Basin-scale evaluation of 2021–22 Commonwealth environmental water: Ecosystem diversity

Commonwealth Environmental Water Holder's Science Program: Flow Monitoring, Evaluation and Research Program (Flow-MER)

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Australian Government
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FLOW Monitoring Evaluation Research

Acknowledgements

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Cover photograph

Reed beds at Millewa Forest
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Executive summary

Strategic management of Commonwealth water for the environment by the Commonwealth Environmental Water Holder (CEWH) is key to achieving the Commonwealth's (Murray–Darling) *Basin Plan 2012* environmental objectives. The Commonwealth Environmental Water Holder's Science Program invests in Flow Monitoring, Evaluation and Research (Flow-MER) to demonstrate Basin-scale outcomes of Commonwealth water for the environment, support adaptive management and fulfil the CEWH's legislative requirements under the Basin Plan.

This evaluation reports on Ecosystem Diversity outcomes from Commonwealth water for the environment for the most recent water year (2021–22) and cumulatively since the beginning of the monitoring program in 2014–15. The evaluation also assesses the contribution of Commonwealth water for the environment to Basin Plan objectives, as well as aspects of adaptive management of Commonwealth water for the environment delivered for environmental outcomes in the Basin.

This evaluation is a high-level desktop analysis to quantify water-dependent ecosystems that potentially benefit from Commonwealth water for the environment. It interprets the diversity of Australian National Aquatic Ecosystem (ANAE) types supported by Commonwealth water for the environment at the Basin scale and more specifically within the Basin's 'managed floodplain' (the area of the Basin in which environmental water can be managed). The evaluation does not measure ecosystem responses directly; that is left to other Flow-MER project themes (Vegetation, Fish, Species Diversity, and Food Webs and Water Quality) that report in more detail on responses of species, populations and ecosystem functions that occur within the Basin's aquatic ecosystems.

The Basin's aquatic ecosystems are classified into 66 ecosystem types using the ANAE classification, of which 64 are located on the managed floodplain.[1] Ecosystem diversity as represented by the number of ecosystem types increases with catchment area, with no individual Basin valleys standing out as exceptionally rich or depauperate. Aquatic ecosystem diversity on the managed floodplain varies from a low of 19 ecosystem types in the Kiewa Valley to a high of 39 in the Condamine Balonne Valley.

Annual watering frequencies and inundation extents are used to examine the contribution of the whole portfolio of Commonwealth water for the environment watering actions to ecosystem diversity in the Basin rather than outcomes from specific actions. For this evaluation, river and floodplain ecosystem types are deemed 'supported' by environmental water in the areas that are inundated, and depressional wetlands (lakes and swamps) are deemed 'supported' by environmental water when all or part of their mapped extent coincides with environmental water inundation. Documenting the ecosystem diversity supported by Commonwealth water for the environment tests alignment of Commonwealth environmental water management to Basin Plan objective at paragraph 8.05(3)(b):

> *to ensure that representative populations and communities of native biota are protected and, if necessary, restored.*

A description of ecosystem types supported by Commonwealth environmental water at Ramsar Sites is provided as a foundation for future work to examine the contribution of Commonwealth environmental water management towards Basin Plan objective at paragraph 8.05(2)(a):

[1] This report uses the consistently classified ANAE geofabric v3 river line mapping to evaluate river ecosystems. The ANAE dataset includes 4 additional river types to cater for data gaps in the polygon mapping for rivers that are not used in this report but have contributed to totals in previous years.

to protect and restore a subset of all water-dependent ecosystems of the Murray–Darling Basin, including by ensuring that declared Ramsar wetlands that depend on Basin water resources maintain their ecological character.

This evaluation addresses the overarching question:

> What did Commonwealth environmental water contribute to ecosystem diversity?

This is addressed for the most recent water year (2021–22) and for the monitoring program's long-term record from 1 July 2014 to 30 June 2022 (2014–22).

Basin-scale evaluation 2021–22

- Commonwealth environmental water supported 55 ANAE ecosystem types (83% of the ecosystem types currently mapped in the Basin and 86% of the types on the managed floodplain).
- Commonwealth environmental water supported 184,000 ha of lakes and wetlands of 23 different ANAE types representing 70% of the lake and wetland ecosystem diversity and 12% of the total area of lakes and wetlands on the managed floodplain.
- Commonwealth environmental water supported longitudinal connectivity through 22,170 km of rivers (44% of the river length on the managed floodplain). These were predominantly permanent and temporary lowland rivers (97% combined) that connected laterally with 72,190 ha of floodplain that included 10 different floodplain vegetation communities and represents 5% of the managed floodplain in the Basin.
- End-of-system flows supported 23,768 ha of estuary habitat in The Coorong and Murray Mouth (100% of the estuary on the managed floodplain) and contributed to maintaining the ecological character of The Coorong, and Lakes Alexandrina and Albert Wetland Ramsar Site.
- Vegetated ecosystems were supported in agreement with the *Basin-wide environmental watering strategy* (the Strategy) rolling priorities and annual priorities for 2021–22:
  - Non-woody vegetation priorities to provide opportunities for growth were met, with Commonwealth environmental water delivered to 31,410 ha of meadow and marsh upstream of the Lower Lakes, another 9,259 ha of marsh around the Lower Lakes and 737 ha of sedge/forb/grassland riparian zone or floodplain.
  - A rolling priority to improve extent and condition of woody vegetation was met, with Commonwealth environmental water delivered to 69,888 ha of woody wetlands (swamps) and inundated 71,303 ha of woody floodplain vegetation.
  - A rolling priority to maintain the extent and improve the condition of lignum shrublands was met, with 13,021 ha of lignum floodplain inundated, and another 298 ha of temporary lignum swamp received Commonwealth environmental water.
  - An annual priority to increase inundation higher on the floodplain to support parched and stressed forests and woodlands was met, with 1,892 ha of black box floodplain (that is typically located higher on the floodplain) inundated by Commonwealth environmental water.
  - A Basin-wide annual watering priority to support inundation of the Warrego floodplain was met, with 2,858 ha of floodplain and 2,716 ha of wetlands inundated by Commonwealth environmental water in the Warrego Valley.

  - A Basin-wide annual watering priority to support inundation of the Lower Balonne floodplain was met, with Commonwealth environmental water inundating 8,387 ha of the Narran Lakes complex, including 2,376 ha of the Narran Lakes Nature Reserve Ramsar Site.
- Commonwealth environmental water delivered 1,380 GL to 9 Ramsar Sites in the Basin, supporting critical components, processes and services (critical CPS):
  - maintenance of waterbird breeding colonies that formed after widespread natural flooding at the Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses, The Macquarie Marshes, Narran Lakes and Barmah Forest Ramsar Site
  - vegetation listed as critical CPS at all sites; for example:
    - 99 ha of freshwater meadows in the Barmah Forest Ramsar Site, potentially supporting the recovery of Moira grass
    - nationally vulnerable river swamp wallaby-grass (*Amphibromus fluitans*) supported at Pollack Swamp in the NSW Central Murray Forests Ramsar Site
    - extensive inundation (2,723 ha, 99%) of the tall marsh of The Macquarie Marshes Ramsar Site
    - extensive inundation (1,679 ha, 43%) of lignum in the Narran Lake Nature Reserve Ramsar Site.

Basin-scale evaluation 2014–22

- Over the 8-year period 2014–22, Commonwealth environmental water supported 59 ecosystem types (89% of the ANAE ecosystem types in the Basin and 92% of the ANAE types currently mapped on the managed floodplain) representing:[2]
  - 35,338 ha of lakes representing 17% of lake area on the managed floodplain upstream of the Lower Lakes or 119,861 ha (41% of lake area on the managed floodplain) for the Basin including lakes Alexandrina and Albert
  - 100,873 ha of 21 types of palustrine wetland (21% of the wetland area on the managed floodplain)
  - 157,907 ha of 12[3] types of floodplain (10% of floodplain ecosystem area on the managed floodplain)
  - 26,245 km of 7 types of waterway (52% of the river length on the managed floodplain)
  - 23,768 ha of 9 estuarine ecosystems (100% of the estuary on the managed floodplain).
- At the Basin scale, Commonwealth environmental water contributed to watering frequencies that were broadly consistent with expected requirements – with more frequent support of permanent rivers, lakes, meadows and permanent tall marsh and less frequent inundation of temporary channels, swamps and floodplains. Detailed comparisons of inundation frequencies against desired frequency objectives for each ecosystem type are yet to be conducted.
- Watering is responsive to climatic conditions from year to year and sufficiently agile to deliver water in accordance with the Strategy's annual priorities, noting that measuring environmental benefits of those watering actions in terms of improvement in ecosystem condition was beyond the scope of this evaluation.

[2] Total figures for the Basin, including The Coorong, Lower Lakes and Murray Mouth (CLLMM) except where stated otherwise.

[3] These 12 floodplain types comprise 11 floodplain types upstream of the CLLMM and one additional type (Paperbark dominated floodplain) adjacent to the Coorong.

Key contributions to Basin Plan objectives

Basin Plan objective at paragraph 8.05(3)(b): 'to ensure that representative populations and communities of native biota are protected and, if necessary, restored'

- The representativeness of ecosystem types on the managed floodplain was established by Brooks (2021b). Of the Basin ecosystem types, 97% occur on the managed floodplain. The relative abundance (by area) of ecosystem types was similar when comparing the managed floodplain with the whole Basin.
- In 2021–22, there were 55 ANAE ecosystem types representing 86% of the ecosystem diversity on the managed floodplain that were recipients of Commonwealth environmental water. They cover a combined area of 305,263 ha with an additional 22,170 km of river representing the *populations and communities of water dependent native biota* that are assumed to have been supported or *protected* by the environmental water they received. The evaluation was unable to examine if ecosystems were *restored*.
- The 8-year watering history, 2014–22, included a similar diversity of ecosystem types through the years, but a wide difference in the total extent. The current 2021–22 year was an outlier, with numerous watering actions building on widespread natural flooding to inundate up to twice the area as previously achieved. Ecosystems that continue to not be watered are the naturally wet bogs, springs and paperbark swamps or saline systems where delivery of fresh water is likely not appropriate.

Basin Plan objective at paragraph 8.05(2)(a): 'to protect and restore a subset of all water-dependent ecosystems of the Murray–Darling Basin, including by ensuring that declared Ramsar wetlands that depend on Basin water resources maintain their ecological character'

- Commonwealth environmental water was delivered to 9 Ramsar Sites in 2021–22, supporting a total of 173,874 ha of 52 different ecosystem types within the Ramsar estate. This areal extent is dominated by the 81,144 ha of lakes Alexandrina and Albert and 18,435 ha of the Coorong. Excluding these three waterbodies in the CLLMM, Commonwealth environmental water directly supported 75,611 ha of Ramsar ecosystems. Some evidence for supporting Ramsar Site critical components, processes and services was identified (e.g. supporting site hydrology, and vegetation); however, a detailed investigation to determine if Ramsar Site ecological character was maintained (the Basin Plan objective) was beyond the scope of this evaluation.

Informing adaptive management

- At the Basin scale, the 8-year evaluation of watering frequencies suggests the Commonwealth Environmental Water Holder current water allocation and delivery is qualitatively fit for purpose.
- The delineation of the managed floodplain was expanded using 8 years of evidence from the Long Term Intervention Monitoring Project (LTIM) (2014–15 to 2018–19) and Flow-MER inundation mapping to add 274,202 ha of aquatic ecosystems that can be managed with environmental water in the Basin.
- Creation of a unified register describing the purpose, timing, duration and extent of all environmental water management, along with observed outcomes and any unintended consequences, would empower improved Flow-MER evaluation and inform the collaborative planning process.

- Development of watering objectives for ecosystem types and expected ecosystem-scale outcomes would support a performance-driven evaluation to assess the impact of Commonwealth environmental water beyond the current simplistic view that documents the pattern of water delivery with assumed benefits.

Overview

The Commonwealth Environmental Water Holder's (CEWH) Science Program invests in monitoring, evaluation and research activities through its Flow Monitoring, Evaluation and Research Program (Flow-MER). The Flow-MER Basin-scale evaluation assesses the contributions of Commonwealth water for the environment to meeting the environmental objectives stated in section 8 of the (Murray–Darling) Basin Plan 2012 and in the Basin-wide environmental watering strategy. Six Basin Themes (Figure 1) are evaluated using data from 7 Flow-MER Selected Areas (left-side map, Figure 2) and the 19 valleys (right-side map, Figure 2) where the CEWH holds water entitlements in the Murray–Darling Basin. The evaluation builds on work undertaken by its predecessors.[4] Research informs the evaluation and the CEWH's Science Program.

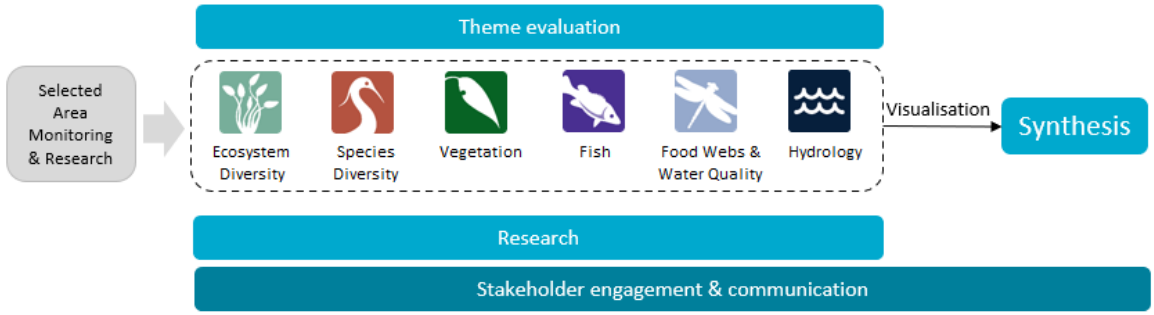

Figure 1 Schematic of the components of the Basin-scale evaluation
The evaluations are informed by Basin-scale research projects, stakeholder engagement and communication, including Indigenous engagement and visualisation, as well as the 7 Selected Area projects.

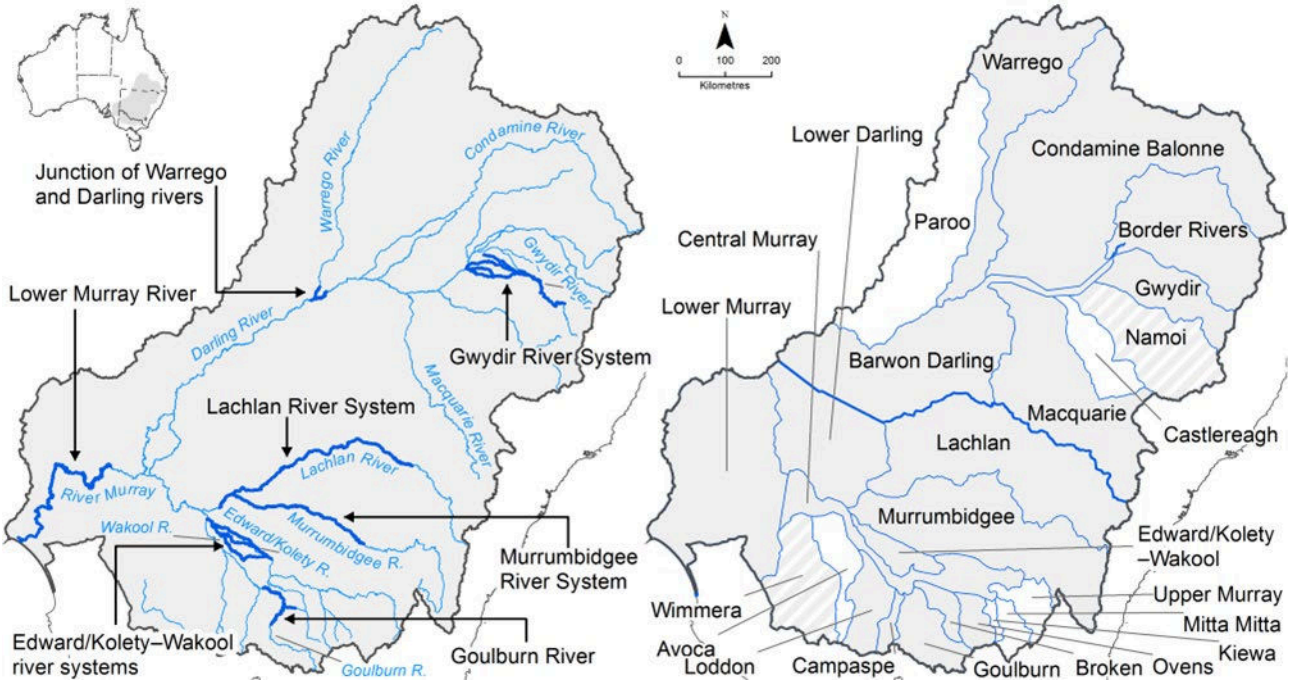

Figure 2 The 7 Selected Areas (left map) and 25 valleys (right map) established for long-term monitoring of the impacts of environmental watering under the LTIM and Flow-MER (2014–15 to present)
In the valleys map, shaded grey and grey stripes show the 19 valleys where the Commonwealth holds water entitlements and which are in scope for evaluation; white identifies those valleys which are not in scope. The thicker blue denotes the northern and southern parts of the Basin. The Wimmera and Namoi valleys (grey stripes) did not receive Commonwealth water for the environment in 2021–22.

[4] The Long Term Intervention Monitoring (LTIM) and Environmental Water Knowledge and Research (EWKR) projects (2014–2019)

Evaluating the contribution of Commonwealth water for the environment to observed environmental outcomes

The Basin-scale evaluation team uses water delivery and outcomes data provided by the CEWH's Science Program, along with monitoring data provided by the 7 Selected Areas. Other publicly available data may be used where relevant data are not collected by the Selected Areas.

Evaluation of the contribution of Commonwealth water for the environment to observed environmental outcomes for the 6 Basin Themes depends on the data available.

> When delivered with other water, ecological outcomes cannot be apportioned and Commonwealth water for the environment is reported as contributing to, or supporting, the environmental outcomes of the watering action.
>
> This was the case in this evaluation year (2021–22) for several of the large watering actions in which Commonwealth water for the environment was not the largest proportion.

- The multi-year Hydrology (instream) and Vegetation and Fish themes have sufficient data to model and compare environmental outcomes both with and without Commonwealth water for the environment (counterfactual modelling5).
- Ecosystem Diversity, Species Diversity and Vegetation themes identify environmental responses in locations that received Commonwealth water for the environment (often in conjunction with other sources of environmental or non-environmental water) and, where feasible, compare with areas that did not receive Commonwealth water for the environment.6
- Hydrology (inundation) and Food Webs and Water Quality themes use flow and water quality metrics to infer likely outcomes.
- Fish (annual), Vegetation and Food Webs and Water Quality themes synthesise findings across Selected Areas.

Partnering on watering actions

Commonwealth water for the environment (also referred to as Commonwealth environmental water, CEW) is often delivered in conjunction with other environmental water holdings and non-environmental water releases (such as for irrigation or during high-flow events).

Commonwealth environmental watering actions for the most recent evaluation year (2021–22) and cumulative over the 8 evaluation years (2014–15 to 2021–22) are provided in Table 1.

Table 1 Summary statistics for most recent evaluation year and multi-year evaluation period

	2021–22	2014–22
Volume of CEW actions (GL)	2,786	14,058
Number of CEW actions	160	979
% of CEW actions with partners or with other flows	40%	–
CEW % of total volume of partnered watering actions	84%	–
CEW % of total Basin surface water inflows	6%	7%

- statistic not provided due to high uncertainty in the data

Evaluation reporting

Each Theme prepares a technical evaluation report for each water year from which key outcomes and lessons for adaptive management are brought together, with research highlights, into an annual Synthesis report. To provide consistency over the life of Flow-MER and its predecessors, some content in these annual reports may be reused from previous years. In these cases, all efforts have been made to cite the relevant LTIM, EWKR or Flow-MER publication. All reports published by the CEWH are available from the DCCEEW website.

Flow-MER partnership

> Flow-MER is led by CSIRO in partnership with the University of Canberra. Collaborators on the 2021–22 evaluation include the Arthur Rylah Institute, Charles Sturt University, South Australian Research & Development Institute, NSW Department of Primary Industries, the Australian River Restoration Centre and Brooks Ecology & Technology.

[5] In the counterfactual approach, Commonwealth environmental water is removed from the observed streamflow time series, creating a hypothetical (counterfactual) daily streamflow time series with no Commonwealth environmental water. This approach is used to infer the effects of Commonwealth water for the environment as an experimental design with controls and/or before–after comparisons is not possible.

[6] In these evaluations it is not possible to attribute the Commonwealth's contribution separately to other environmental water under the current methods.

Contents

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Tables

Part I Evaluation of outcomes

This part provides the results of the 21–22 evaluation and includes an overview of the evaluation objectives, approach and methods, contribution to Basin Plan objectives and a reflection on adaptive management.

1 Introduction

Biological diversity describes the variety of living organisms and ecosystems on Earth. The concept of biodiversity is often understood in terms of numbers of species of plants, animals and microbes, but increasingly the definition is expanded to include other forms of biological variation, including genetic diversity, ecosystem diversity and diversity of ecosystem function (Figure 1.1).

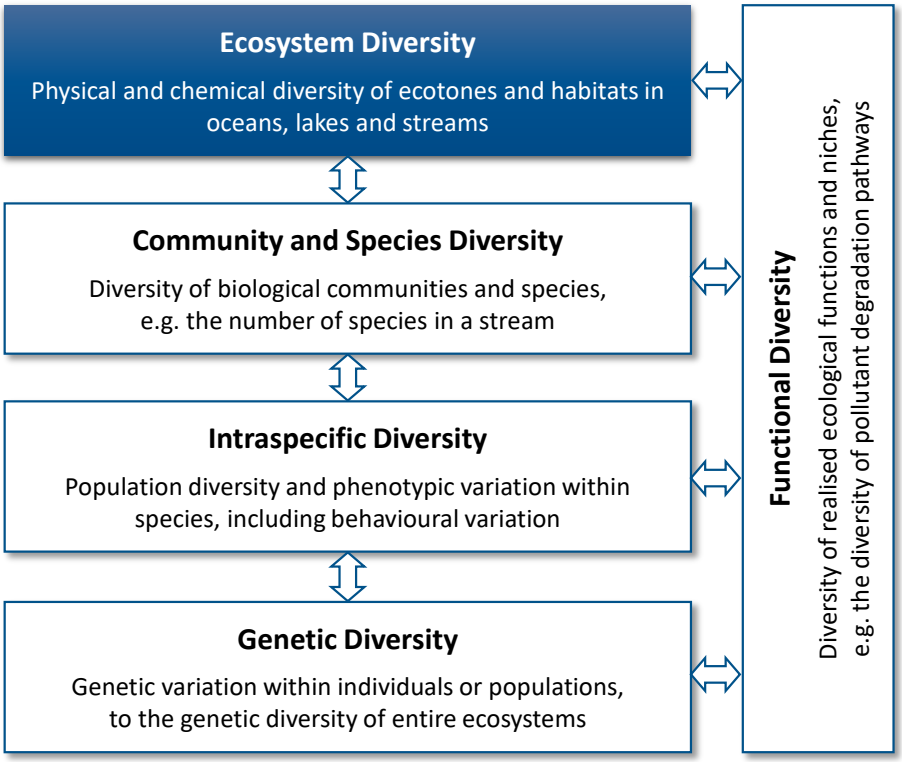


Figure 1.1 Hierarchical levels of biodiversity in aquatic ecosystems

Source: Geist (2011)

Commonwealth environmental water is delivered to ecosystems in the Basin to support water-dependent species, critical habitats, fluxes of nutrients, food webs and ecosystem services that benefit people; for example, recreational fishing and cultural heritage (MDBA 2019).

