Ruff	Migratory	Rare			Y	1
Physeter macrocephalus	Sperm Whale	n/a	Rare			Y	1
Plectorhyncha lanceolata	Striped Honeyeater	n/a	Rare	Y	Y	Y	3
Plegadis falcinellus	Glossy Ibis	Migratory	Rare	Y	Y	Y	3
Pluvialis fulva	Pacific Golden Plover	Migratory	Rare	Y		Y	2
Podiceps cristatus	Great Crested Grebe	n/a	Rare	Y	Y	Y	3
Polytelis anthopeplus	Regent Parrot	ssp	Vulnerable	Y	Y		2
Pomatostomus temporalis	Grey-crowned Babbler	n/a	ssp			Y	1
Porzana tabuensis	Spotless Crake	n/a	Rare	Y	Y	Y	3
Pseudophryne bibronii	Brown Toadlet	n/a	Rare	Y		Y	2
Rattus lutreolus	Swamp Rat	n/a	Rare		Y	Y	2
Rostratula australis	Australian Painted-snipe	Endangered; Migratory	Vulnerable	Y		Y	2
Saccolaimus flaviventris	Yellow-bellied Sheath-tailed Bat	n/a	Rare			Y	1

Scientific Name	Common Name	EPBC Status[52]	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Stagonopleura bella	Beautiful Firetail	n/a	Rare			Y	1
Stagonopleura guttata	Diamond Firetail	n/a	Vulnerable	Y			1
Sterna hirundo	Common Tern	Migratory	Rare			Y	1
Sternula albifrons	Little Tern	Migratory	Endangered	Y		Y	2
Sternula nereis	Fairy Tern	Vulnerable	Endangered	Y		Y	2
Stictonetta naevosa	Freckled Duck	n/a	Vulnerable	Y	Y	Y	3
Stipiturus malachurus	Southern Emuwren	ssp	ssp			Y	1
Stipiturus malachurus intermedius	Southern Emu-wren (Mt Lofty Ranges ssp)	Endangered; Migratory	Endangered			Y	1
Stipiturus malachurus polionotum	Southern Emu-wren (South East ssp)	n/a	Rare			Y	1
Strepera versicolor	Grey Currawong	n/a	ssp	Y	Y	Y	3
Thalassarche chrysostoma	Grey-headed Albatross	Endangered; Migratory	Vulnerable			Y	1
Thalassarche melanophris	Black-browed Albatross	Vulnerable; Migratory	ssp			Y	1
Thinornis rubricollis	Hooded Plover (Hooded Dotterel)	Vulnerable	Vulnerable		Y	Y	2
Trichosurus vulpecula	Common Brushtail Possum	n/a	Rare	Y	Y	Y	3
Tringa brevipes	Grey-tailed Tattler	Migratory	Rare			Y	1
Tringa glareola	Wood Sandpiper	Migratory	Rare	Y	Y	Y	3

Scientific Name	Common Name	EPBC Status[52]	State Status	Priority Environmental Asset			No. of assets recorded in
				Channel	Floodplain	CLLMM	
Turnix varius	Painted Buttonquail	n/a	Rare			Y	1
Varanus rosenbergi	Heath Goanna	n/a	Vulnerable			Y	1
Varanus varius	Lace Monitor	n/a	Rare	Y	Y		2
Vombatus ursinus	Common Wombat	n/a	Rare			Y	1
Xenus cinereus	Terek Sandpiper	Migratory	Rare			Y	1
Total per Priority Environmental Asset				**64**	**50**	**93**	
Total number of threatened species	**121**						

Appendix 4. Species lists for the CLLMM Priority Environmental Asset ecological targets

Species lists sourced from Department of Environment Water and Natural Resources, (in prep (a), cited in O'Connor, et al., 2015).

Table 21. TLM target waterbird species

Common Name	Scientific Name
Australasian bittern	*Botaurus poiciloptilus*
Australian pelican	*Pelecanus conspicillatus*
Australian spotted crake	*Porzana tabuensis*
Banded stilt	*Cladorhynchus leucoceohalus*
Black swan	*Cygnus atratus*
Chestnut teal	*Anas castanea*
Common greenshank	*Tringa nebularia*
Curlew sandpiper	*Calidris ferruginea*
Fairy tern	*Sterna nereis*
Latham‟s snipe	*Gallinago hardwickii*
Pied oyster catcher	*Haematopus longirostris*
Red-capped plover	*Charadrius ruficapillus*
Red-necked avocet	*Recurvirosta novaehollandiae*
Red-necked stint	*Calidris ruficollis*
Sanderling	*Calidris alba*
Sharp-tailed sandpiper	*Calidris acuminata*