The Ecosystem Diversity evaluation reported here is conducted at a whole-of-Basin scale, including monitored and unmonitored catchments, to evaluate the contribution of Commonwealth environmental water to biodiversity objectives outlined in the Commonwealth Environmental Water Outcomes Framework (CEWH 2013) and the Commonwealth's *Basin Plan 2012*. It does this by quantifying the ecosystems potentially supported by Commonwealth environmental water during the 2021–22 water year and over the 8 years of monitoring from 2014–15 to 2021–22 (2014–22).

The methods described below repeat or adapt text from the previous year (Brooks 2022) with all hydrological data from 2014–15 onwards being re-analysed to ensure consistent use of updated datasets for the entire 8-year duration of the analysis.

1.1 Evaluation objectives

This evaluation examines the contribution of Commonwealth environmental water towards Basin Plan objectives by addressing the following overarching evaluation question, in line with previous reports:

> What did Commonwealth environmental water contribute to ecosystem diversity?

This question was developed under the Commonwealth Environmental Water Outcomes Framework (CEWH 2013) to meet the broader objectives of the Basin Plan.

This evaluation examines the contribution of Commonwealth environmental water towards the Basin Plan objective at paragraph 8.05(3)(b):

> *to ensure that representative populations and communities of native biota are protected and, if necessary, restored.*

A description of ecosystem types supported by Commonwealth environmental water at Ramsar Sites is provided as a foundation for future work to examine the contribution of Commonwealth environmental water management towards the Basin Plan objective at paragraph 8.05(2)(a):

> *to protect and restore a subset of all water-dependent ecosystems of the Murray–Darling Basin, including by ensuring that declared Ramsar wetlands that depend on Basin water resources maintain their ecological character.*

1.2 Evaluation coverage

This evaluation summarises the maximum annual extent of Commonwealth environmental water across all water-dependent ecosystems in the Basin (including lakes, wetlands, rivers, floodplains and the estuary) during 2021–22 and cumulatively over the 8-year period 2014–22. Spatially, the evaluation is presented for the whole Basin, for each of the 25 major river valleys, and for Ramsar Sites. A complete assessment of the status of ecological character of Ramsar Sites is beyond the scope of this evaluation. Where possible, the contribution of Commonwealth environmental water to ecosystem types that align with Hydrology and Vegetation Basin themes listed as critical components of Ramsar Sites is considered.

Table 1.1 provides a summary of the ecosystem types on the managed floodplain supported by Commonwealth environmental water.

Table 1.1 Ecosystem types on the managed floodplain and number of types supported by Commonwealth environmental water

Valley	Total types	Supported types	%
Barwon Darling	24	16	67%
Border Rivers	34	22	65%
Broken	19	5	26%
Campaspe	16	2	13%
Central Murray	35	24	69%
Condamine Balonne	39	25	64%
Edward/Kolety–Wakool*	24	13	54%
Goulburn*	23	3	13%
Gwydir*	28	10	36%
Lachlan*	29	14	48%
Lower Darling	21	4	19%
Loddon	19	2	11%
Lower Murray*	35	27	77%
Murrumbidgee*	31	24	77%
Macquarie	28	23	82%
Ovens	20	2	10%
Warrego*	31	18	58%

* Contains Selected Area

1.3 About this report

This ecosystem diversity evaluation is prepared by Shane Brooks in partnership with CSIRO.

The report is presented in 9 chapters:

- Chapter 1 is the introduction
- Chapter 2 outlines how the evaluation was undertaken and summarises the datasets that contribute to the evaluation
- Chapter 3 summarises the data that underpin the evaluation
- Chapter 4 is the annual evaluation for 2021–22
- Chapter 5 is the cumulative evaluation for 8 years 2014–22
- Chapter 6 summarises the contribution to Basin Plan objectives
- Chapter 7 summarises ecosystem outcomes that align to Basin annual environmental watering priorities 2021–22
- Chapter 8 provides adaptive management recommendations
- Chapter 9 details methods used in the analysis.

Data tables and analyses that support the evaluation are provided in appendices. Long-term data from 2014–15 to 2019–20 that support the cumulative evaluation are published by the CEWO on Data.gov.au.

2 Overview of approach

This is a high-level desktop analysis that collectively evaluates the entire portfolio of Commonwealth environmental water management, rather than assessing or making technical recommendations for individual watering actions. The contribution of Commonwealth environmental water to ecosystem diversity is quantified as the number of Australian National Aquatic Ecosystem (ANAE) types (described below) that received Commonwealth environmental water for the water year 2021–22 and cumulatively over the 8-year period of monitoring 2014–22. The evaluation is conducted at the scales of the whole Basin, within each of the 25 major river valleys and for high conservation value Ramsar Sites.

It presumes that environmental water is of benefit to the receiving water-dependent ecosystems without measuring the ecosystem response to water directly. Other Flow-MER Basin Themes (Vegetation, Fish, Species Diversity, and Food Webs and Water Quality) report more specifically on responses of species, populations and ecosystem functions that occur within the aquatic ecosystems of the Basin (Figure 2.1).

This evaluation continues the sequence of annual and cumulative evaluation established during the Long Term Intervention Monitoring Project (LTIM) (2014–15 to 2018–19) (described in Brooks 2020). While the approach has not changed substantively from that used in previous evaluations, the datasets and mapping have improved, prompting a re-analysis of all previous hydrological inundation and ecosystem mapping data since monitoring began in 2014–15 to incorporate these improvements and to ensure results are comparable among years.

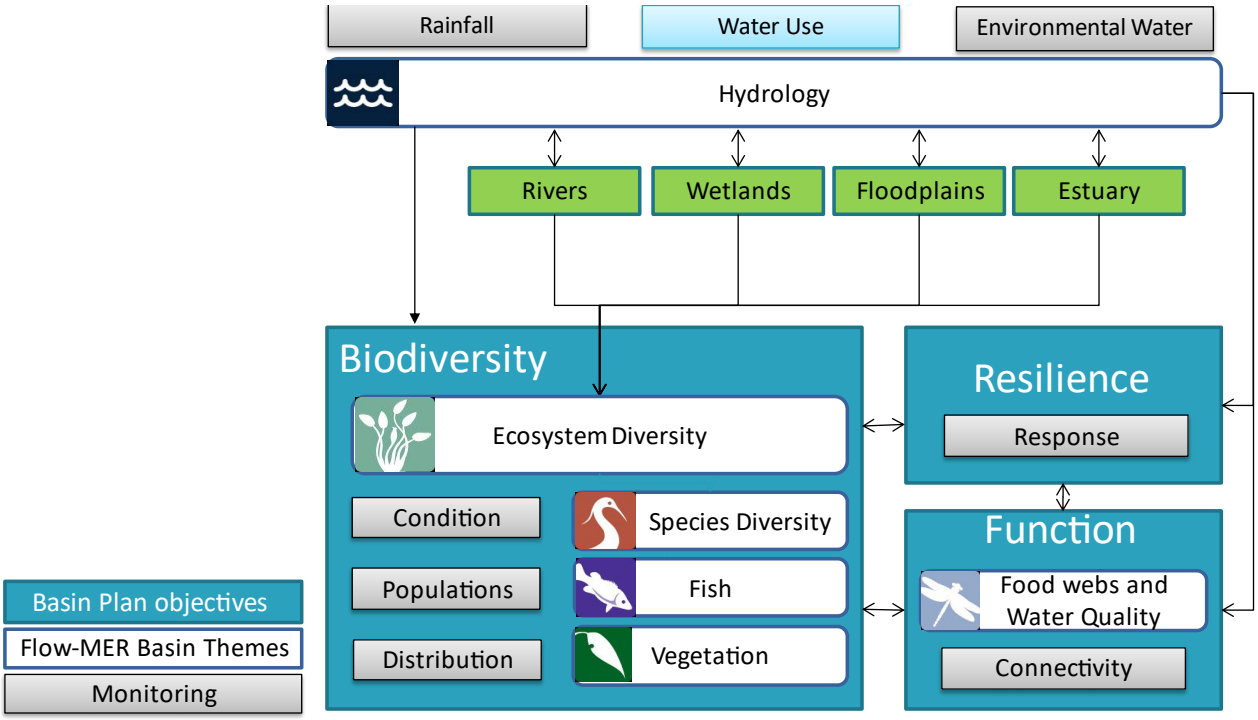


Figure 2.1 Flow-MER evaluation is undertaken in a number of themes that collectively assess the contribution of Commonwealth environmental water to Basin biodiversity, resilience and ecosystem function

Ecosystem Diversity is directly influenced by hydrology and in turn provides the diverse array of water-dependent habitats that support Basin species and food webs.

3 Data

This chapter summarises the spatial datasets that underpin the evaluation. The datasets are summarised in Table 3.1 and an overview of how these data have been analysed and synthesised follows below. Technical detail required to replicate the analysis is provided in Chapter 9.

Table 3.1 Data sets contributing to the Ecosystem Diversity evaluation

Dataset	Purpose	Reference
The Australian National Aquatic Ecosystem (ANAE) Classification of the Murray–Darling Basin v3.0	Spatial dataset mapping all the estuary, lakes, wetlands, floodplains and rivers in the Basin. The richness of ANAE types defines Ecosystem Diversity	Brooks (2021a)
Inundation by Commonwealth environmental water	Maps the annual extent of inundation by Commonwealth environmental water in each year of monitoring	Guarino and Sengupta (2023) for the 2021–22 year
CEWO Murray–Darling Basin valleys	Spatial mapping of boundaries for the 25 major river valleys in the Basin	CEWO (2022a)
Flow-MER MDB managed floodplain	Mapped extent estimating the area of the Basin that can be influenced by management of water for environmental outcomes	CEWO (2022b)

3.1 The Australian National Aquatic Ecosystem (ANAE) classification of the Murray–Darling Basin v3.0

Ecosystem types in the Basin are defined by the ANAE Classification Framework (Aquatic Ecosystems Task Group 2012). The framework was designed to help support adaptive management and monitoring of water-dependent ecosystems across the multiple jurisdictions in the Basin by providing a common language for describing and naming aquatic ecosystem types. The ANAE classification of the Basin v3.0 provides the most complete contemporary mapping of the distribution and extent of water-dependent ecosystems in the Basin (Brooks 2021a). The areas of approximately 300,000 aquatic ecosystems have been mapped to 5 high-level system classes (Figure 3.1) that are further classified into 66 ANAE types, including 8 types of lake, 29 types of palustrine wetland, 12 floodplain types, 8 river types (Figure 3.2), 9 estuarine ecosystem types and waterholes and springs. They represent a combined area of approximately 83,000 km^2 or nearly 8% of the Basin. The ANAE classes provide the unit of currency in this evaluation to quantify ecosystem diversity as the number of different ANAE types and their area that received Commonwealth environmental water.

Only the larger rivers are mapped as areas. To provide a comprehensive map of all rivers and smaller streams, the ANAE v3.0 uses the Geofabric v3.2 Network Streams line mapping (BOM 2020) (Figure 3.2). The Geofabric line mapping was generated consistently for the Australian continent using a 1 second (30 m) resolution digital elevation model This consistency is important because river length measurement is highly dependent on the level of detail in mapping, with higher resolution mapping capturing more bends in the river planform that increased measurement of river length between 2 points. There are approximately 200,000 river features mapped, representing 50,000 km of perennial flowing rivers and more than 400,000 km of temporary flowing rivers and streams (Figure 3.2). Because they are mapped as line segments, the ecosystems receiving Commonwealth environmental water are quantified by their river length (km), in contrast to the wetlands and floodplains that are quantified by area (hectares; ha).

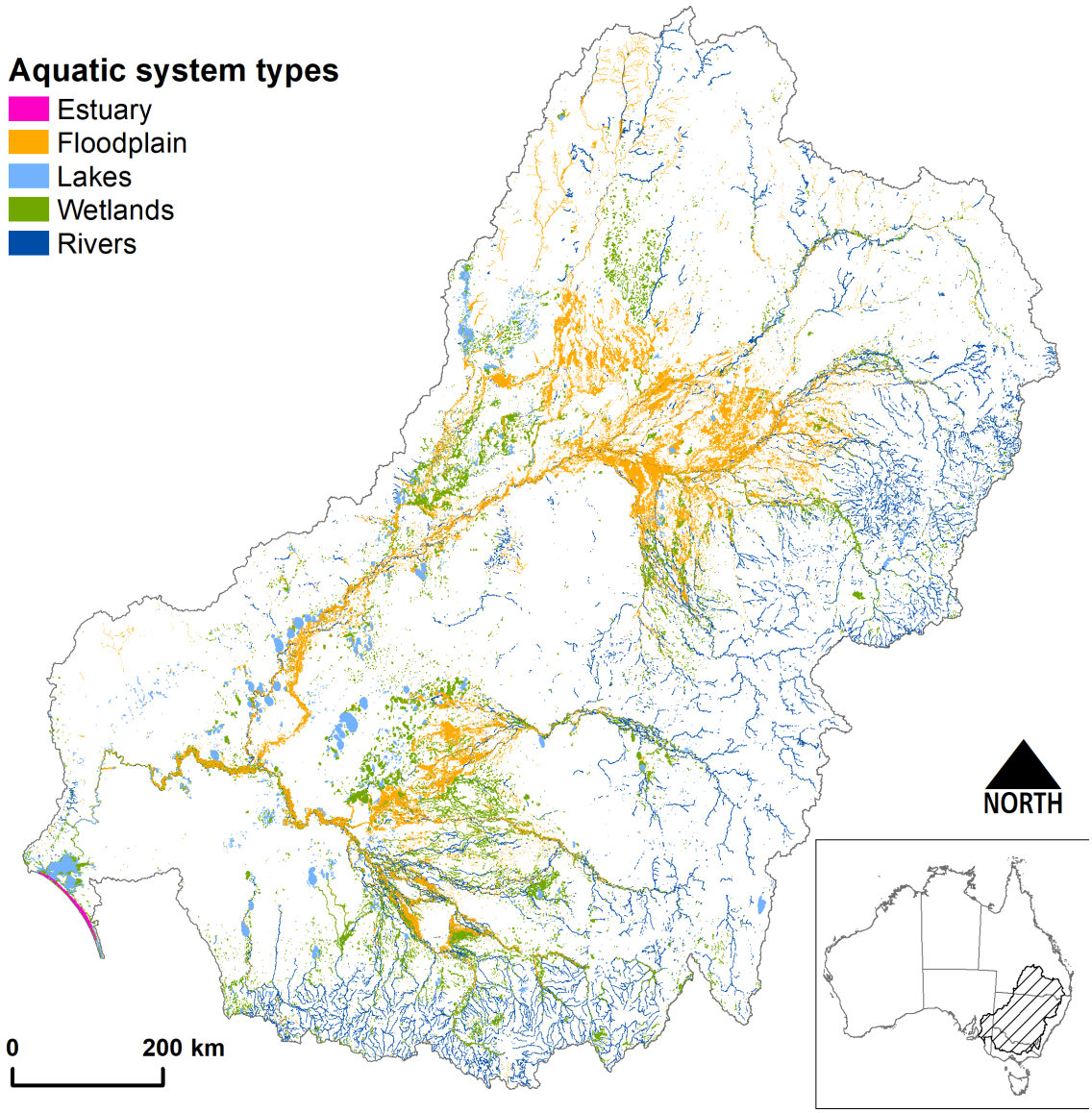


Figure 3.1 Aquatic system types of the Murray–Darling Basin

The full diversity of Australian National Aquatic Ecosystem (ANAE) types can be seen in the Basin summaries in Chapter 4

Data source: Brooks (2021a)

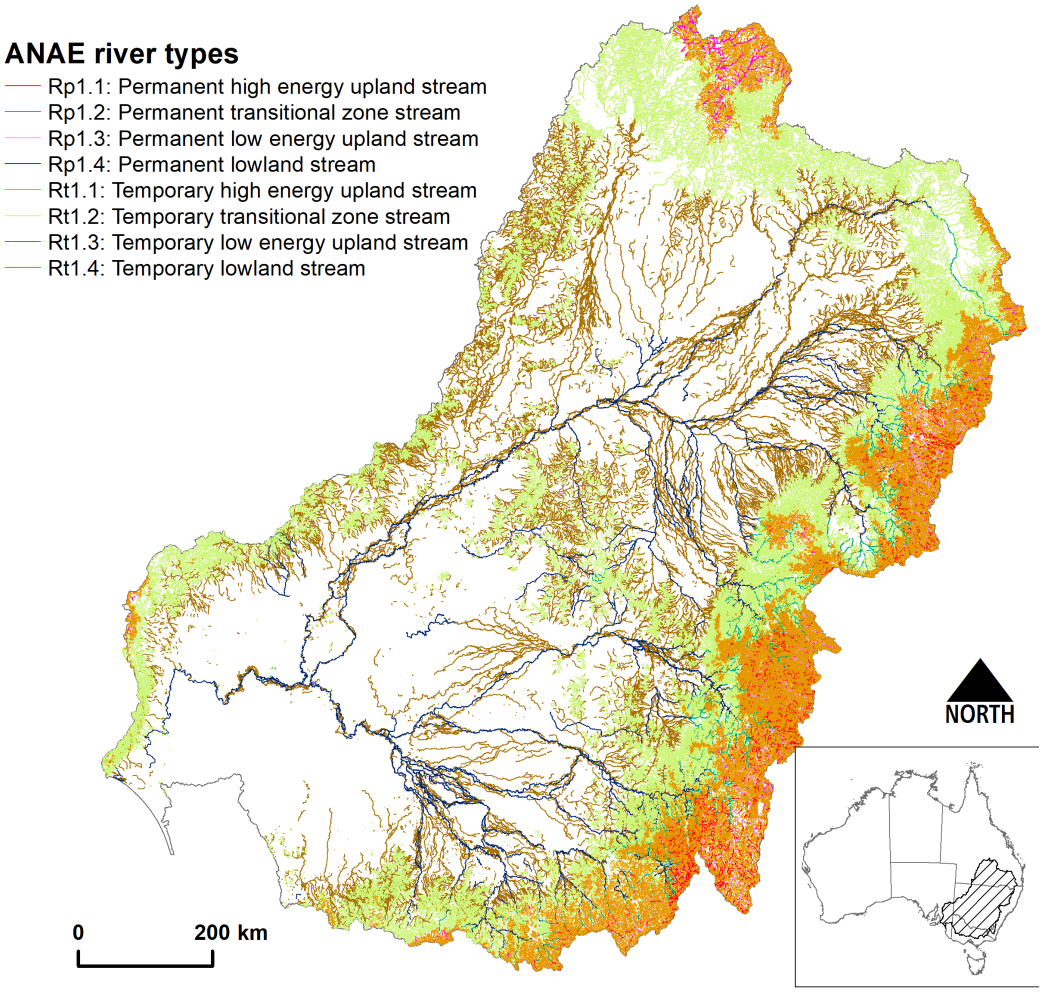


Figure 3.2 Australian National Aquatic Ecosystem (ANAE) riverine aquatic ecosystem types in the Murray–Darling Basin

Data source: Brooks (2021a)

3.2 Inundation by Commonwealth environmental water 2021–22

In 2021–22, there were 160 watering actions that delivered Commonwealth environmental water to aquatic systems in the Basin. Commonwealth environmental water supported 66 actions (62% by volume) for instream flow component types: base flows (32 actions), freshes (27 actions), bankfull flows (3 actions), combinations of base flows and freshes (3 actions) and combinations of bankfull flows and freshes (1 action). Of the remaining actions, 81 were delivered to support wetlands (21% by volume), 4 actions were purposed as combination flows supporting instream and overbank flows (1% by volume) and 9 were combinations of wetland, overbank and instream flow components (16% by volume).

The maximum extent of inundation by all Commonwealth environmental water delivered in the 2021–22 water year has been mapped by Guarino and Sengupta (2023) as a combined annual summary (Figure 3.3). Where Commonwealth environmental water is provided in conjunction with other environmental water (such as from state agencies) in a combined delivery, the extent mapped is the combined extent. The data do not include watering actions delivered by other stakeholders where Commonwealth environmental water is not included. This is a limitation of the current evaluation and a recommendation to improve the capture of all environmental water is included in Chapter 8.

Commonwealth environmental water inundation mapping is in 2 datasets which are combined in Figure 3.3:

- a raster dataset representing inundation of wetlands and floodplains by environmental water outside of river channels
- the ANAE river line mapping for all river segments that contained environmental water during the water year. River reaches that received in-channel pulses, freshes and passing flows are identified; however, the river channel inundation mapping is not of sufficient resolution to quantify increases in river width nor to identify local inundation of riverbanks, benches or fringing habitats along channel margins.

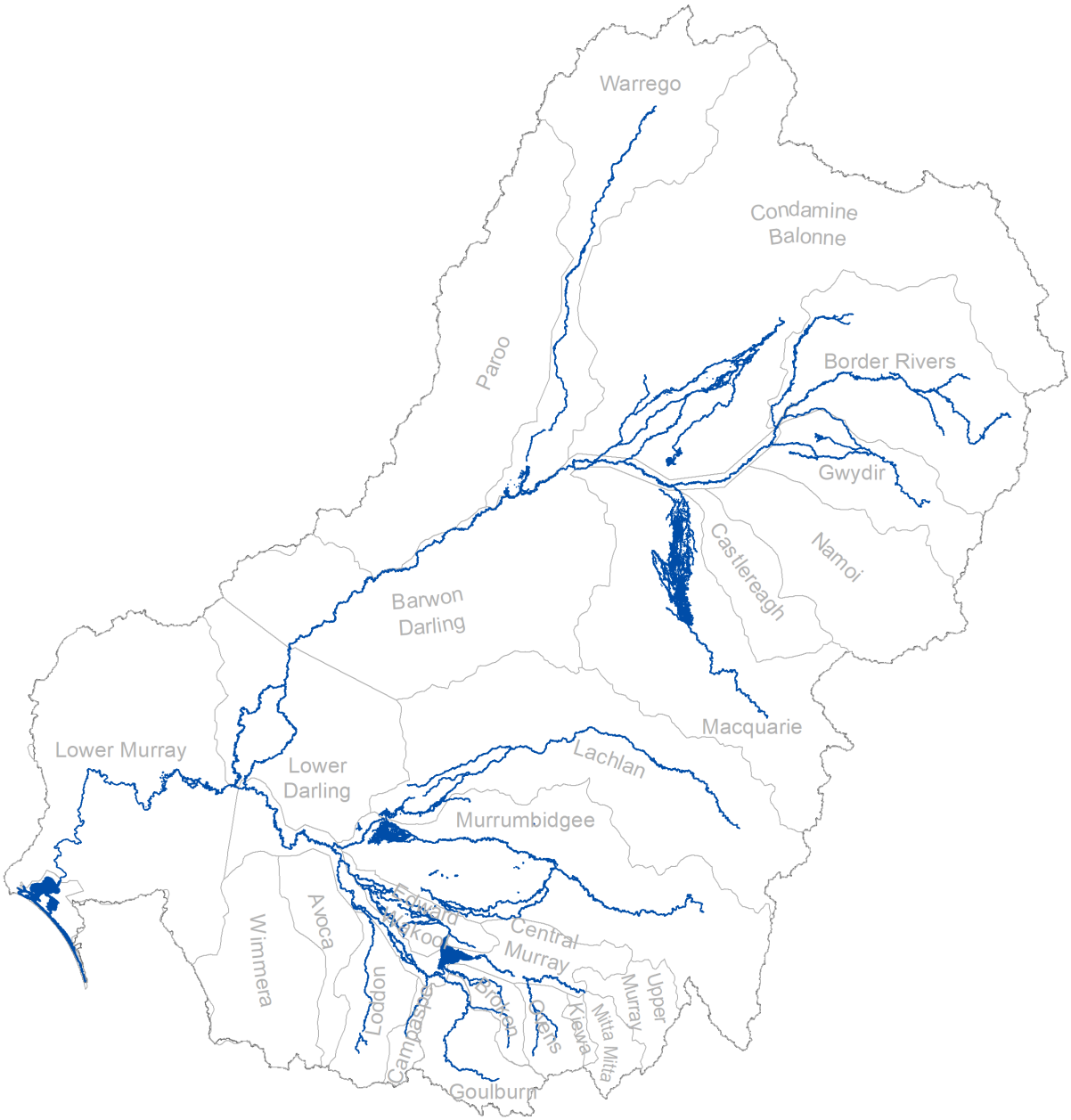


Figure 3.3 Maximum extent of all Commonwealth environmental water in rivers, wetlands and floodplains, 2021–22

For this evaluation, river and floodplain ecosystem types are deemed 'supported' by Commonwealth environmental water in the areas that are ***inundated***. The inundated area is the floodplain area that is overlapped by the mapped extent of inundation. Floodplains occur as broad continuous expanses and most ecosystem responses are limited to the wetted area. For rivers, the sum length of all channel segments

containing Commonwealth environmental water is calculated directly from the inundation mapping (Figure 3.3).

Depressional wetlands (lakes and swamps) are deemed 'supported' by Commonwealth environmental water when all or part of their mapped extent coincides with environmental water inundation. The entire wetland area is considered ***influenced*** by the water management. This approach acknowledges that wetland ecosystems, particularly vegetated palustrine systems, are not limited to the open water's edge. They include areas of wet hydric soils and vegetation that are connected by local watertables. Providing water to the deepest parts of the wetland also benefits fringing vegetation and provides habitat for waterbirds, frogs and turtles that can be found outside of the waterbodies. Quantifying the total area of the wetland influenced also addresses the underestimation of inundation extent in wetlands where water is obscured by the thick overstorey of emergent vegetation in which water is not reliably mapped from satellite imagery. This is particularly notable in tall marsh, grass marshes, sedgelands and meadows where green vegetation obscures a high proportion of the water such that water detection in satellite imagery may only show a few scattered pixels of water when the entire wetland is filled (e.g. Figure 3.4).

GIS workflows for calculating these 2 measures are provided in Chapter 9.

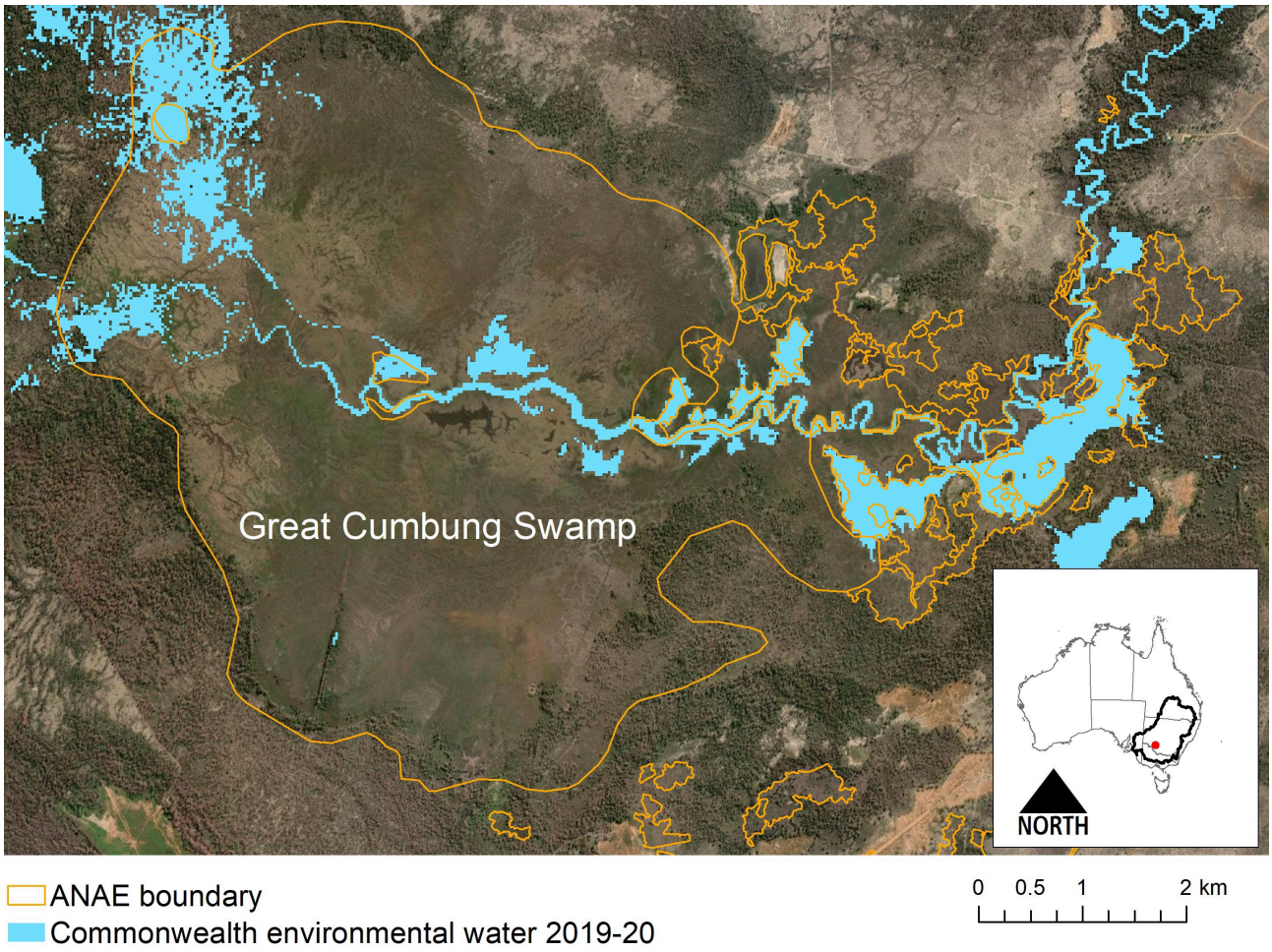


Figure 3.4 Area of the Great Cumbung Swamp showing visible inundation by Commonwealth environmental water, whereas that mapped by Sentinel-2 satellite is limited to where open water is visible between the reed beds
ANAE = Australian National Aquatic Ecosystem

Source: Brooks (2021b)

3.3 Basin valleys

A spatial layer was developed for LTIM that divides the Basin into 25 major river valleys (see Figure 3.3). These boundaries were derived from the Sustainable Rivers Audit catchment boundaries (MDBA 2012) with a modification to separate the Edward/Kolety–Wakool Valley from the Central Murray and to assign wetlands near valley boundaries to the valley to which they are allocated by water managers and Commonwealth environmental water accounting procedures (Stewardson and Guarino 2016).

3.4 Extent of managed floodplain

The 'managed floodplain' is the estimated area of the Basin that can be influenced with the 2,075 GL of environmental water allocated to the environment under the Basin Plan. It includes actively managed areas that can receive environmental water delivered from large headwater storages or via 'environmental works' sites on the Murray River floodplain from The Living Murray Program. It also includes passively managed areas that receive environmental water via flow rules in water resource plans or via natural events. Approximately 32% of the Basin's total area of lakes occurs on or adjacent to the managed floodplain, as well as 37% of total Basin palustrine wetland area, 25% of floodplains and 10% of river lengths (Brooks 2021b).

The managed floodplain was originally mapped for the *Basin-wide environmental watering strategy* (the Strategy) (MDBA 2019) as the 'managed floodplain with current constraints' by the Murray–Darling Basin Authority (MDBA) (MDBA 2018). Compared with the inundation from Commonwealth environmental water 2014–21 mapped by LTIM and Flow-MER, an additional 274,202 ha (a 7% increase) in areas of environmental water management were identified and added to the managed floodplain by Brooks (2022) (Figure 3.5). Additional watered extents from the current 2021–22 year were not added to the managed floodplain mapping due to uncertainty in the extent to which widespread natural flooding may have carried environmental water to areas that would typically be considered out of scope for water management.

This evaluation compares the ecosystem diversity supported by Commonwealth environmental water with the managed floodplain area to couch the reported outcomes in the context of the area of the Basin that is considered to be in scope for water management.

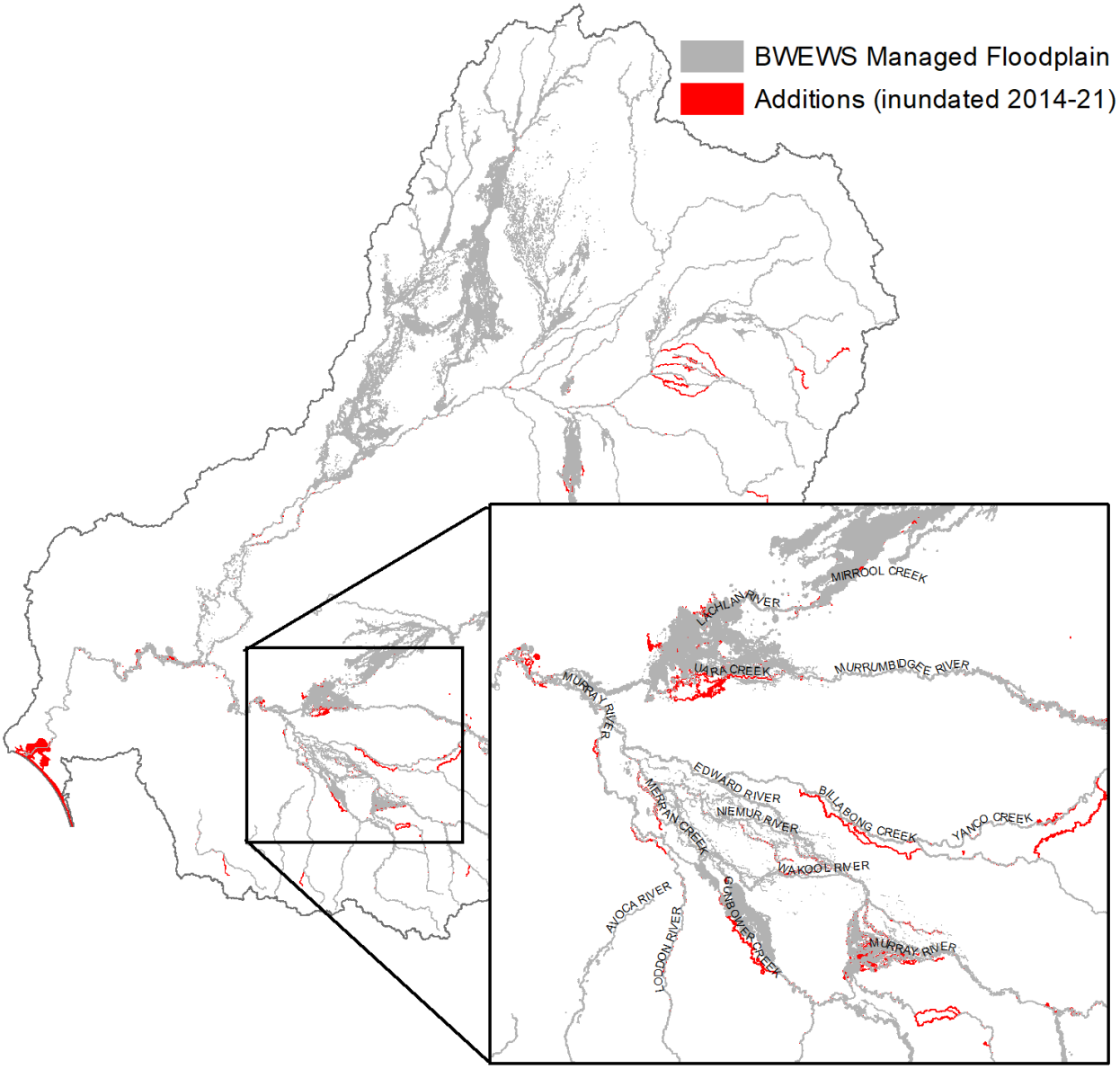


Figure 3.5 Extent of the *Basin-wide environmental watering strategy* (the Strategy) managed floodplain expanded to include areas receiving water for the environment in 2014–21

Source: Brooks (2022)

4 Basin-scale evaluation 2021–22

This chapter evaluates the contribution of Commonwealth environmental water to ecosystem diversity in the Basin by examining the measured extent of lakes, wetlands and rivers that received Commonwealth environmental water across the whole Basin, and within Ramsar Sites.

4.1 Key findings

- Commonwealth environmental water supported 55 ANAE ecosystem types (83% of the ecosystem types currently mapped in the Basin and 86% of the types on the managed floodplain).
- Commonwealth environmental water supported 184,000 ha of lakes and wetlands of 23 different types representing 70% of the lake and wetland diversity and 12% of the total area of lakes and wetlands on the managed floodplain.
- Commonwealth environmental water supported longitudinal connectivity through 22,170 km of rivers (44% of the river length on the managed floodplain). These were predominantly permanent and temporary lowland rivers (97% combined) that connected laterally with 72,190 ha of floodplain that included 10 different floodplain vegetation communities and represents 5% of the managed floodplain in the Basin.
- End-of-system flows supported 23,768 ha of estuary habitat in the Coorong and Murray Mouth (100% of the estuary on the managed floodplain) and contributed to maintaining the ecological character of The Coorong, and Lakes Alexandrina and Albert Wetland Ramsar Site.
- Vegetated ecosystems were supported in agreement with the Strategy's Basin-wide annual watering priorities for 2021–22:
  - Non-woody vegetation priorities to provide opportunities for growth were met, with Commonwealth environmental water delivered to 31,410 ha of meadow and marsh upstream of the Lower Lakes, another 9,259 ha of marsh around the Lower Lakes and 737 ha of sedge/forb/grassland riparian zone or floodplain.
  - A rolling priority to improve extent and condition of woody vegetation was met, with Commonwealth environmental water delivered to 69,888 ha of woody wetlands (swamps) and inundated 71,303 ha of woody floodplain vegetation
  - A rolling priority to maintain the extent and improve the condition of lignum shrublands was met, with 13,021 ha of lignum floodplain inundated, and another 298 ha of temporary lignum swamp received Commonwealth environmental water.
  - An annual priority to increase inundation higher on the floodplain to support parched and stressed forests and woodlands was met, with 1,892 ha of black box floodplain (that is typically located higher on the floodplain) inundated by Commonwealth environmental water.
  - A Basin-wide annual watering priority to support inundation of the Warrego floodplain was met, with 2,858 ha of floodplain and 2,716 ha of wetlands inundated by Commonwealth environmental water in the Warrego Valley.
  - A Basin-wide annual watering priority to support inundation of the Lower Balonne floodplain was met, with Commonwealth environmental water inundating 8,387 ha of the Narran Lakes complex, including 2,376 ha of the Narran Lakes Nature Reserve Ramsar Site.

- Commonwealth environmental water delivered 1,380 GL to 9 Ramsar Sites in the Basin supporting critical CPS:
  - maintenance of waterbird breeding colonies that formed after widespread natural flooding at the Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses, The Macquarie Marshes, Narran Lakes and Barmah Forest Ramsar Sites
  - vegetation listed as critical CPS at all sites, For example:
    - 99 ha of freshwater meadows in the Barmah Forest Ramsar Site, potentially supporting the recovery of Moira grass
    - nationally vulnerable river swamp wallaby-grass (*Amphibromus fluitans*) supported at Pollack Swamp in the NSW Central Murray Forests Ramsar Site)
    - extensive inundation (2,723 ha, 99%) of the tall marsh of The Macquarie Marshes Ramsar Site
    - extensive inundation (1,679 ha, 43%) of lignum in the Narran Lakes Ramsar Site.

4.2 Outcomes for Basin ecosystems

The 160 watering actions in 2021–22 inundated floodplains and floodplain wetlands in 12 of the 25 valleys of the Basin (Table 4.1). Commonwealth environmental water delivered to the Campaspe, Goulburn, Loddon and Ovens rivers in Victoria was confined to the river channel. The largest areas of inundated wetlands and floodplain of more than 10,000 ha were from Commonwealth environmental water that was delivered to extend the duration of widespread natural flooding and provide cues to support waterbird breeding rookeries (Gwydir, Macquarie and Murrumbidgee valleys) and fish movement and breeding (Central Murray, Murrumbidgee).

Table 4.1 Major categories of aquatic ecosystems in each valley inundated or influenced by Commonwealth environmental water, 2021–22

The Coorong, Lower Lakes and Murray Mouth is within the Lower Murray Valley but is reported separately in this evaluation. Dashes indicate there was no inundation by Commonwealth environmental water.

Valley	Selected Area	Estuary (ha)	Lakes and wetlands area (ha)	Floodplain area (ha)	Length of waterways (km)
Northern Basin					
Barwon Darling		–	299	1,272	1,973
Border Rivers		–	444	1,945	1,643
Castlereagh		–	–	–	–
Condamine Balonne		–	6,163	4,047	2,177
Gwydir	Gwydir River System	–	3,215	1,943	750
Macquarie		–	24,713	25,734	2,568
Namoi		–	–	–	–
Paroo		–	–	–	–
Warrego	Junction of Warrego and Darling rivers	–	2,716	2,858	1,281
Southern Basin					
Avoca		–	–	–	–
Broken		–	181	–	396

Valley	Selected Area	Estuary (ha)	Lakes and wetlands area (ha)	Floodplain area (ha)	Length of waterways (km)
Campaspe		–	–	–	112
Central Murray		–	28,291	14,034	2,277
Edward/Kolety–Wakool	Edward/Kolety–Wakool river systems	–	70	250	1,300
Goulburn	Goulburn River	–	–	–	410
Kiewa		–	–	–	–
Lachlan	Lachlan River System	–	4,508	2,393	1,861
Loddon		–	–	–	365
Lower Darling		–	–	–	1,026
Lower Murray	Lower Murray River	–	2,376	601	936
Lower Murray: Coorong, Lower Lakes and Murray Mouth	Lower Murray River	23,768	103,451	65	–
Mitta Mitta		–	–	–	–
Murrumbidgee	Murrumbidgee River System	–	7,573	17,048	2,835
Ovens		–	–	–	260
Upper Murray		–	–	–	–
Wimmera		–	–	–	–
Total		**23,768**	**184,000**	**72,190**	**22,170**

Ecosystem diversity, as expressed as the number of ANAE types or 'richness' of ecosystem types, is shown for the managed floodplain in each valley in Figure 4.1. The Coorong, Lower Lakes and Murray Mouth (CLLMM) in Figure 4.1 is part of the Lower Murray Valley but is evaluated separately in this report to isolate the overwhelming influence of the very large areas of Lake Alexandrina and Lake Albert and the 9 estuary ecosystem types that are unique to the CLLMM.

Ecosystem diversity on the managed floodplain broadly increases with valley area (Figure 4.2). It is low in the Victorian catchments of the Mitta Mitta, Campaspe and Kiewa valleys (1,700–6,200 km^2, 13–17 ecosystem types), and highest in the largest valley, the Condamine Balonne (164,000 km^2, 39 ecosystem types on the managed floodplain). The floodplains of the Paroo, Central Murray and Lower Murray valleys are the second most diverse, with 35 ecosystem types in each (Figure 4.1).

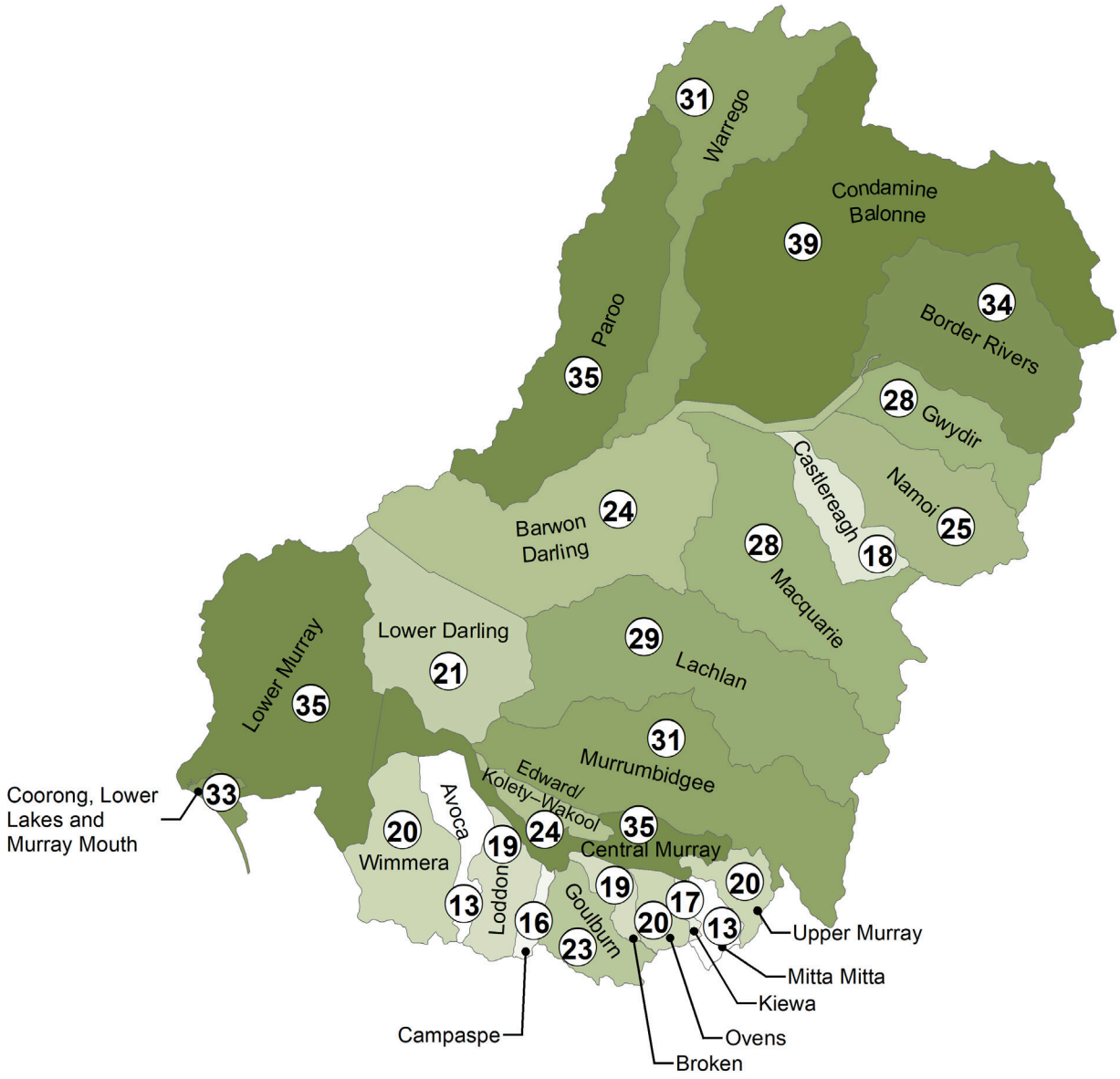


Figure 4.1 Map of ecosystem diversity on the managed floodplain by valley

Numbers are the number of mapped Australian National Aquatic Ecosystem (ANAE) types on the managed floodplain in each valley. Depth of shading indicates lowest (lightest) to highest (darkest) ecosystem diversity. The Coorong, Lower Lakes and Murray Mouth is within the Lower Murray Valley but is reported separately in this evaluation.