Table 22. Waterbird species that breed annually in the CLLMM

Common Name	Scientific Name
Australian pelican	*Pelecanus conspicillatus*
Black swan	*Cygnus atratus*
Caspian tern	*Hydropogne* (*Sterna*) *caspia*
Crested tern	*Thalasseus bergii*
Fairy tern	*Sterna nereis nereis*
Hooded plover	*Thinornis rubricollis*
Australian white ibis	*Threskiornis molucca*
Australian pied oyster catcher	*Haematopus longirostris*
Sooty oystercatcher	*Haematopus fuliginosus*
Red-capped plover	*Charadrius ruficapillus*
Straw necked ibis	*Threskiornis spinicollis*

Table 23. Waterbird species that breed regularly in the CLLMM

Common Name	Scientific Name
Pied cormorant	*Phalacrocorax varius*
Red-capped plover	*Charadrius ruficapillus*
Royal spoonbill	*Platalea regia*
Silver gull	*Chroicocephalus novaehollandiae*

Table 24. Waterbird species that should be present in the CLLMM in abundances >1% of current flyway thresholds

Common name	Scientific name
Fairy Tern	*Sterna nereis nereis*
Australian Pelican	*Pelecanus conspicillatus*
Australian Pied Oystercatcher	*Haematopus longirostris*
Banded Stilt	*Cladorhynchus leucocephalus*
Chestnut Teal	*Anas castanea*
Curlew Sandpiper	*Calidris ferruginea*
Great Cormorant	*Phalacrocorax carbo carboides*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Red-necked Stint	*Calidris ruficollis*
Sharp-tailed Sandpiper	*Calidris acuminata*
Red-capped Plover	*Charadrius ruficapillus*
Sanderling	*Calidris alba*

Table 25. Common CLLMM fish families

Family	Scientific name	Common name
Anguillidae	*Anguilla australis*	Southern shortfin eel
Arripidae	*Arripis georgianus*	Australian herring
Arripidae	*Arripis truttaceus*	Western Australian salmon
Atherinidae	*Atherinosoma microstoma*	Smallmouth hardyhead
Atherinidae	*Craterocephalus fluviatilus*	Murray hardyhead
Atherinidae	*Craterocephalus stercusmuscarum fulvus*	Unspecked hardyhead
Bovichtidae	*Pseudaphritis urvillii*	Congolli
Clupeidae	*Hyperlophus vittatus*	Sandy sprat
Clupeidae	*Nematolosa erebi*	Bony herring
Clupeidae	*Sardinops sagax*	Australian pilchard
Clupeidae	*Spratelloides robustus*	Blue sprat
Eleotridae	*Hypseleotris spp.*	Carp gudgeon complex
Eleotridae	*Philypnodon grandiceps*	Flat-headed gudgeon
Eleotridae	*Philypnodon macrostomus*	Dwarf flat-headed gudgeon
Engraulidae	*Engraulis australis*	Australian anchovy
Galaxiidae	*Galaxias maculatus*	Common galaxias
Geotriidae	*Geotria australis*	Pouched lamprey
Gobiidae	*Afurcagobius tamarensis*	Tamar goby
Gobiidae	*Arenigobius bifrenatus*	Bridled goby
Gobiidae	*Favonigobius lateralis*	Southern Longfin Goby
Gobiidae	*Pseudogobius olorum*	Bluespot goby
Gobiidae	*Tasmanogobius lasti*	Lagoon goby

Family	Scientific name	Common name
Hemiramphidae	*Hyporhamphus melanochir*	Southern garfish
Hemiramphidae	*Hyporhamphus regularis*	River garfish
Melaenotaenidae	*Melanotaenia fluviatilis*	Murray rainbowfish
Mordaciidae	*Mordacia mordax*	Short-headed lamprey
Mugilidae	*Aldrichetta forsteri*	Yelloweye mullet
Mugilidae	*Liza argentea*	Goldspot mullet
Mugilidae	*Mugil cephalus*	Sea mullet
Myliobatidae	*Myliobatis australis*	Southern eagle ray
Nannopercidae	*Nannoperca australis*	Southern pygmy perch
Nannopercidae	*Nannoperca obscura*	Yarra pygmy perch
Percichthyidae	*Macquaria ambigua*	Golden perch
Pleuronectidae	*Ammotretis rostratus*	Longsnout flounder
Pleuronectidae	*Rhombosolea tapirina*	Greenback flounder
Retropinnidae	*Retropinna semoni*	Australian smelt
Sciaenidae	*Argyrosomus japonicus*	Mulloway
Sparidae	*Acanthopagrus butcheri*	Black bream
Tetraodontidae	*Contusus brevicaudus*	Prickly toadfish
Tetraodontidae	*Contusus richei*	Barred toadfish
Tetraodontidae	*Tetractenos glaber*	Smooth toadfish
Tetrarogidae	*Gymnapistes marmoratus*	Soldier