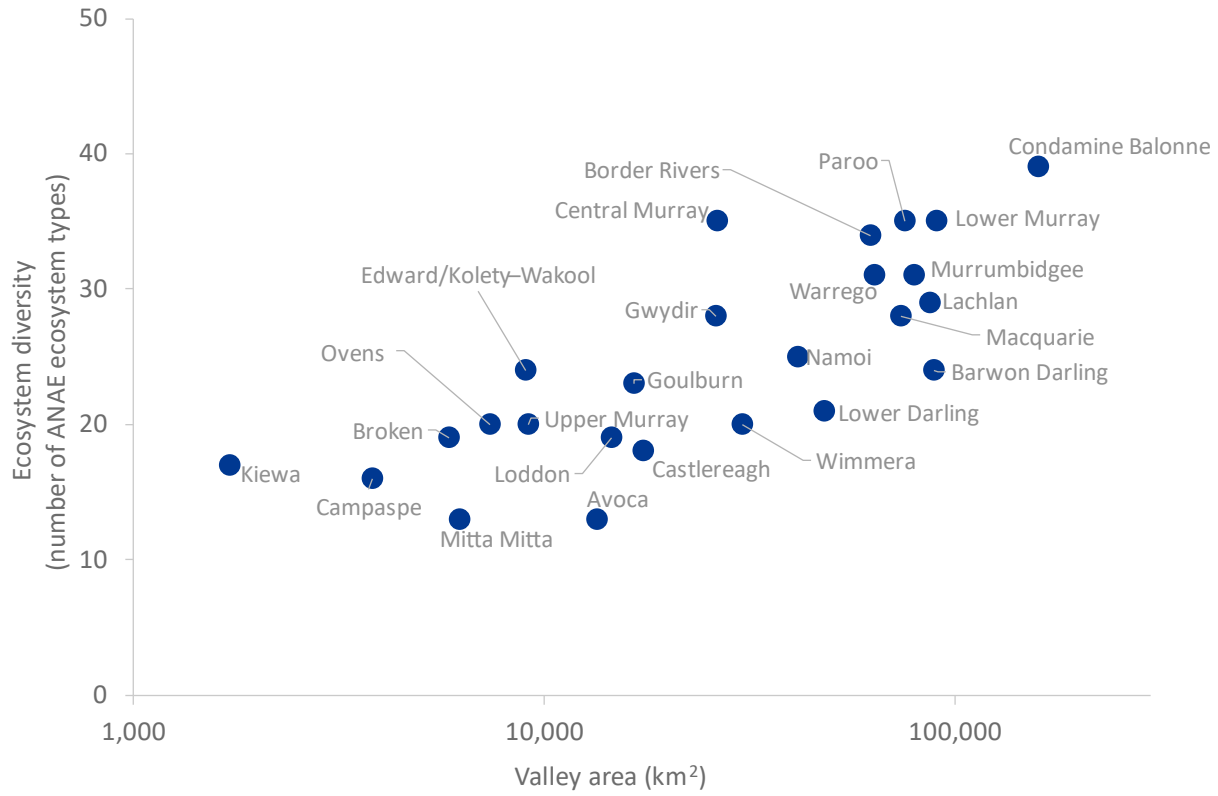


Figure 4.2 Ecosystem diversity (number of Australian National Aquatic Ecosystem [ANAE] types on the managed floodplain) scaled with valley area (x-axis log scale)
Lower Murray excludes the 9 estuarine ecosystem types found in the Coorong and Murray Mouth.

Within the 12 relevant valleys, Commonwealth environmental water delivered in 2021–22 inundated floodplains and floodplain wetlands, contributing to the ecosystem diversity in these valleys (10 to 27 ecosystem types; Figure 4.3). In 6 valleys, Commonwealth environmental water was delivered only to riverine ecosystems consisting of 2 to 5 ecosystem types (permanent and temporary, lowland or transitional rivers). The highest diversity of ecosystem types receiving Commonwealth environmental water was 33 types in the CLLMM. This reflects the contribution of end-of-system flows to the lakes, fringing wetlands and the additional 9 estuarine ecosystem types that are not found elsewhere in the Basin. In 2021–22, there was no water delivered to the Paroo, Namoi, Castlereagh, Upper Murray, Mitta Mitta, Kiewa, Avoca and Wimmera valleys.

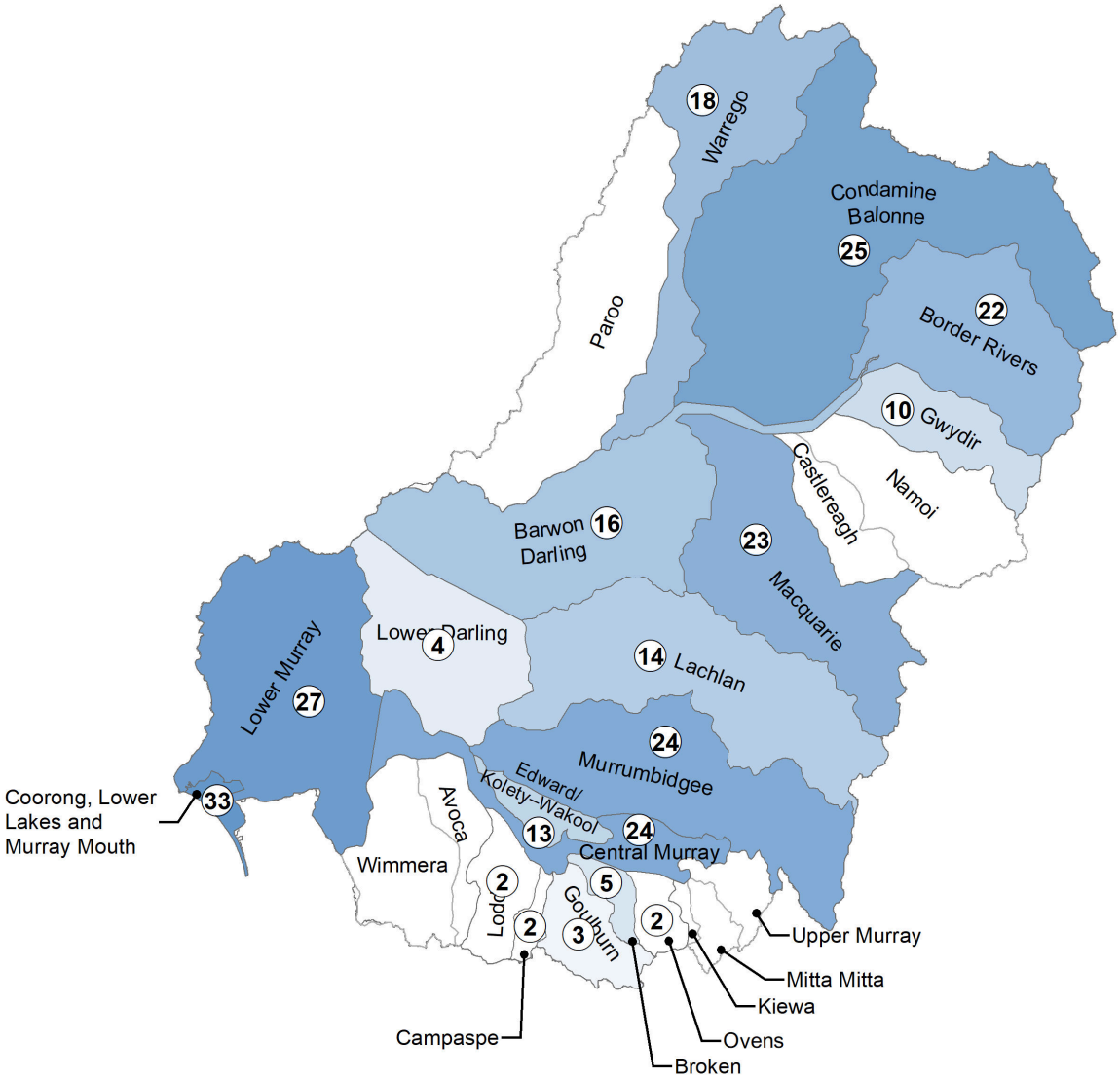


Figure 4.3 Map of ecosystem diversity supported by Commonwealth environmental water in 2021–22
Numbers are the number of Australian National Aquatic Ecosystem (ANAE) types inundated by, or influenced by, Commonwealth environmental water on the managed floodplain in each valley (see also Appendix A to Appendix C). Depth of shading indicates lowest (lightest) to highest (darkest) ecosystem diversity. The Coorong, Lower Lakes and Murray Mouth is within the Lower Murray Valley but is reported separately in this evaluation.

The contribution of Commonwealth environmental water to ecosystem diversity upstream of Lake Alexandrina is tabulated in broad ecosystem categories for lakes and wetlands (Table 4.2), floodplains (Table 4.3) and river channels (Table 4.4). The contribution of Commonwealth environmental water to ecosystem diversity in the CLLMM is presented separately in Table 4.5 to prevent the constant water levels and large areas of lakes Alexandrina and Albert from reducing sensitivity to detect patterns of inundation elsewhere in the Basin.

At the Basin scale, Commonwealth environmental water in 2021–22 contributed to the inundation of 55 of 64 ecosystem types found on the managed floodplain (86%). This is similar to previous years and included 28 of 35 (80%) lakes and palustrine wetland types (Table 4.2, Table 4.5), 11 of 12 (92%) floodplain ecosystem types (Table 4.3, Table 4.5), 7 of 8 (88%) river channel types (Table 4.4), and all 9 estuarine ecosystem types in the CLLMM (Table 4.5). A detailed breakdown of ecosystem types receiving Commonwealth environmental water in each valley is provided in Appendix A (lakes, palustrine wetlands and estuarine ecosystems), Appendix B (floodplains) and Appendix C (river channels).

As for previous years, the ecosystem diversity supported by Commonwealth environmental water in 2021–22 was heavily skewed towards temporary river red gum swamps with 31,056 ha (54% of all temporary river red gum swamp on the managed floodplain) potentially benefiting from Commonwealth environmental water (Table 4.2). Much of the temporary river red gum swamp was watered through actions to flood Barmah Forest and the Lowbidgee Redbank system, with many smaller swamps connected to the Murray, Murrumbidgee, Loddon and Goulburn rivers benefiting from freshes in these systems. This is a similar pattern to that seen in previous years whenever the large expanse of the Barmah–Millewa Forest complex is a recipient of Commonwealth environmental water.

Excluding the large Lower Lakes in South Australia (lakes Alexandrina and Albert; 82,325 ha), Commonwealth environmental water also topped up 7,376 ha of permanent lakes, representing 10% of the permanent lakes on the managed floodplain above Lake Alexandrina; Table 4.2). A large contributor to this pattern is Narran Lake in the Condamine Balonne Valley (5,200 ha).

Commonwealth environmental water supported a significant area (31,410 ha combined) of meadows and marshes, consisting of permanent and temporary tall emergent marshes, temporary sedge/grass/forb marsh, permanent grass marsh and freshwater meadow. This includes the tall marsh reed beds (5,185 ha) and freshwater meadows (3,560 ha) in the Macquarie Marshes, the reed beds of the Great Cumbung Swamp at the terminus of the Lachlan River (3,449 ha) and grassy freshwater meadows of the Gwydir Valley floodplains (2,998 ha). Much of the marshland was inundated by widespread natural flooding, which initiated breeding of colonial waterbirds. Commonwealth environmental water was used to extend the flood duration in the rookeries to support completion of breeding and to supply foraging habitat for juvenile birds. The combination of widespread floods and environmental water consolidated the recovery of these marsh ecosystems from the drought conditions of 2017–20.

In 2021–22, Commonwealth environmental water inundated the largest extent of floodplain (72,126 ha upstream of the CLLMM) since monitoring began in 2014–15. This represents 5% of the managed floodplain. The largest contributors to this total were 20,475 ha of river red gum floodplain in the Macquarie Valley (combining river red gum forest and woodland), 13,848 ha of river red gum floodplain in the Central Murray Valley and 10,365 ha of lignum floodplain in the Murrumbidgee Valley.

The pattern of Commonwealth environmental water supporting ecosystem diversity of river channels was similar to all previous years. The majority (97%) of watered channels were lowland rivers (14,979 km of permanent lowland river and 7,188 km of temporary lowland river). In total, 44% of river length on the managed floodplain, representing 7 of the 8 ANAE river types, included Commonwealth environmental water during 2021–22 (Table 4.4).

Table 4.2 Lake and wetland ecosystem types on the managed floodplain showing which are supported* by Commonwealth environmental water (CEW), 2021–22

Excludes the Coorong, Lower Lakes and Murray Mouth area, which is tabulated separately (Table 4.5). *See Section 3.2 for the definition of area supported by Commonwealth environmental water.

Australian National Aquatic Ecosystem (ANAE) wetland type	Total area (ha)	Area on managed floodplain (ha)	Area of CEW (ha)	% of managed floodplain
Pt1.1.2: Temporary river red gum swamp	76,067	57,794	31,056	53.7
Pt2.2.2: Temporary sedge/grass/forb marsh	329,304	129,573	12,980	10.0
Lp1.1: Permanent lake	130,559	73,379	7,346	10.0
Pt2.3.2: Freshwater meadow	103,117	27,289	7,288	26.7
Pt2.1.2: Temporary tall emergent marsh	70,414	55,742	6,863	12.3
Pp2.1.2: Permanent tall emergent marsh	8,001	7,690	4,173	54.3
Pt1.8.2: Temporary shrub swamp	189,953	52,643	3,037	5.8
Pp4.2: Permanent wetland	57,991	23,064	2,401	10.4
Pt3.1.2: Clay pan	117,887	41,393	2,094	5.1
Lt1.1: Temporary lake	457,526	118,967	1,508	1.3
Pt1.6.2: Temporary woodland swamp	96,360	31,054	493	1.6
Pt1: Temporary swamps	3,744	3,216	421	13.1
Pt1.2.2: Temporary black box swamp	61,058	21,777	304	1.4
Pt1.7.2: Temporary lignum swamp	37,613	7,891	298	3.8
Pt4.2: Temporary wetland	17,407	2,737	139	5.1
Pt1.3.2: Temporary coolibah swamp	8,274	5,148	55	1.1
Pp2.3.2: Permanent grass marsh	329	250	48	19.2
Psp4: Permanent saline wetland	2,029	1,617	16	1.0
Pp2.4.2: Permanent forb marsh	740	149	16	10.7
Pst2.2: Temporary salt marsh	15,906	1,809	6	0.3
Pu1: Unspecified wetland	63	60	3	5.0
Pst1.1: Temporary saline swamp	5,391	9	2	22.2
Pp2.2.2: Permanent sedge/grass/forb marsh	4,395	396	2	0.5
Lt1.2: Temporary lake with aquatic bed	9,052	8,177	–	–
Lsp1.1: Permanent saline lake	8,988	6,041	–	–
Lst1.1: Temporary saline lake	27,898	1,656	–	–
Pst3.2: Salt pan or salt flat	2,847	253	–	–
Lp1.2: Permanent lake with aquatic bed	2,067	196	–	–
Pp3: Peat bog or fen marsh	3,307	187	–	–
Lst1.2: Temporary saline lake with aquatic bed	2,238	180	–	–
Pst4: Temporary saline wetland	6,003	50	–	–
Pps5: Permanent spring	122	2	–	–
Pp1.1.2: Permanent paperbark swamp	1	1	–	–

Table 4.3 Australian National Aquatic Ecosystem (ANAE) floodplain ecosystem types supported* by Commonwealth environmental water, ordered by inundated area, 2021–22

*See Section 3.2 for the definition of area supported by Commonwealth environmental water. Dashes indicate there was no inundation by Commonwealth environmental water.

ANAE floodplain type	Total area (ha)	Area on managed floodplain (ha)	Area of CEW (ha)	% of total	% of managed floodplain
F1.2: River red gum forest riparian zone or floodplain	625,609	326,699	27,915	4.5%	8.5
F1.4: River red gum woodland riparian zone or floodplain	297,969	145,664	14,775	5.0%	10.1
F2.2: Lignum shrubland riparian zone or floodplain	294,481	85,138	13,021	4.4%	15.3
F1.10: Coolibah woodland and forest riparian zone or floodplain	2,107,271	492,035	8,356	0.4%	1.7
F2.4: Shrubland riparian zone or floodplain	461,201	140,679	4,351	0.9%	3.1
F1.8: Black box woodland riparian zone or floodplain	1,713,211	279,375	1,892	0.1%	0.7
F1.11: River cooba woodland riparian zone or floodplain	16,898	5,060	851	5.0%	16.8
F3.2: Sedge/forb/grassland riparian zone or floodplain	62,784	6,822	737	1.2%	10.8
F1.12: Woodland riparian zone or floodplain	152,733	43,645	142	<0.1%	0.3
F4: Unspecified riparian zone or floodplain	19,813	5,286	86	0.4%	1.6
F1.6: Black box forest riparian zone or floodplain	3,179	450	0	–	–
F1.13: Paperbark riparian zone or floodplain	897	271	0	–	–

Table 4.4 Australian National Aquatic Ecosystem (ANAE) river channel ecosystem types of the Basin supported* by Commonwealth environmental water, ordered by river length containing CEW, 2021–22

*See Section 3.2 for the definition of area supported by Commonwealth environmental water. Dashes indicate river types without Commonwealth environmental water.

ANAE waterway type	Total length (km)	Length on managed floodplain (km)	CEW Length (km)	% of total	% on managed floodplain
Rp1.4: Permanent lowland stream	28,888	20,036	14,912	51.6%	74.4
Rt1.4: Temporary lowland stream	136,028	23,031	6,656	4.9%	28.9
Rt1.2: Temporary transitional zone stream	179,114	3,846	295	0.2%	7.7
Rp1.2: Permanent transitional zone stream	10,555	2,037	270	2.6	13.3
Rt1.1: Temporary high energy upland stream	110,649	318	19	<0.1	6.0
Rt1.3: Temporary low energy upland stream	3,554	247	13	0.4	5.3
Rp1.1: Permanent high energy upland stream	11,106	321	5	<0.1	1.6
Rp1.3: Permanent low energy upland stream	4,726	621	0	–	–

Commonwealth environmental water reaching the end of the Murray–Darling system contributes to the maintenance of the Coorong, Lower Lakes (lakes Alexandrina and Albert) and the Murray Mouth ecosystems (the CLLMM). The evaluation of outcomes for Basin ecosystem diversity separates the CLLMM from the rest of the Basin to prevent the constant water levels and vast area of lakes Alexandrina and Albert (82,325 ha combined) from masking the detection of ecosystem diversity outcomes elsewhere in the Basin.

The large lake area and volume relative to annual volumes of Commonwealth environmental water mean the influence of Commonwealth environmental water on lake levels is small. Current inundation modelling is not sensitive enough to quantify lake-level influences on the fringing palustrine ecosystems that might be attributed to Commonwealth environmental water. For this evaluation, the extent of inundation is estimated from the mapped extent of the CLLMM. This estimate is considered satisfactory because the lakes are managed for a relatively constant water level of 0.5–0.8 metres Australian Height Datum (mAHD) by regulating outflows through the barrages. Below the barrages, water levels in the Murray Mouth and Coorong are maintained near sea level. This means that the reported area of influence for Commonwealth environmental water in the CLLMM varies little from year to year (as the system is always receiving end-of-system flows containing Commonwealth environmental water). The CLLMM contains the only areas of paperbark riparian zone or floodplain in the Basin that are regularly recorded as inundated. However, these are associated with spring-fed systems in the dunes along the Coorong and are likely not to be influenced by Commonwealth environmental water. Ecosystem diversity supported by Commonwealth environmental water is the highest in the CLLMM (33 ANAE types; Figure 4.3, Table 4.5). This includes the 9 estuarine ecosystem types in the Murray-Mouth and along the Coorong lagoon and a number of other saline wetlands and saltmarshes that are not found elsewhere in the Basin.

Table 4.5 Australian National Aquatic Ecosystem (ANAE) ecosystem types in the Coorong, Lower Lakes and Murray Mouth (CLLMM) supported* by Commonwealth environmental water (CEW), 2021–22

*See Section 3.2 for the definition of area supported by Commonwealth environmental water.

ANAE type	Total area (ha)	Area on managed floodplain (ha) (all supported by CEW) in 2021–22
Ewd1.3.2: Coastal lagoon	18,934	18,855
Etd1.3.3: Tide dominated estuary	2,246	2,240
Ewd1.2.4: Intertidal mudflat or sand bar	965	924
Etd1.2.2: Tide dominated mudflats and sandbar	631	631
Ewd1.2.3: Intertidal saltmarsh	482	482
Etd1.2.1: Tide dominated saltmarsh	324	324
Ewd1.2.5: Intertidal rocky shoreline	285	285
Etd1.2.3: Tide dominated forest	19	19
Etd1.1.1: Tide dominated rocky shoreline	7	7
Lp1.1: Permanent lake	82,483	82,325
Pt3.1.2: Clay pan	11,752	7,800
Pt2.1.2: Temporary tall emergent marsh	8,041	5,924
Pt2.2.2: Temporary sedge/grass/forb marsh	7,115	2,930
Lsp1.1: Permanent saline lake	2,687	2,182

ANAE type	Total area (ha)	Area on managed floodplain (ha) (all supported by CEW) in 2021–22
Pst1.1: Temporary saline swamp	2,765	787
Psp4: Permanent saline wetland	687	601
Pst4: Temporary saline wetland	590	452
Pst2.2: Temporary salt marsh	427	371
Psp1.1: Saline paperbark swamp	132	132
Pst3.2: Salt pan or salt flat	527	122
Pp4.2: Permanent wetland	95	91
Pt4.2: Temporary wetland	5,271	86
Pt2.3.2: Freshwater meadow	38	34
F4: Unspecified riparian zone or floodplain	2,062	30
F2.4: Shrubland riparian zone or floodplain	546	22
Lt1.1: Temporary lake	4,979	16
F1.13: Paperbark riparian zone or floodplain	248	11
Pt1.8.2: Temporary shrub swamp	35	8
Pt1.7.2: Temporary lignum swamp	23	3
F1.12: Woodland riparian zone or floodplain	57	2
Psp2.1: Permanent salt marsh	3	2
F2.2: Lignum shrubland riparian zone or floodplain	43	1
Pp2.4.2: Permanent forb marsh	1	1
TOTAL	**154,500**	**127,700**

4.3 Outcomes for Ramsar Sites

There are 16 Ramsar wetlands in the Basin of which 12 are regularly supported by allocations of water from the Commonwealth, Murray–Darling Basin Authority (MDBA) (e.g. The Living Murray Program) and state jurisdictions, with Commonwealth environmental water being allocated to 11 sites over the period of monitoring 2014–22 (Figure 4.4). The Kerang Wetlands Ramsar Site is managed solely by Victoria and 4 Ramsar Sites in the Basin currently cannot receive managed environmental water (Figure 4.4): Currawinya Lakes and the Paroo River Wetlands are in unregulated northern Basin locations and Ginini Flats Wetland Complex is in the alpine region above any water storages. The fourth site, Lake Albacutya, is the second of 2 large terminal lakes at the end of the Wimmera River – there is currently an insufficient volume of water in the system to first fill Lake Hindmarsh so that water can spill to Lake Albacutya.

In 2021–22, approximately 1,888 GL of environmental water containing 1,380 GL of Commonwealth environmental water was delivered to 9 Ramsar Sites in the Basin (Table 4.6). In many instances, water delivered to floodplains is returned to the river and used again to inundate sites downstream. For example, water in the Barmah Forest Ramsar Site flows back into the Murray and then can be used to inundate Gunbower Forest, Hattah–Kulkyne Lakes and Riverland Ramsar Sites further downstream. Water that reaches The Coorong and Lakes Alexandrina and Albert Wetland Ramsar Site mainly comprises return flows from upstream watering.

The evaluation of ecosystem diversity supported by Commonwealth environmental water in Ramsar Sites differs from the Basin-scale method by using ANAE polygon mapping for riverine ecosystems instead of the Basin-scale river line mapping. The ANAE polygon mapping is not used at the Basin scale because it does not include all rivers in the Basin. It is, however, complete within the limited extent of the Ramsar estate and within Ramsar Sites is better compared with other ecosystem types when evaluated by area. The site-scale river polygons are evaluated using the same logic applied to lakes where the entire area of river polygons within Ramsar Sites are deemed supported by Commonwealth environmental water when overlapped in whole or in part by the satellite-derived inundation extent. At most Ramsar Sites, the water is delivered to the site via the river channel and occupies the whole channel.

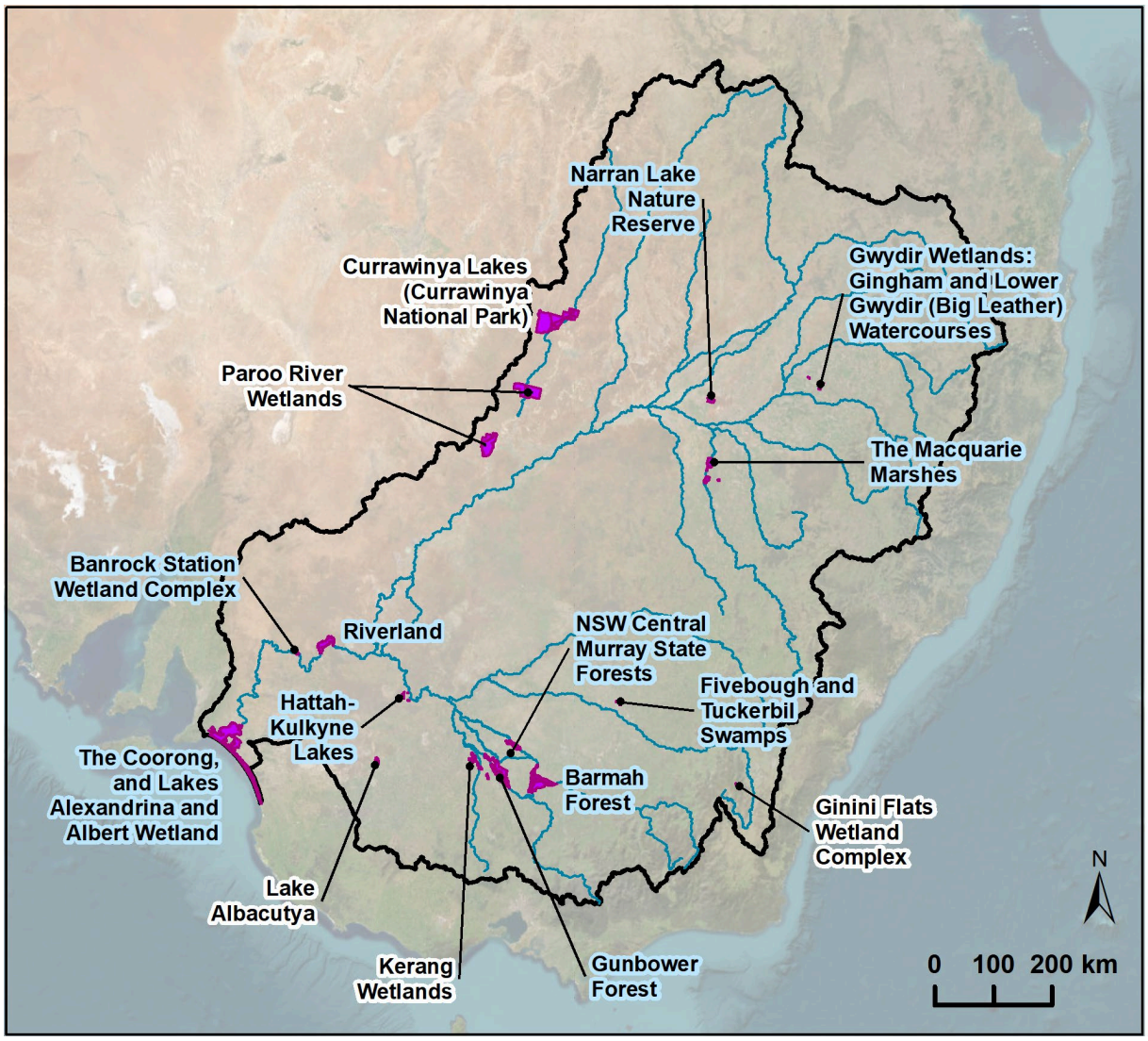


Figure 4.4 Ramsar Sites in the Murray–Darling Basin
Blue highlights the Ramsar Sites that have received Commonwealth environmental water over the period of monitoring, 2014–22

Table 4.6 Ramsar Sites in the Basin, their area and, for those sites that received Commonwealth environmental water (CEW) in 2021–22, the volume of that water

Numbers are rounded to the nearest ha or GL. Dashes indicate there was no inundation by Commonwealth environmental water.

Ramsar Site	Area (ha)	2021–22 CEW (GL)
Northern Basin		
Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses	842	7 (+21 from NSW)
Narran Lake Nature Reserve (Narran Lakes)	8,454	317
Paroo River Wetlands	138,304	–
The Macquarie Marshes	18,423	11 (+61 from NSW)
Southern Basin		
Banrock Station Wetland Complex	1,375	1
Barmah Forest / NSW Central Murray Forests (Millewa Forest)	29,159	220 (+194 from other)
Currawinya Lakes	151,300	–
Fivebough and Tuckerbil Swamps	620	–
Ginini Flats Wetland Complex	125	–
Gunbower Forest	19,931	2 (+8 from Vic)
Hattah–Kulkyne Lakes	955	–
Kerang Wetlands	9,419	–
Lake Albacutya	5,659	–
NSW Central Murray Forests (Pollack Swamp)	84,000	4
Riverland	30,665	2
The Coorong, and Lakes Alexandrina and Albert Wetland	140,500	816 (+224 from other)
Total	**639,731**	**1,380**

Data sources: SCBEWC (2023); CEWH watering actions table. A table of watering actions is provided to the project team by CEWH each year. It is prepared from information contained in CEWH water delivery acquittal reports.

4.3.1 Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses

The Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses Ramsar Site consists of 4 small discrete wetland areas in the broader Gwydir River wetland system (Figure 4.5). They support extensive stands of water couch in freshwater meadows that are a defining characteristic of the site. The sites are important for the diversity of waterbirds they support.

The site experienced widespread natural flooding in November 2021, and as the floodwaters drained away in December through February 2022, environmental water was delivered in targeted actions to ensure core wetland areas were inundated long enough to support significant bird breeding. The waterbird colonies in the Old Dromana section of the site on the Gwydir River received 7 GL of Commonwealth environmental water and 3.7 GL of NSW Environmental Contingency Allowance water from late December 2021 to March 2022 (CEWO 2022c). This inundated 86% of Old Dromana (62% of the total Ramsar Site area; Figure 4.5), supporting 498 ha (74%) of the freshwater meadow and 16 ha (94%) of temporary tall emergent marsh that are characteristic of the site (Table 4.7). The Gingham Watercourse received 17.7 GL of NSW Environmental Contingency Allowance water that inundated the Goddard's Lease wetlands without additional environmental water from the Commonwealth (CEWO 2022c).

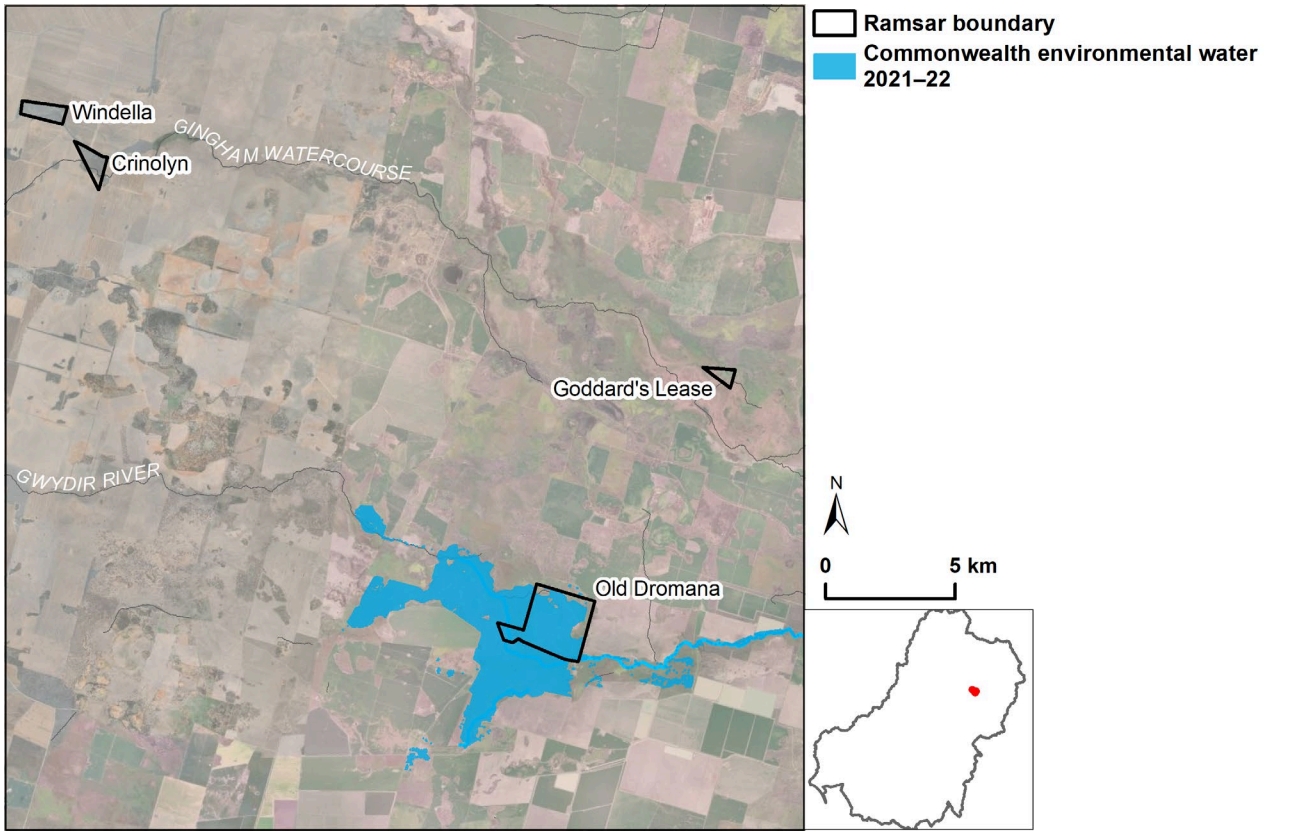


Figure 4.5 Ecosystem diversity within the Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses Ramsar Site showing 2021–22 inundation by 10.7 GL of water for the environment that included 7 GL of Commonwealth environmental water added to naturally occurring floodwaters

Not mapped: 17.3 GL of NSW water inundated the Gingham Watercourse wetlands including Goddard's Lease.

Table 4.7 Area of Australian National Aquatic Ecosystem (ANAE) wetland and floodplain types within the Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses Ramsar Site supported by Commonwealth environmental water (CEW) in 2021–22

Dashes indicate there was no inundation by Commonwealth environmental water.

ANAE ecosystem type	Area within Ramsar Site (ha)	Area supported by CEW (ha)	Percentage (%)
Pt2.3.2: Freshwater meadow	672	498	74
Pt2.1.2: Temporary tall emergent marsh	17	16	94
F1.10: Coolibah woodland and forest riparian zone or floodplain	117	3	3
F1.11: River cooba woodland riparian zone or floodplain	8	1	13
Pt3.1.2: Clay pan	7	–	–
Not water dependent	21	–	–
Total	**842**	**519**	**62**

4.3.2 Narran Lake Nature Reserve

The Narran Lake Nature Reserve Ramsar Site is the northern part of the large terminal lake system at the end of the Narran River (Figure 4.6). The Ramsar Site contains extensive channelised wetlands supporting lignum, river cooba and black box vegetation and is an important breeding site for colonial nesting waterbirds (Butcher et al. 2011).

Providing water to Narran Lakes was a Basin priority in 2021–22 to support lignum communities and waterbird breeding and recruitment (MDBA 2021). Through the first half of 2022, 317 GL of Commonwealth environmental water was delivered through the Condamine Balonne and Lower Balonne floodplain system. It supported 28% of the Ramsar Site, including 1,679 ha of lignum floodplain within the site (Table 4.8), and flowed south through lignum floodplain to Narran Lakes, inundating a total area of 8,387 ha (Figure 4.6). A mosaic of wetland areas – including marshes and floodplain trees (coolibah, river cooba and river red gum) – was also inundated and permanent wetlands (Long Arm, Back Lake and Clear Lake) were filled (Brandis et al. 2022). These areas contribute to habitat diversity within the site and support the waterbird rookeries and feeding and roosting habitat. The 2021–22 waterbird breeding was the largest breeding event in a decade and the first time in 24 years that included simultaneous breeding across Narran Lakes, the Macquarie Marshes and Gwydir Wetlands (Brandis et al. 2022).

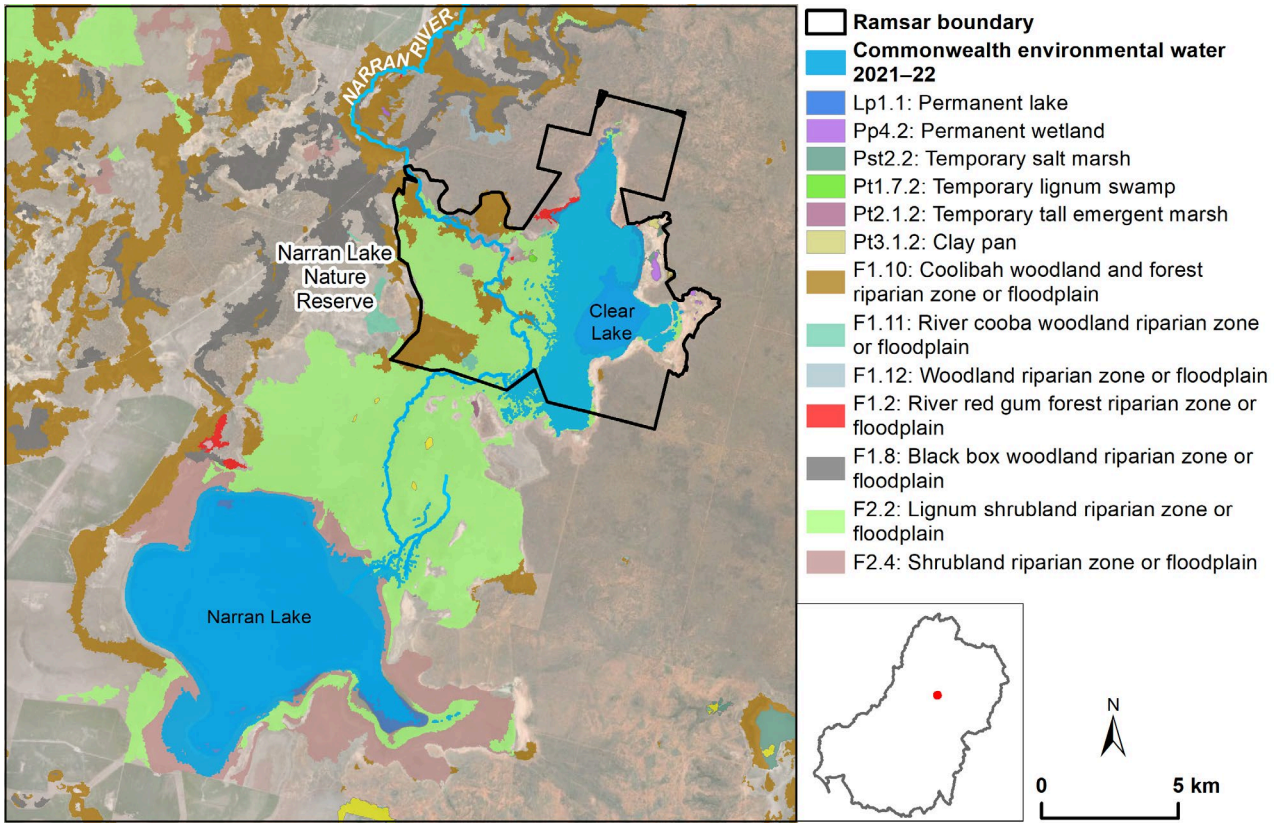


Figure 4.6 Ecosystem diversity within the Narran Lake Nature Reserve (Narran Lakes) Ramsar Site showing 2021–22 inundation by 317 GL of Commonwealth environmental water

Table 4.8 Area of Australian National Aquatic Ecosystem (ANAE) wetland and floodplain types within the Narran Lake Nature Reserve (Narran Lakes) Ramsar Site supported by Commonwealth environmental water (CEW) in 2021–22

Dashes indicate there was no inundation by Commonwealth environmental water.

ANAE ecosystem type	Area within Ramsar Site (ha)	Area supported by CEW (ha)	Percentage (%)
F2.2: Lignum shrubland riparian zone or floodplain	3,933	1,679	43
Pp4.2: Permanent wetland	476	445	93
Pt2.1.2: Temporary tall emergent marsh	51	51	100
F1.2: River red gum forest riparian zone or floodplain	112	49	44
Rt1.4: Temporary lowland stream	48	48	100
F2.4: Shrubland riparian zone or floodplain	33	33	100
Lp1.1: Permanent lake	35	27	77
Rp1.4: Permanent lowland stream	22	22	100
F1.10: Coolibah woodland and forest riparian zone or floodplain	836	15	2
F1.11: River cooba woodland riparian zone or floodplain	41	4	10
Pst2.2: Temporary salt marsh	14	3	21
Pt3.1.2: Clay pan	14	–	–
F1.8: Black box woodland riparian zone or floodplain	7	–	–
Pt1.7.2: Temporary lignum swamp	7	–	–
F1.12: Woodland riparian zone or floodplain	2	–	–
Not water dependent	2,823	–	–
Total	**8,454**	**2,376**	**28**

4.3.3 The Macquarie Marshes

The Macquarie Marshes Ramsar Site is a small portion of the larger Macquarie Marshes ecosystem comprising Macquarie Marshes Nature Reserve and the privately owned Wilgara Wetland and U-Block (Figure 4.7). The Ramsar Site values include significant vegetation communities dominated by tall marsh and river red gum forest and abundance and diversity of waterbirds and colonial nesting waterbird species (OEH 2012).

Providing water to the Macquarie Marshes to support waterbird habitat was a priority for 2021–22 (MDBA 2021). In total, more than 72 GL was delivered, including 11 GL of Commonwealth environmental water in 8 watering actions. The bulk of the water was delivered over the summer months (November to March) with smaller supplementary water delivered through to July 2022 to maintain water levels in breeding colonies to support completion of waterbird breeding and provide foraging habitat for juvenile birds. The Ramsar Site was extensively inundated (62%), supporting 95–100% of the wetland habitats within the site that are nominated as critical to the ecological character of the Ramsar Site (OEH 2012) (Table 4.9).

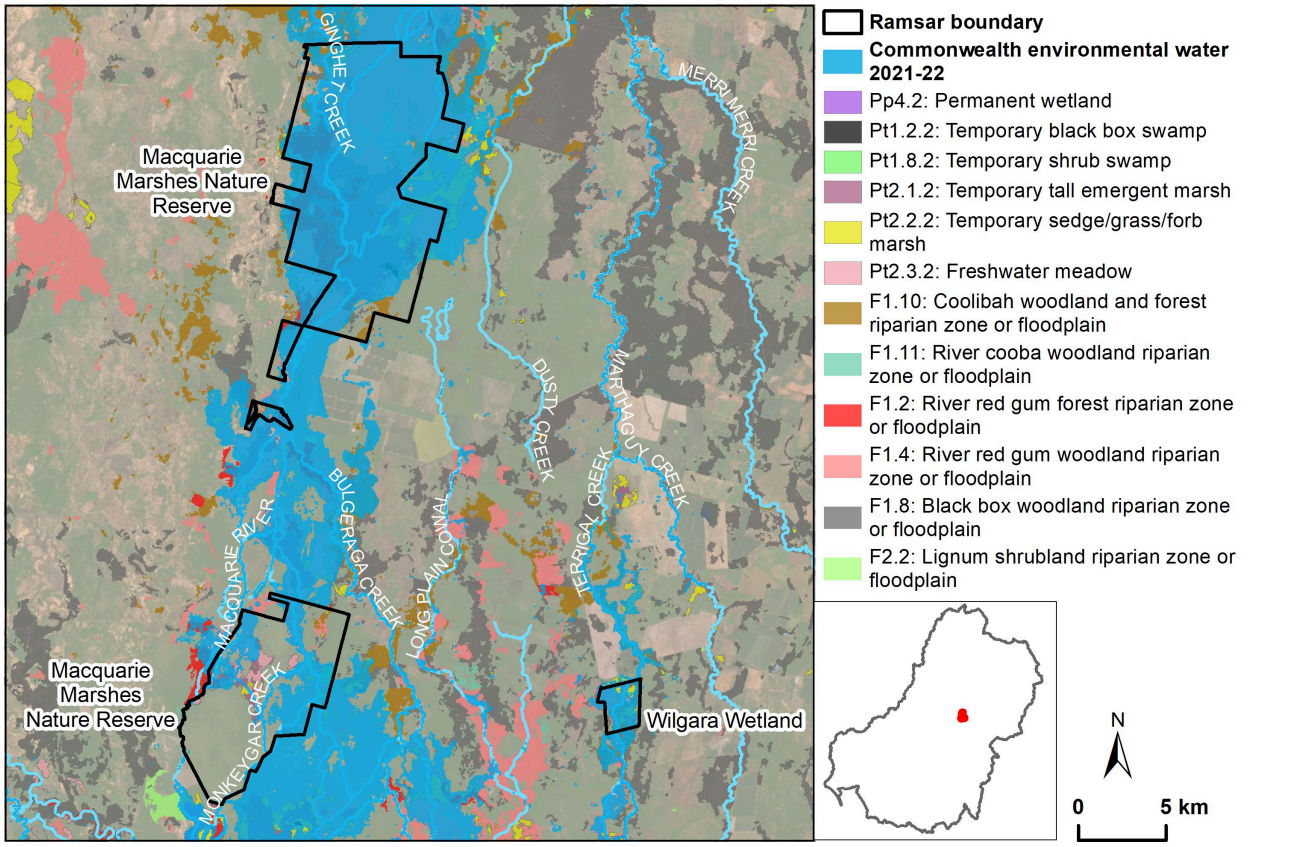


Figure 4.7 Ecosystem diversity within The Macquarie Marshes Ramsar Site showing 2021–22 inundation by 72 GL of water for the environment that included 11 GL of Commonwealth environmental water

Table 4.9 Area of Australian National Aquatic Ecosystem (ANAE) wetland and floodplain types within The Macquarie Marshes Ramsar Site supported by Commonwealth environmental water (CEW) in 2021–22

Dashes indicate there was no inundation by Commonwealth environmental water.