Appendix 5. Historical pump sites within the Channel and Floodplain Priority Environmental Assets

Table 26. Commence-to-flows (ML/day QSA) for selected temporary wetlands within the SA River Murray WRP Area

Wetlands are in order of increasing commence-to-flow (estimated upper value). This information has been provided by the Natural Resources SA MDB section of DEWNR and is based on many years of wetland pumping projects within the SA River Murray WRP Area.

Temporary Wetland	Lock Reach	Estimated surface area (hectares)	Commence-to-flow[53]		EWR[54] #
			Estimated lower value (ML/day QSA)	Estimated upper value (ML/day QSA)	
Templeton	Lock 5 - 6	8		10,000	IC1
Old Loxton Road	Lock 3 - 4	2	10,000	15,000	IC2
Piggy Creek	Lock 3 - 4	33		25,000	IC4
Sugar Shack temporary basin S0000556	Below Lock 1	5	20,000	25,000	IC4
Overland Corner - larger basin	Lock 2 - 3	93	15,000	30,000	IC5
Whirlpool Corner	Lock 5 - 6	11	15,000	30,000	IC5
Overland Corner - lignum basins	Lock 2 - 3	93	15,000	30,000	IC5
Morgan Conservation Park (Southern Lagoons)	Lock 1 - 2	15	20,000	30,000	IC5
Akuna wetland	Lock 2 - 3	6		30,000	IC5
Markaranka South	Lock 1 - 2	69		30,000	IC5
Wiela - pumped site	Lock 5 - 6	7		30,000	IC5
Morgan East	Lock 1 - 2	7		30,000	IC5

[53] Commence-to-flow is an estimate only and is based on RiMFiM modelling outputs and ground-truthing where possible. Many wetland basins have more than one inlet channel or there is a degree of uncertainty around when water begins to enter the wetland basin, hence upper and lower commence-to-flow values are provided.

[54] The EWR number relates to the lowest Channel or Floodplain EWR (provided in Table 4 and Table 6) likely to inundate the wetland, based on the discharge metric of the EWR and the upper commence-to-flow value for the wetland. A comparison of the EWR duration and average return interval metrics against the required duration and frequency of inundation for the specific wetland (based on the site-specific management objectives) has not been undertaken. For example, the EWR duration may not be sufficient to provide frog and bird breeding outcomes in which case a higher EWR would need to be delivered to achieve these outcomes or duration of inundation extended through pumping.

Temporary Wetland	Lock Reach	Estimated surface area (hectares)	Commence-to-flow[53]		EWR[54] #
			Estimated lower value (ML/day QSA)	Estimated upper value (ML/day QSA)	
Yabby Creek and Katarapko Basins	Lock 3 - 4	100	15,000	40,000	IC7
Wiela shedding basin	Lock 5 - 6	2	30,000	40,000	IC7
Maize Island	Lock 2 - 3	8	30,000	40,000	IC7
Carpark Lagoon	Lock 3 - 4	15	40,000	45,000	FP1
Sugar Shack temporary basin S0000555	Below Lock 1	1	40,000	45,000	FP1
Wigley Reach	Lock 2 - 3	10		50,000	FP1
Molo Flat	Lock 1 - 2	62		60,000	FP2
Katarapko Creek	Lock 3 - 4	4		60,000	FP2
Martins Bend temporary wetlands	Lock 4 - 5	16	25,000	65,000	FP3
Markaranka East	Lock 1 - 2	9		65,000	FP3
Morgan Conservation Park (Northern Lagoons)	Lock 1 - 2	18	65,000	70,000	FP3
Hogwash Bend	Lock 1 - 2	25		75,000	FP4
Gerard black box waterings		5		TBD	
Murtho Park temporary wetland		10		TBD	
Island Reach				TBD	
Gerard lignum basins				TBD	
Markaranka temporary floodrunners		2		TBD	
Nikalapko		46		TBD	

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