ANAE ecosystem type	Area within Ramsar Site (ha)	Area supported by CEW (ha)	Percentage (%)
F1.4: River red gum woodland riparian zone or floodplain	5,424	5,154	95
Pt2.1.2: Temporary tall emergent marsh	2,737	2,723	99
F1.2: River red gum forest riparian zone or floodplain	1,493	1,411	95
Pt2.3.2: Freshwater meadow	848	848	100
Pt2.2.2: Temporary sedge/grass/forb marsh	495	467	94
F1.10: Coolibah woodland and forest riparian zone or floodplain	792	380	48
Pt1.8.2: Temporary shrub swamp	119	119	100
Rt1.4: Temporary lowland stream	91	91	100
Pp4.2: Permanent wetland	43	43	100
F1.8: Black box woodland riparian zone or floodplain	222	38	17
Rp1.4: Permanent lowland stream	38	38	100
Pt1.2.2: Temporary black box swamp	31	31	100
F1.11: River cooba woodland riparian zone or floodplain	32	25	78
F2.2: Lignum shrubland riparian zone or floodplain	13	13	100
Lt1.1: Temporary lake	12	12	100
Rp1: Permanent stream	3	3	100
Not water dependent	6,030	–	–
Total	**18,423**	**11,396**	**62%**

4.3.4 Banrock Station Wetland Complex

The Banrock Station Wetland Complex Ramsar Site is a floodplain wetland complex in South Australia that is typical of the Lower Murray River, comprising lagoons, areas of river red gum and black box woodland, lignum shrublands and marsh (Figure 4.8). The site was listed under the Ramsar Convention in 2002 on the basis that it supports threatened species, including the regent parrot (*Polytelis anthopeplus*) and southern bell frog (*Litoria raniformis*), and a variety of waterbirds during critical life stages of migration, breeding and moulting (Butcher et al. 2009). A delivery of 1,420 ML between September and December 2021 was recorded as inundating 82 ha in the CEWH acquittal report but inundation mapping from satellite imagery showed water in 243 ha or 18% of the site (Figure 4.8, Table 4.10). Inundated areas were mostly in the permanent wetlands (219 ha) supporting southern bell frog, with a small area (2 ha) of black box floodplain in the north-eastern corner of the site supporting regent parrot habitat. As in previous years, areas of lignum floodplain on the New South Wales bank of the Murray River were also inundated. These are outside of the Ramsar boundary but may support waterbirds that use the Ramsar Site.

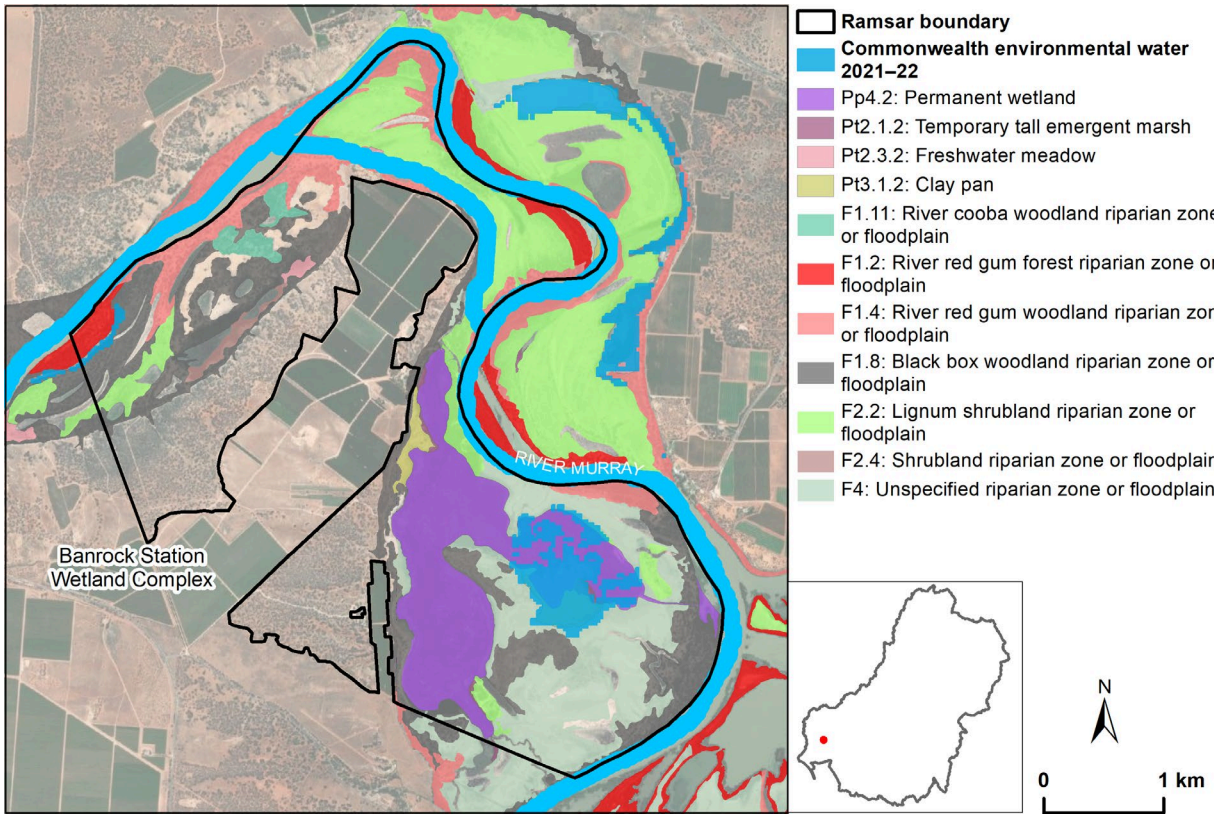


Figure 4.8 Ecosystem diversity within the Banrock Station Wetland Complex Ramsar Site showing 2020–21 inundation by 1 GL of Commonwealth environmental water

Table 4.10 Area of Australian National Aquatic Ecosystem (ANAE) wetland and floodplain types within the Banrock Station Wetland Complex Ramsar Site supported by Commonwealth environmental water (CEW) in 2021–22

Dashes indicate there was no inundation by Commonwealth environmental water.

ANAE ecosystem type	Area within Ramsar Site (ha)	Area supported by CEW (ha)	Percentage (%)
Pp4.2: Permanent wetland	222	219	99
Pt3.1.2: Clay pan	21	12	57
F4: Unspecified riparian zone or floodplain	196	6	3
F1.8: Black box woodland riparian zone or floodplain	250	2	1
Pt2.1.2: Temporary tall emergent marsh	5	2	40
F2.2: Lignum shrubland riparian zone or floodplain	147	1	1
Pt1: Temporary swamps	39	1	3
F1.4: River red gum woodland riparian zone or floodplain	95	–	–
Rp1.4: Permanent lowland stream	23	–	–
F1.2: River red gum forest riparian zone or floodplain	21	–	–
F1.11: River cooba woodland riparian zone or floodplain	16	–	–
F2.4: Shrubland riparian zone or floodplain	12	–	–
Pt2.3.2: Freshwater meadow	3	–	–
Rt1.4: Temporary lowland stream	3	–	–
Rt1: Temporary stream	1	–	–
Not water dependent	321	–	–
Total	**1,375**	**243**	**18**

4.3.5 Barmah Forest and NSW Central Murray Forests (Millewa Forest)

The Barmah and Millewa forests include 2 Ramsar Sites that are managed together. Water allocated from the Murray River spills northwards into the Millewa Forest Group of the NSW Central Forests Ramsar Site and to the south into the Barmah Forest Ramsar Site in Victoria. Both sites are an extensive floodplain wetland system dominated by river red gum forest and woodland (Figure 4.9). Together, these 2 forests form the largest intact floodplain forest in the bioregion, supporting threatened species that include Australasian bittern (*Botaurus poiciloptilus*), superb parrot (*Polytelis swainsonii*), Murray cod (*Maccullochella peelii peelii*), trout cod (*M. macquariensis*) and silver perch (*Bidyanus bidyanus*). The forests and marshes also provide important habitat for colonial nesting waterbird species (Hale and Butcher 2011).

The Barmah Forest Ramsar Site contains areas of open lake and floodplain marshes. When listed by the Ramsar Convention in 1982, the site contained large expanses of Moira grass (*Pseudoraphis spinescens*) that are recognised as a critical component of the ecological character of the site (Hale and Butcher 2011). Moira grass extent declined dramatically during the Millennium Drought and its restoration using water management is now a multi-year priority in the Strategy (MDBA 2019, 2021).

Three watering actions between May 2021 and February 2022 delivered 414 GL of water, including 220 GL of Commonwealth environmental water, to the site which was already 45% inundated by naturally occurring high flows (SCBEWC 2023). The additional water led to 25,921 ha (89%) of the Barmah Forest, being inundated, including 100% of the wetlands within it (Table 4.11). At the same time, a further 12,919 ha of river red gum floodplain was inundated in the Millewa Forest Group of the NSW Central Forests Ramsar Site.

Breeding in the nationally Endangered Australasian bittern – listed as critical to the site's ecological character – was observed in response to the inundation of the site (SCBEWC 2023).

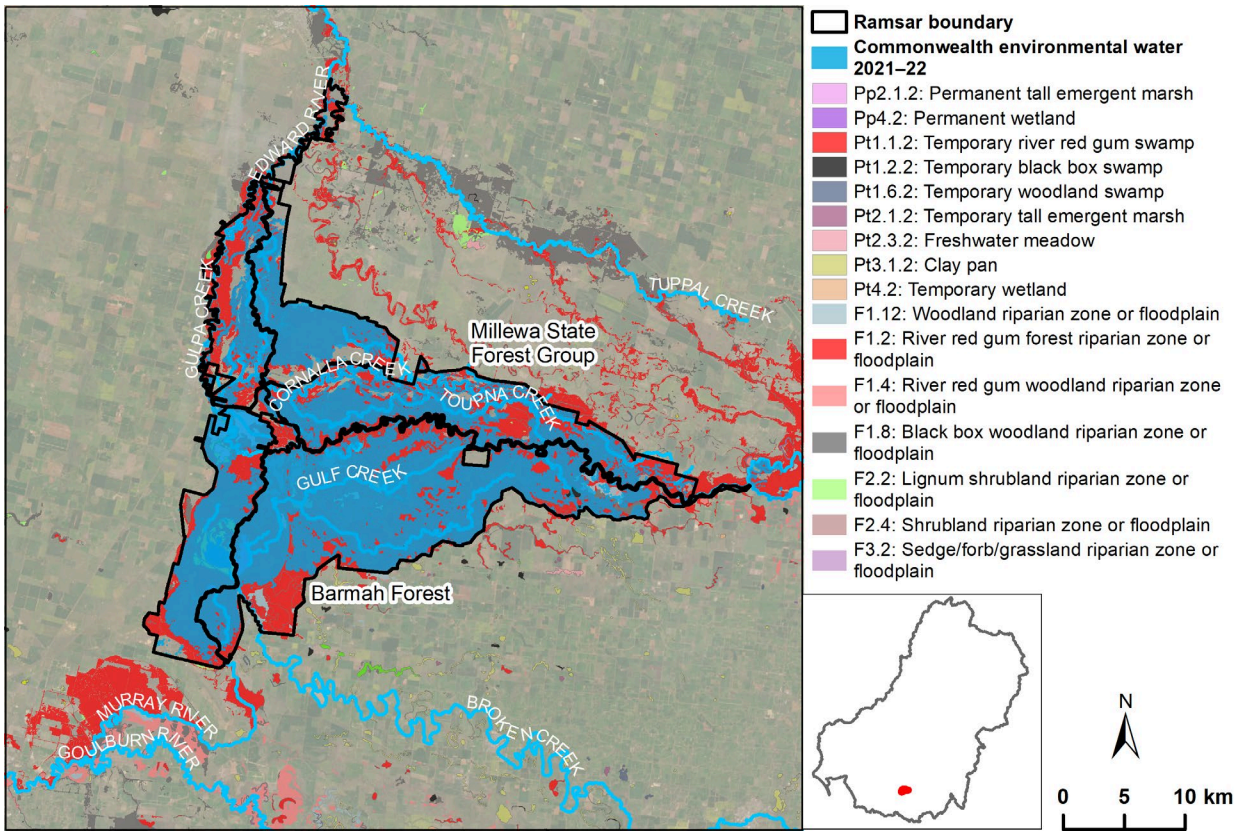


Figure 4.9 Ecosystem diversity within the Barmah Forest Ramsar Site and Millewa Forest Group of the NSW Central Forests Ramsar Site showing 2020–21 inundation by 414 GL of environmental water that included 220 GL of Commonwealth environmental water

Table 4.11 Area of Australian National Aquatic Ecosystem (ANAE) wetland and floodplain types within the Barmah Forest Ramsar Site supported by Commonwealth environmental water (CEW) in 2021–22

Dashes indicate there was no inundation by Commonwealth environmental water. The ANAE maps the river redgum floodplain in Barmah Forest as a very large palustrine wetland. Area inundated was used rather than area influenced (Section 3.2) to be consistent with the evaluation of floodplain and more accurately reflect the area influenced by water. This allows the data to be combined with the Millewa section on the New South Wales side of the Murray River.

ANAE ecosystem type	Area within Ramsar Site (ha)	Area supported by CEW (ha)	Percentage (%)
Pt1.1.2: Temporary river red gum swamp	23,617	23,500	100
Pt2.1.2: Temporary tall emergent marsh	676	676	100
F1.2: River red gum forest riparian zone or floodplain	2,836	467	16
Pt1.6.2: Temporary woodland swamp	359	359	100
Pp4.2: Permanent wetland	279	279	100
Pt4.2: Temporary wetland	124	124	100
F1.12: Woodland riparian zone or floodplain	675	123	18
Pt2.3.2: Freshwater meadow	99	99	100
Rp1.4: Permanent lowland stream	92	92	100
Pt1.2.2: Temporary black box swamp	86	86	100
Lt1.1: Temporary lake	76	76	100
F3.2: Sedge/forb/grassland riparian zone or floodplain	23	16	70
Rt1.4: Temporary lowland stream	12	12	100
F4: Unspecified riparian zone or floodplain	10	7	70
F1.8: Black box woodland riparian zone or floodplain	169	3	2
Pp2.1.2: Permanent tall emergent marsh	2	2	100
F1.4: River red gum woodland riparian zone or floodplain	24	–	–
Pt3.1.2: Clay pan	0	–	–
Not water dependent	0	–	–
Total	**29,159**	**25,921**	**89**

4.3.6 Gunbower Forest

Gunbower Forest Ramsar Site in northern Victoria contains an area of river red gum floodplain adjacent to the Murray River that is subjected to periodic inundation. The site was listed by the Ramsar Convention in 1982 with critical values including the hydrology, river red gum forest and floodplain marshes, 12 species of native fish and 66 species of wetland birds, including 9 waterbirds protected under international agreements and the Endangered Australasian bittern (Hale and Butcher 2011). The provision of critical habitat for feeding and breeding of wetland birds is listed as a critical service.

Gunbower Creek is an anabranch of the Murray River that is 127 km long with 52 km within the Gunbower Forest Ramsar Site boundary (Figure 4.11). In 2021–22, there were 3 watering actions to maintain base flows and provide a fresh in Gunbower Creek, primarily to support native fish. Inundation of the river red gum forest was not recorded; however, water from Gunbower Creek was released through regulators into a number of small wetlands within the northern section of the Gunbower Forest Ramsar Site (Reedy Lagoon, Little Reedy Lagoon, Black Swamp, Yarran Creek and Little Gunbower Lagoon) (SCBEWC 2023).

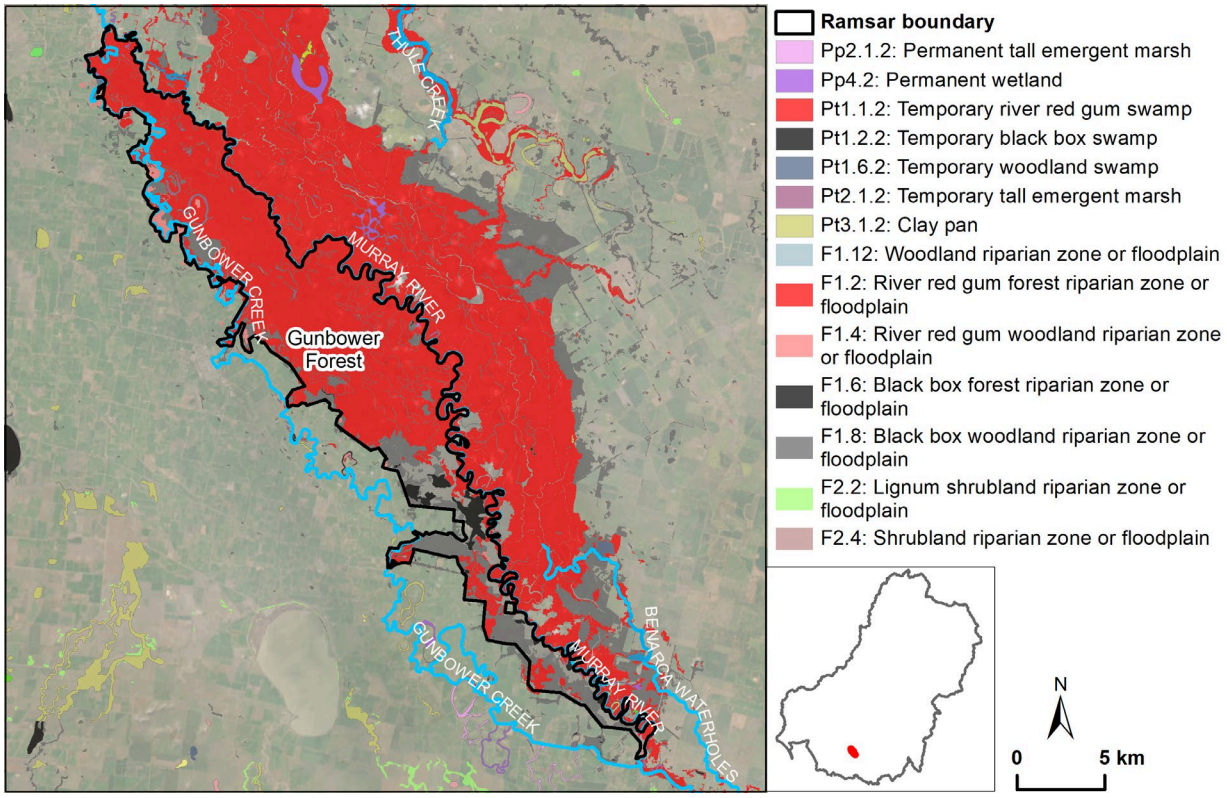


Figure 4.10 Ecosystem diversity within the Gunbower Forest Ramsar Site showing 2021–22 flows in Gunbower Creek augmented by 10 GL of environmental water that included 2 GL of Commonwealth environmental water

4.3.7 NSW Central Murray Forests (Koondrook and Werai forests)

The NSW Central Murray Forests Ramsar Site comprises 3 river red gum floodplain forests: Millewa, Koondrook–Perricoota and Werai (Figure 4.11). The site was listed in 2003 for its intact floodplain forest and wetland mosaics supporting waterbird breeding and threatened species, including Australasian bittern, Australian painted snipe (*Rostratula benghalensis*), superb parrot and Murray cod (Harrington and Hale 2011). Commonwealth environmental water is used primarily to support the Millewa Forest and the small Pollack Swamp (around 500 ha) at the northern end of the Koondrook group. The remainder of the extensive Koondrook Forest Group (34,524 ha) and the Werai Forest Group (11,421 ha) have not received Commonwealth environmental water since monitoring began in 2014. Millewa Forest receives water in conjunction with the Barmah Forest Ramsar Site (414 GL of water for the environment in 2021–22; see Section 4.3.5) to maintain and improve the condition of the river red gum forest floodplain and the mosaic of permanent wetlands and marshes that are embedded within (Table 4.12). The extensive inundation of the Millewa Forest river red gum represents 83% of the inundated area and 17% of the Ramsar Site. Another 4 GL of Commonwealth environmental water was delivered to inundate Pollack Swamp, a permanent wetland within the Koondrook–Perricoota section of the site that supports nationally vulnerable river swamp wallaby-grass (*Amphibromus fluitans*), river red gum and waterbirds.

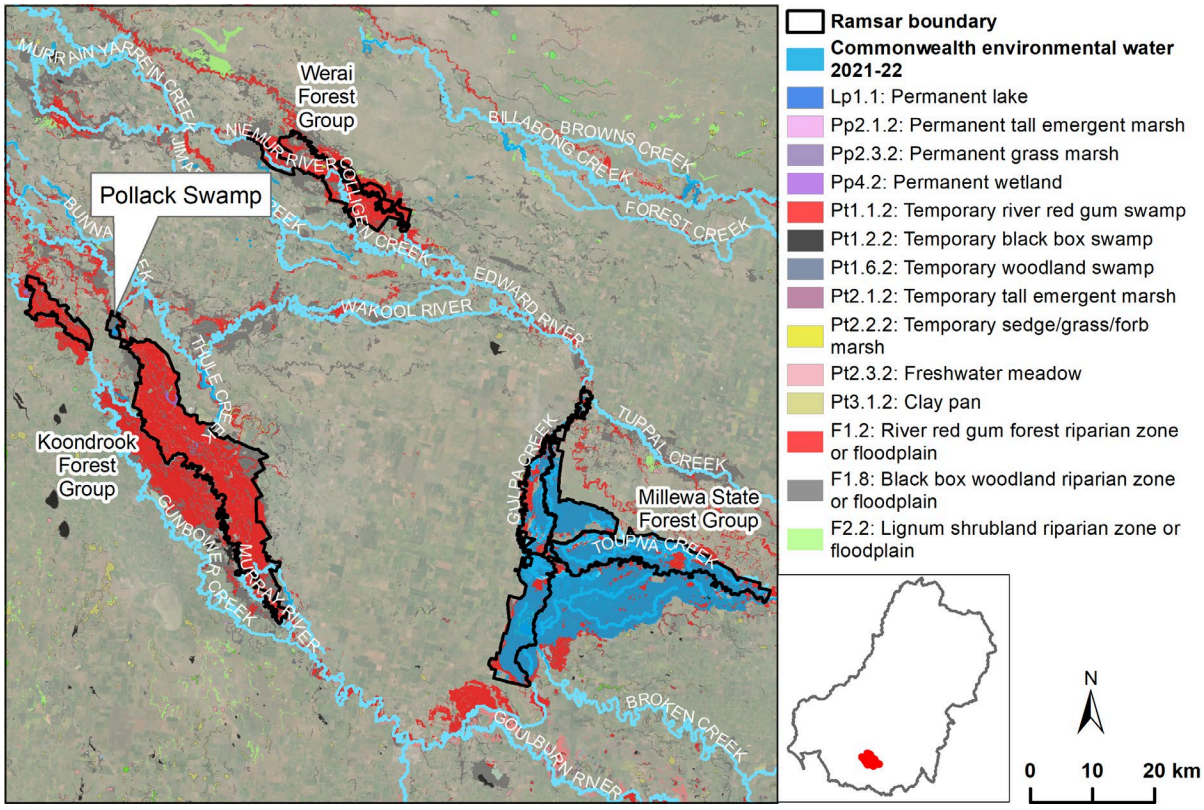


Figure 4.11 Ecosystem diversity within the NSW Central Murray State Forests Ramsar Site showing 2021–22 inundation by 3 GL of Commonwealth environmental water delivered to the Koondrook Forest and 370 GL, including 278 GL of Commonwealth environmental water, delivered to the Barmah–Millewa Forest

Table 4.12 Area of Australian National Aquatic Ecosystem (ANAE) wetland and floodplain types within the NSW Central Murray Forests Ramsar Site supported by Commonwealth environmental water (CEW) in 2021–22
Dashes indicate there was no inundation by Commonwealth environmental water.

ANAE ecosystem type	Area within Ramsar Site (ha)	Area supported by CEW (ha)	Percentage (%)
F1.2: River red gum forest riparian zone or floodplain	67,026	12,919	19
Pt1.1.2: Temporary river red gum swamp	1,351	654	48
Pp2.1.2: Permanent tall emergent marsh	598	598	100
Pt2.2.2: Temporary sedge/grass/forb marsh	707	587	83
Lp1.1: Permanent lake	407	407	100
Rp1.4: Permanent lowland stream	820	324	40
Rt1.4: Temporary lowland stream	804	317	39
Pp4.2: Permanent wetland	744	257	35
Pt2.1.2: Temporary tall emergent marsh	47	45	96
Pt1.6.2: Temporary woodland swamp	139	16	12
Rt1: Temporary stream	18	5	28
Pt3.1.2: Clay pan	22	4	18
F1.8: Black box woodland riparian zone or floodplain	5,091	3	<1
Rt1.2: Temporary transitional zone stream	20	3	15
Pp2.3.2: Permanent grass marsh	7	2	29
Rp1: Permanent stream	8	1	13
Lt1.1: Temporary lake	1	1	100
Pt2.3.2: Freshwater meadow	33	–	–
F2.2: Lignum shrubland riparian zone or floodplain	7	–	–
Pt1.2.2: Temporary black box swamp	6	–	–
Rp1.2: Permanent transitional zone stream	2	–	–
Not water dependent	6,142	–	–
Total	**84,000**	**16,143**	**19**

4.3.8 Riverland

The Riverland Ramsar Site is located on the floodplain of the Murray River in South Australia following the extent of the 1956 flood line from the New South Wales border. It contains a very diverse array of aquatic ecosystems across a height gradient, with black box woodlands on the uplands, river red gum floodplain adjacent to the river channels, and a mix of temporary and permanent wetlands in floodplain depressions (Figure 4.12).

There were 8 small Commonwealth environmental water watering actions totalling 1.6 GL in 2021–22 to support recovery of upland black box woodlands and maintenance of black box recruits at Calperum Station, and to promote recovery of canegrass swamps from high salinity conditions (230 ha of freshwater meadows, which include canegrass, were watered; Table 4.13). Another 0.5 GL of Commonwealth environmental water was regulated from the Murray River at Weila to flow through to Murtho (Figure 4.12), providing support to river red gum and black box habitat hosting one of the few colonies of regent parrot in South Australia. These watering actions were small compared with the total extent of floodplain, inundating 1% of the total Ramsar Site area (Table 4.13).

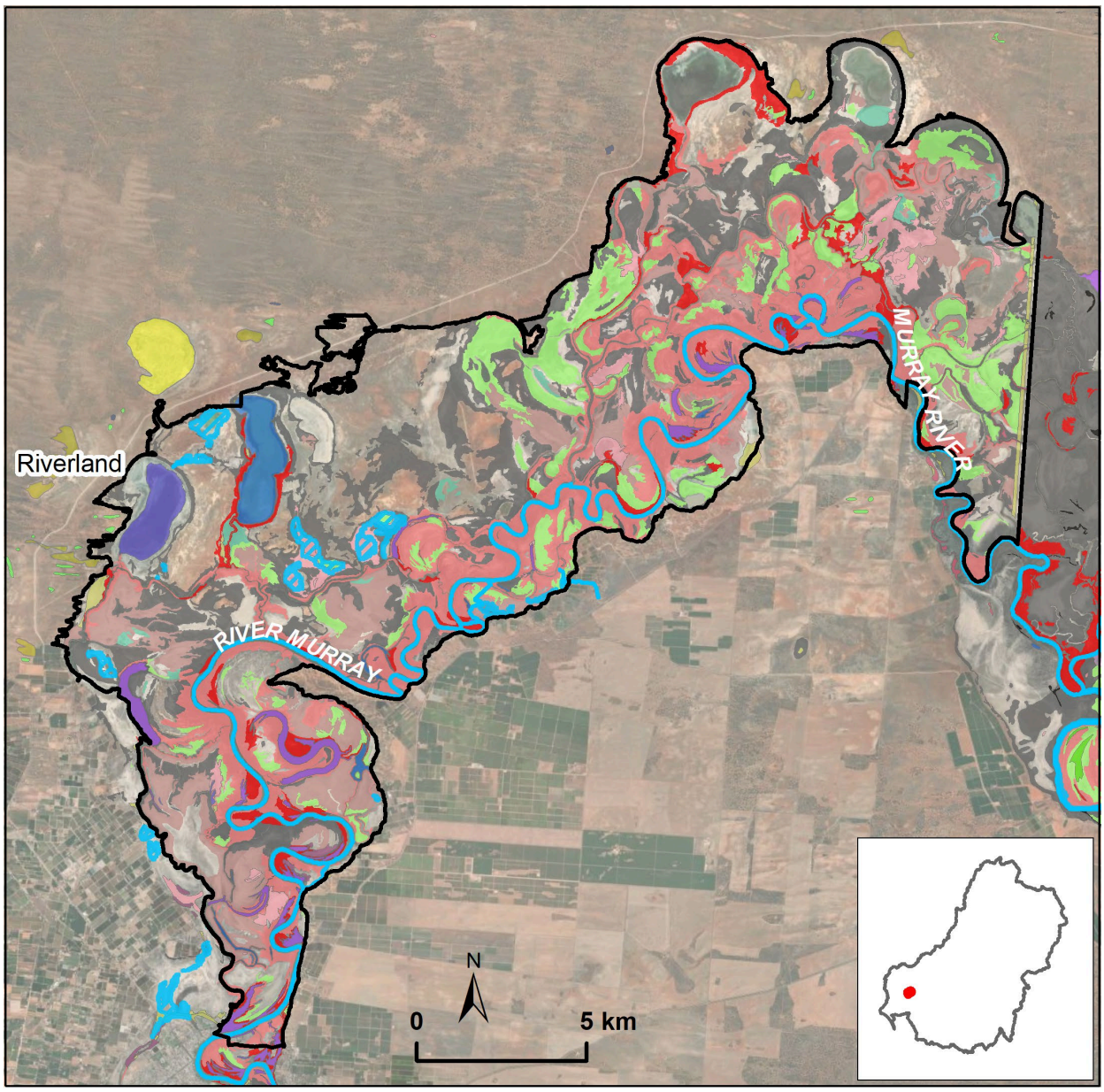


Figure 4.12 Ecosystem diversity within the Riverland Site showing 2021–22 inundation by 2 GL of Commonwealth environmental water delivered to support the Calperum floodplain and regent parrot habitat along the Weila-Murtho connector

Table 4.13 Area of Australian National Aquatic Ecosystem (ANAE) wetland and floodplain types within the Riverland Ramsar Site supported by Commonwealth environmental water (CEW) in 2021–22

Dashes indicate there was no inundation by Commonwealth environmental water.

ANAE ecosystem type	Area within Ramsar Site (ha)	Area supported by CEW (ha)	Percentage (%)
Pt2.3.2: Freshwater meadow	818	230	28
Pt1: Temporary swamps	1,180	60	5
Rp1.4: Permanent lowland stream	1,530	51	3
F1.8: Black box woodland riparian zone or floodplain	5,787	27	<1
F2.2: Lignum shrubland riparian zone or floodplain	2,713	23	1
F2.4: Shrubland riparian zone or floodplain	3,347	15	<1
F4: Unspecified riparian zone or floodplain	1,186	15	1
Pu1: Unspecified wetland	28	3	11
Pt3.1.2: Clay pan	166	2	1
F1.4: River red gum woodland riparian zone or floodplain	5,426	1	<1
Rt1: Temporary stream	2	1	50
F1.2: River red gum forest riparian zone or floodplain	1,204	–	–
Pp4.2: Permanent wetland	581	–	–
Lp1.1: Permanent lake	481	–	–
Psp4: Permanent saline wetland	303	–	–
Rt1.4: Temporary lowland stream	256	–	–
F1.11: River cooba woodland riparian zone or floodplain	204	–	–
Pt2.1.2: Temporary tall emergent marsh	45	–	–
F1.12: Woodland riparian zone or floodplain	20	–	–
Pt1.2.2: Temporary black box swamp	1	–	–
Not water dependent	5,387	–	–
Total	**30,665**	**428**	**1**

4.3.9 The Coorong, and Lakes Alexandrina and Albert Wetland

The Coorong, and Lakes Alexandrina and Albert Wetland Ramsar Site is the large floodplain lake, estuarine and lagoon system at the terminus of the Murray River. The site supports significant vegetation, fish and waterbird communities and is a priority asset in the Strategy, with rolling priorities stated for freshwater connectivity through to the Murray Mouth and to maintain the abundance of shorebird species that feed and breed in the site. In support of these priorities, the lakes received 1,040 GL of environmental water that included 816 GL of Commonwealth environmental water in 2021–22, in addition to end-of-system return flows. The Ramsar Site closely follows the inundated shoreline of the CLLMM (Figure 4.13), with ecosystems supported by Commonwealth environmental water in 2021–22 reported in detail in Table 4.5.

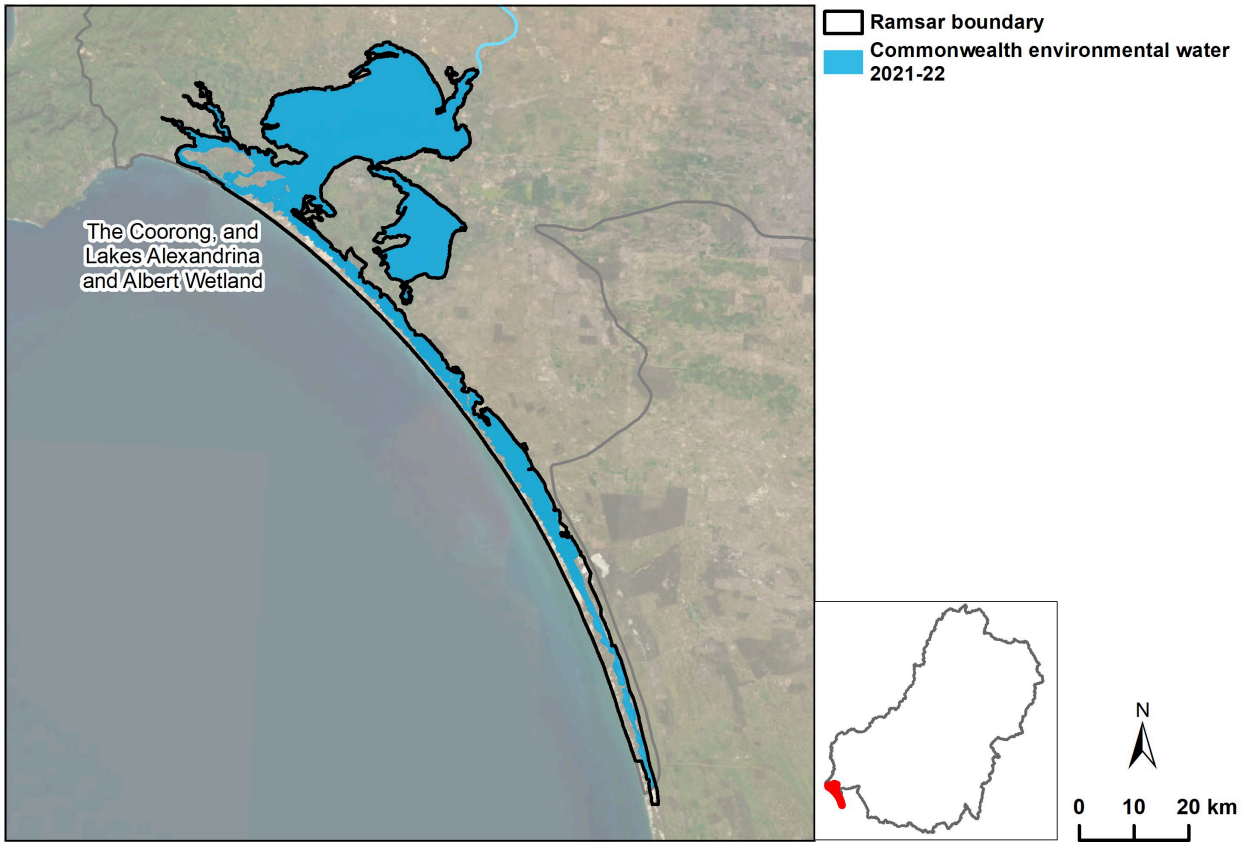


Figure 4.13 The Coorong, and Lakes Alexandrina and Albert Wetland Ramsar Site

5 Basin-scale evaluation 2014–22

This cumulative evaluation quantitatively assesses the distribution of Commonwealth environmental water delivered to aquatic ecosystems in the Basin since monitoring began in July 2014 to June 2022. All figures and tables in the cumulative evaluation presented here have been recalculated for the full 8-year duration using the most recent data and expanded managed floodplain mapping developed in 2022. This means that individual results for particular places and times may differ from earlier reporting; however, it ensures the entire monitoring period is treated equally so that results are comparable among years.

5.1 Key findings

Commonwealth environmental water has contributed to ecosystem outcomes in 19 of the 25 Basin valleys over the 8-year period. Wetland and floodplain inundation are most common in 10 valleys (4 or more of the 8 years). The Victorian Loddon, Campaspe, Goulburn, Ovens, Broken and Wimmera rivers are intentionally managed with no or little overbank inundation to protect agricultural land and infrastructure. In the northern Basin, the Border Rivers, Namoi and Barwon Darling also have had little or no overbank inundation, but in-channel base flows and freshes have been delivered in most years. There has been no Commonwealth environmental water delivered to support ecosystems in the Paroo, Castlereagh, Mitta Mitta, Upper Murray and Avoca valleys. In summary:

- Over the 8-year period 2014–22, Commonwealth environmental water has supported 59 ecosystem types (89% of the ANAE ecosystem types in the Basin and 92% of the ANAE types currently mapped on the managed floodplain) representing:[7]
  - 35,338 ha of lakes representing 17% of lake area on the managed floodplain upstream of the Lower Lakes or 119,861 ha (41% of lake area on the managed floodplain) for the Basin including lakes Alexandrina and Albert
  - 100,873 ha of 21 types of palustrine wetland (21% of the wetland area on the managed floodplain)
  - 157,907 ha of 12[8] types of floodplain (10% of floodplain ecosystem area on the managed floodplain)
  - 26,245 km of 7 types of waterways (52% of the river length on the managed floodplain)
  - 23,768 ha of 9 estuarine ecosystems (100% of the estuary on the managed floodplain).
- At the Basin scale, Commonwealth environmental water contributed to watering frequencies that were broadly consistent with expected requirements – with more frequent support of permanent rivers, lakes, meadows and permanent tall marsh and less frequent inundation of temporary channels, swamps and floodplains. Detailed comparisons of inundation frequencies against desired frequency objectives for each ecosystem type has yet to be conducted.
- Water delivery is responsive to climatic conditions from year to year and sufficiently agile to deliver water in accordance with the Strategy's annual priorities, noting that measuring environmental benefits of those watering actions in terms of improvement in ecosystem condition was beyond the scope of this evaluation.

[7] Total figures for the Basin including the CLLMM

[8] These 12 floodplain types comprise 11 floodplain types upstream of the CLLMM and one additional type (Paperbark dominated floodplain) adjacent to the Coorong.

5.2 Outcomes for Basin ecosystems

5.2.1 Lake ecosystems

Commonwealth environmental water was consistently delivered to only 2 of the 8 lake types found in the Basin (temporary and permanent lakes; Figure 5.1), but together they make up 92% of the lakes by area in the Basin and on the managed floodplain (Table 4.2). Commonwealth environmental water was delivered more frequently for the maintenance of permanent lakes (Figure 5.1, Figure 5.2), except in 2020–21 when water was delivered to the large temporary Lake Brewster (6,500 ha) in the Lachlan Valley to support pelican breeding and waterbird foraging. This pattern is consistent with the hydrological needs of these systems as temporary lakes also require dry periods to maintain ecosystem processes.

The large increase in permanent lake inundation in 2017–18 (Figure 5.1) was due to weir pool raising at Lock 8 and Lock 9 on the Murray River to push Commonwealth environmental water into Lake Victoria (a 10,738 ha permanent lake), banking some water in a wet year.

Four of the 5 lake ecosystem types that did not receive Commonwealth environmental water in the past 8 years have lake beds supporting aquatic macrophytes ('aquatic bed' in the ANAE typology) (Table 4.2). Lake macrophytes are poorly surveyed in the Basin and it is likely that there are many more permanent lakes with aquatic macrophyte beds than the 95 that are mapped in the ANAE dataset. Of these 95 lakes, there are 23 with aquatic macrophyte beds on the managed floodplain – 2 in Victoria (Lake Buloke and Little Lake Buloke) in the Wimmera, and 21 in Queensland in the Border Rivers and Condamine Balonne systems.

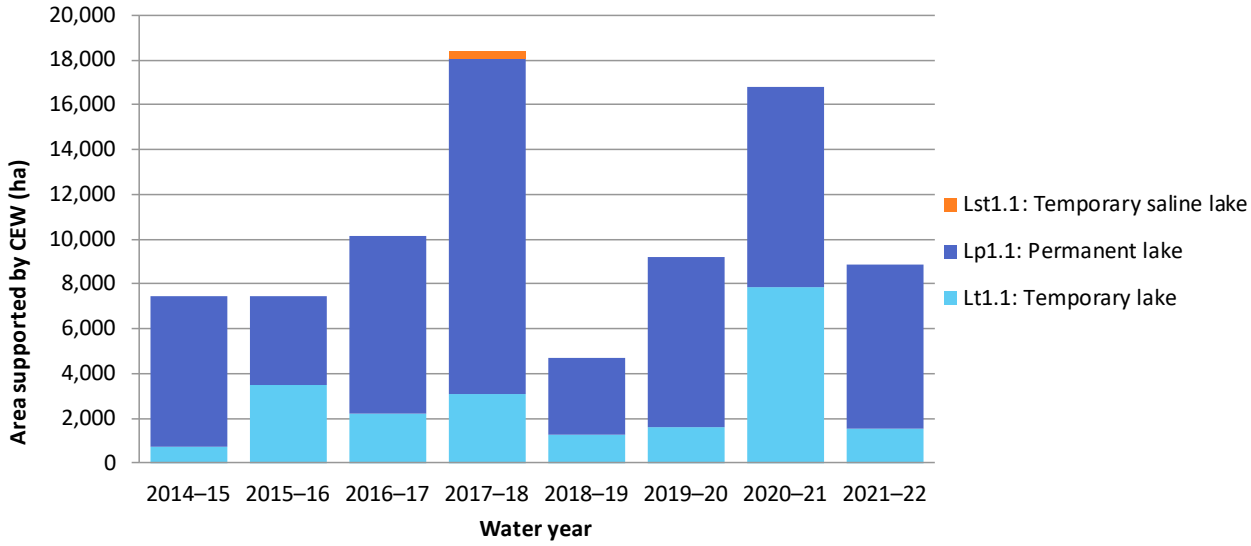
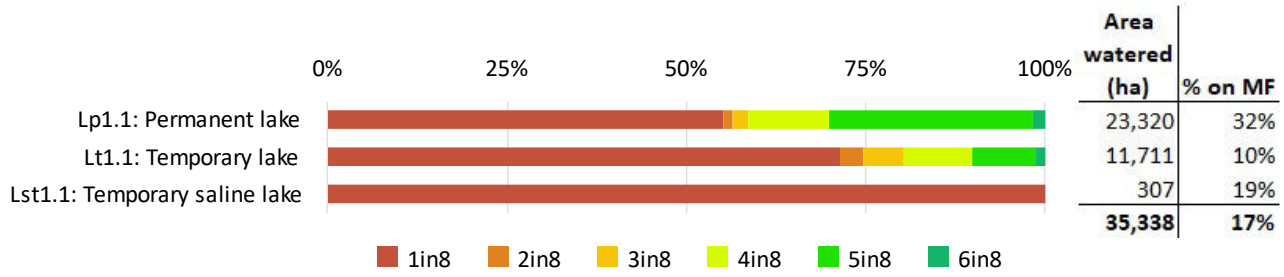


Figure 5.1 Lake ecosystem types supported by Commonwealth environmental water (CEW), 2014–22
Tabulated data are presented in Table D.1.

Over the 8 years of monitoring since 2014–15, Commonwealth environmental water supported 35,338 ha of lake ecosystems (Figure 5.2), which represents 32% of the permanent and 10% of the temporary lake area on the managed floodplain. This figure excludes lakes Alexandrina and Albert in South Australia which are inevitably supported by those environmental releases that reach the end of the system in every year (another 82,325 ha). Commonwealth environmental water was distributed among lakes, with most (61% by area, 21,538 ha) receiving water only once in 8 years (Figure 5.2). However, a small number of lakes received Commonwealth water repeatedly, with 546 ha of lakes watered in 6 of the 8 years.

It is important to remember that Commonwealth environmental water does not support ecosystems in isolation of other water management. Lakes within internationally significant Ramsar Sites (Hattah Lakes, Kerang Lakes and Barmah Lake) were also supported by Victoria and The Living Murray environmental water reserves in years when Commonwealth environmental water was not delivered (Hale et al. 2020). Inundation by these other sources of environmental water is currently not mapped by Flow-MER, so the presented Commonwealth environmental water watering frequencies do not represent the hydrological regime of the lakes.



	Area watered (ha)	% on MF
Lp1.1: Permanent lake	23,320	32%
Lt1.1: Temporary lake	11,711	10%
Lst1.1: Temporary saline lake	307	19%
	35,338	**17%**

Figure 5.2 Annual watering frequencies of lake ecosystem types over the 8-year period 2014–22, with the total area and percentage of each lake type on the managed floodplain (MF) that received Commonwealth environmental water

No lakes upstream of the Coorong, Lower Lakes and Murray Mouth received Commonwealth environmental water in 7 or more of the last 8 years.

5.2.2 Wetland ecosystems (palustrine)

In the 8 years 2014–22, Commonwealth environmental water supported 100,873 ha of palustrine wetland of 21 different ANAE wetland types (Figure 5.3, Figure 5.4, with area of all ANAE types tabulated in Table D.2). Between 28,402 ha (2014–15) and 74,562 ha (2020–21) were watered in any one year (average 56,828 ha), with only 2 wetland types receiving Commonwealth environmental water in every year (74 ha of temporary sedge/grass/forb marsh and 196 ha of permanent wetland; Figure 5.5). Eight wetland types did not receive any Commonwealth environmental water (Table 4.2; values exclude the CLLMM). Including the CLLMM adds another 19,344 ha supported by Commonwealth environmental water (mostly fringing marshes and unvegetated depressions around lakes).

Temporary sedge/grass/forb marsh is the most extensive ecosystem type on the managed floodplain (129,573 ha) and 11% (13,965 ha) was watered over the 8 years, with many of these areas watered 2–7 times (Figure 5.4). There were regular watering actions in the Gwydir Wetlands and Macquarie Marshes that also regularly inundated permanent and temporary tall emergent marsh, freshwater meadow, permanent wetland, permanent forb marsh and permanent sedge/grass/forb marsh (combined 28,310 ha), with much of the tall marsh being watered in 7 of the last 8 years (Figure 5.4).

Temporary river red gum swamp was the wetland type with the largest area supported by Commonwealth environmental water over the 8 years (37,332 ha), with most of this area (66%, 24,592 ha) being inundated in 6 of the 8 years since 2014–15, corresponding to the years the Barmah–-Millewa Forest received an allocation from the Commonwealth (Figure 5.3). Temporary river red gum swamp is an ecosystem type that is commonly supported by environmental water due to its proximity and connectedness to lowland river channels. Fringing river red gums and swamps that are connected to waterways often receive water during channel freshes or weir pool raising actions, in addition to actions that specifically target overbank flooding. For example, weir pool raising at Locks 7–9 on the Murray River floods river red gum swamps and anabranches around Lindsay, Wallpolla and Mulcra islands.

Ecosystem types that did not receive Commonwealth water at all over 8 years included saline systems (salt flats, saline wetlands and salt marsh) for which freshwater additions could be detrimental, and ecosystems that are consistently wet and perhaps not in need of supplementary water (e.g. permanent springs, paperbark swamps, peat bogs and fen marshes). These systems occur rarely on the managed floodplain (only 190 ha combined; see Appendix D for a complete tabulation of all ecosystem types).

The proportion of palustrine wetland types supported by Commonwealth environmental water was similar across all 8 years (Figure 5.3) with 3 notable exceptions:

- reduced watering of temporary river redgum swamp in 2014–15 and 2016–17, when Commonwealth environmental water was not used to flood the river red gum dominated Barmah–Millewa Forest (The Living Murray Program delivered environmental water to Barmah–Millewa in these 2 years)
- reduced watering of temporary tall emergent marsh and freshwater meadow in 2019–20, when there were no significant overbank flows in the Gwydir Wetlands and Macquarie Marshes
- no watering of permanent tall emergent marsh in 2016–17 due to widespread natural flooding. Note that 2021–22 was also a year with widespread natural flooding; however, in this year, tall marshes in the Macquarie Marshes and Gwydir Wetlands received Commonwealth environmental water to extend the flood duration to support waterbird breeding.

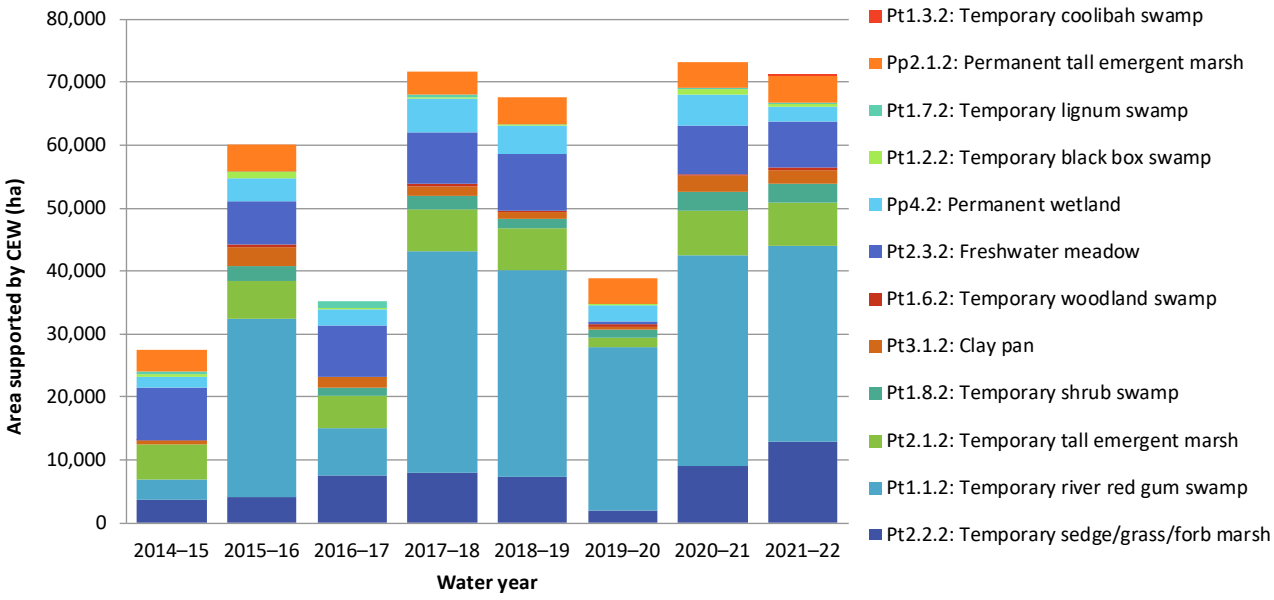


Figure 5.3 Palustrine wetland ecosystem types supported by Commonwealth environmental water (CEW), 2014–22
For clarity, only the 12 most extensive wetland types are presented, representing 96% of the wetland area on the managed floodplain. Complete tabulated data are presented in Appendix D.

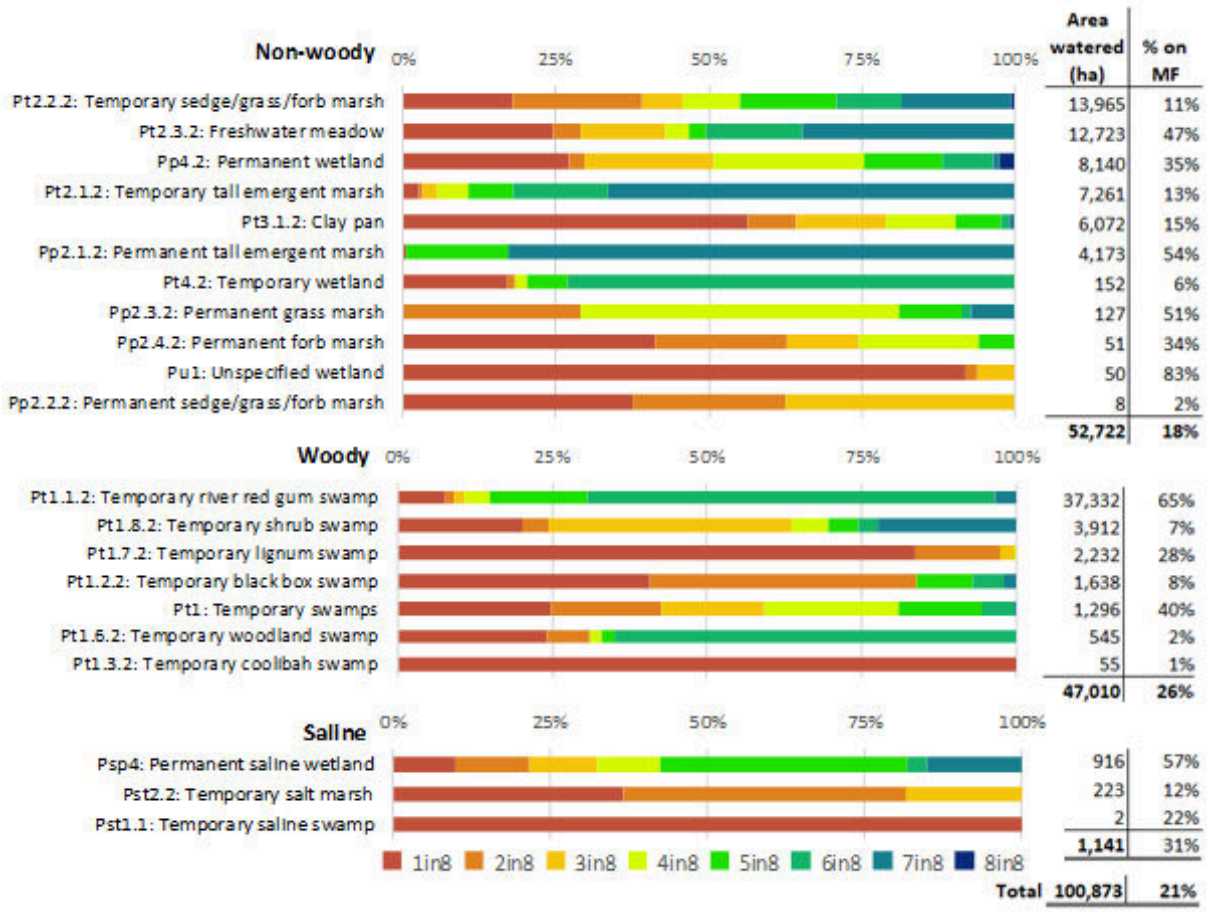


Figure 5.4 Annual watering frequencies of wetland ecosystem types (non-woody, woody, saline) supported by Commonwealth environmental water (CEW) over the 8-year period 2014–22, with the total area and percentage of each wetland type on the managed floodplain (MF) that received CEW

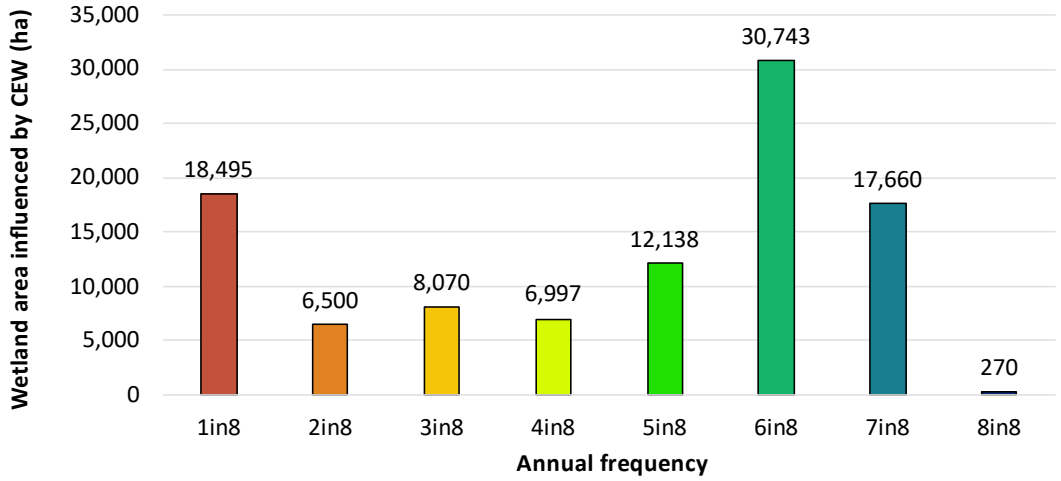


Figure 5.5 Combined area of palustrine wetlands influenced by Commonwealth environmental water (CEW) at different annual frequencies over 8 years, totalling 100,873 hectares, 2014–22

5.2.3 Floodplain ecosystems

Limited water volumes and policies to avoid inundating built assets or agricultural land often constrain Commonwealth environmental water to in-channel flows and watering of floodplain wetlands through regulators and connecting channels rather than by overbank flooding. On average, from 2014–15 to 2020–21, only 3% of the managed floodplain received Commonwealth environmental water in any one year. In 2021–22, Commonwealth environmental water was delivered to the Macquarie Marshes, Gwydir Wetlands, Narran Lakes and Lowbidgee to support the maintenance of water at waterbird breeding colonies that formed in response to extensive natural flooding. As a result, the extent of floodplain supported by Commonwealth environmental actions in 2021–22 was higher than in any previous year (72,126 ha, 5% of the managed floodplain) (Figure 5.6). Over the 8-year period of monitoring, 157,842 ha of floodplains (157,907 ha including the CLLMM), comprising 10% of the managed floodplain, was inundated by Commonwealth environmental water at least one time (Figure 5.7).

River red gum forest riparian zone/floodplain was inundated by Commonwealth environmental water to the greatest extent, with 71,356 ha inundated over the 8 years at varying frequencies, representing 22% of this ecosystem type on the managed floodplain (Figure 5.6, Figure 5.7). River red gum forest and woodland floodplain types comprised between 32% and 82% of the floodplain area inundated in any one year over the last 8 years. This reflects the high value of this ecosystem type in priority assets (e.g. Barmah–Millewa Forest, the Lowbidgee floodplain and along the Murray River channel) and the proximity of river red gum ecosystems to river channels.

The pattern of watering across years seen in Figure 5.6 reveals some contrasts. The 2 years with the least floodplain inundation were a very wet year (2016–17) where watering of floodplains by Commonwealth environmental water was not seen as a priority, and the driest year on record (2019–20) where available Commonwealth environmental water was directed to supporting base flows, with only 2 of 155 planned watering actions targeting overbank flows. The 2021–22 year was also very wet, but unlike 2016–17, there was extensive use of Commonwealth environmental water to support completion of waterbird breeding.

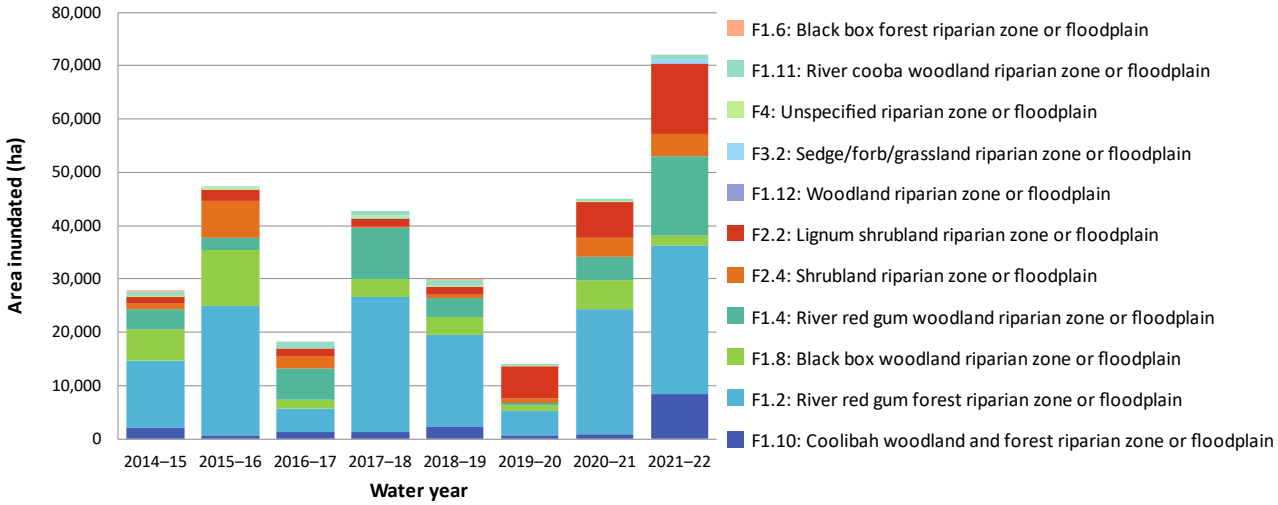


Figure 5.6 Floodplain ecosystem types inundated by Commonwealth environmental water, 2014–22
Tabulated data are presented in Table D.3. Floodplain types inundated comprise 11 floodplain types upstream of the CLLMM and excludes F1.13 Paperbark dominated floodplain) adjacent to the Coorong.

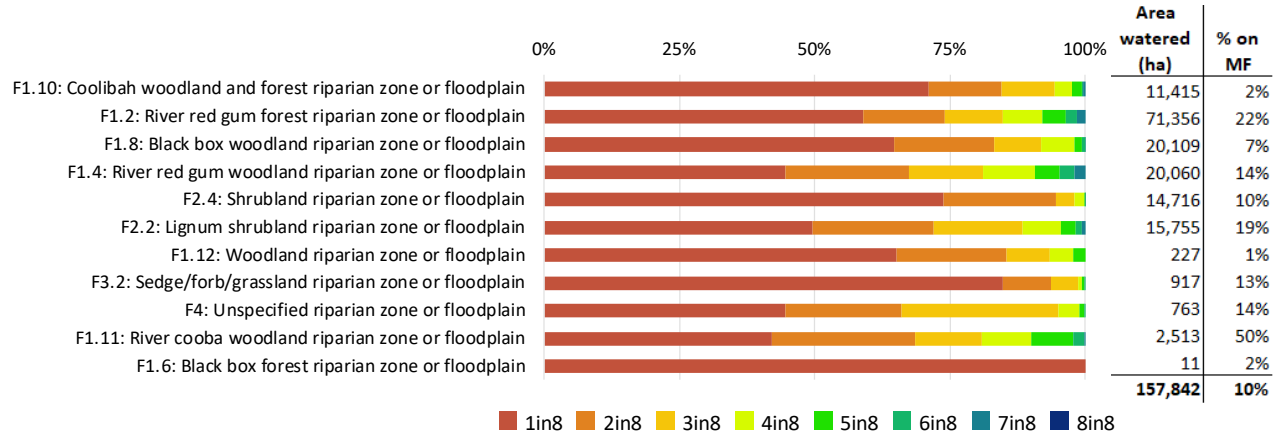


Figure 5.7 Annual watering frequencies of floodplain ecosystem types inundated by Commonwealth environmental water (CEW) over the 8-year period, with the total area and percentage of each floodplain type on the managed floodplain (MF) that has received CEW, 2014–22

Floodplain types inundated comprise 11 floodplain types upstream of the CLLMM and excludes F1.13 Paperbark dominated floodplain) adjacent to the Coorong.

5.2.4 River ecosystems

The managed floodplain contains approximately 10% of total river length in the Basin. Lowland rivers and streams dominate, representing 86% of the approximately 50,000 km of rivers that are potentially in scope for environmental water management. Commonwealth environmental water primarily supports permanent and temporary lowland rivers, with 97% of flow delivery in any one year being in lowland reaches. At the Basin scale in 2014–22, the annual allocation to river flows was very consistent, with 14,105–22,170 km of waterways potentially benefiting from Commonwealth environmental water annually (Figure 5.8).

Over the 8-year period, 26,245 km of river was supported by Commonwealth environmental water (52% of the rivers on the managed floodplain) (Figure 5.9), with 38% (9,847 km) watered in every year along permanent lowland sections of the Barwon, Macquarie, Gwydir, Lachlan, Murrumbidgee, Edward, Wakool, Murray, Ovens, Broken, Goulburn and Loddon rivers (Figure 5.10). Permanent reaches in the lowland sections of the Bokhara, Culgoa, Darling and Campaspe rivers, and the smaller upland, transitional Severn River received Commonwealth environmental water in 6 of the 8 years. Some temporary rivers have also received water in 7–8 of the years: Gunbower Creek, Tuppal Creek, the Moonie River, and lower end of the Warrego River (Figure 5.10).

The upland and transitional streams that received Commonwealth environmental water were mostly outflows from storages into the upper reaches of the King, Lachlan, Gwydir, Severn and Dumaresq rivers. However, there were some unregulated flows managed by water licence rules – in the Severn River above Glenlyon Dam (7 in 8 years) and in the upper Warrego River (5 in 8 years).

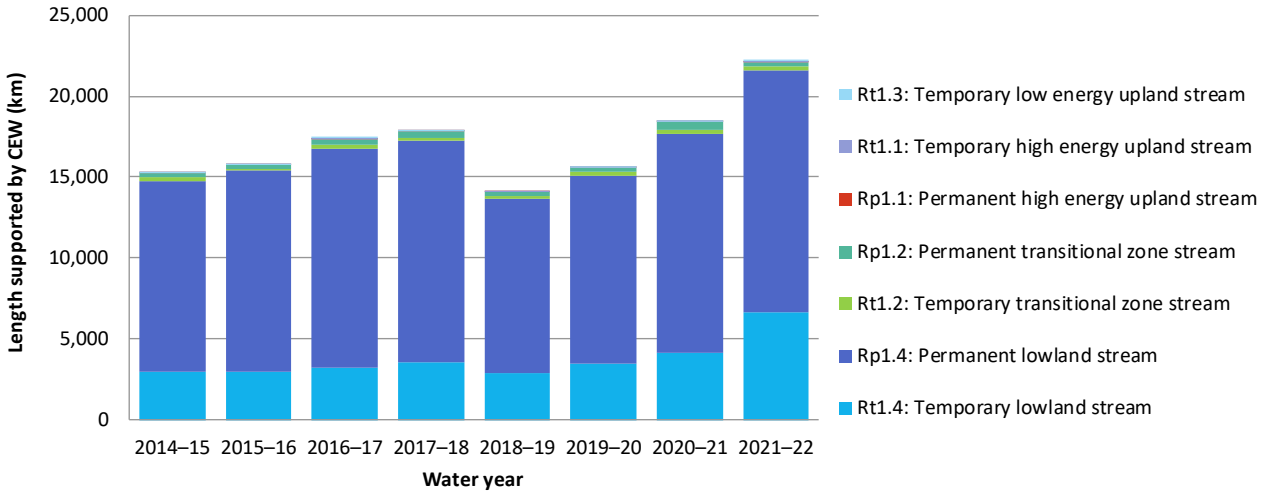


Figure 5.8 Length of river channels that included Commonwealth environmental water (CEW), 2014–22
Tabulated data are presented in Table D.4.

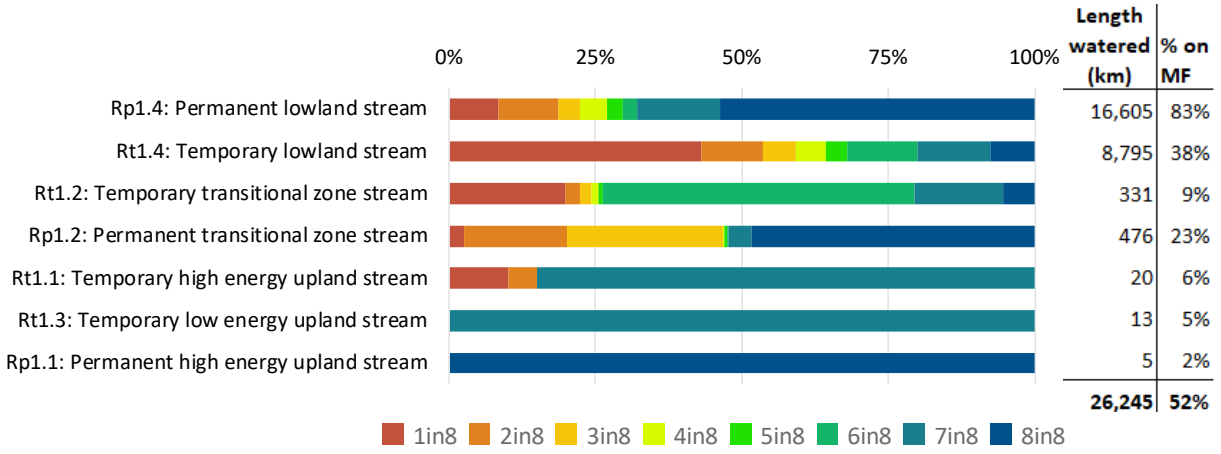


Figure 5.9 Annual watering frequencies of river ecosystem types with Commonwealth environmental water (CEW) over the 8-year period, with the total river length and percentage of river length on the managed floodplain (MF) that has received CEW, 2014–22

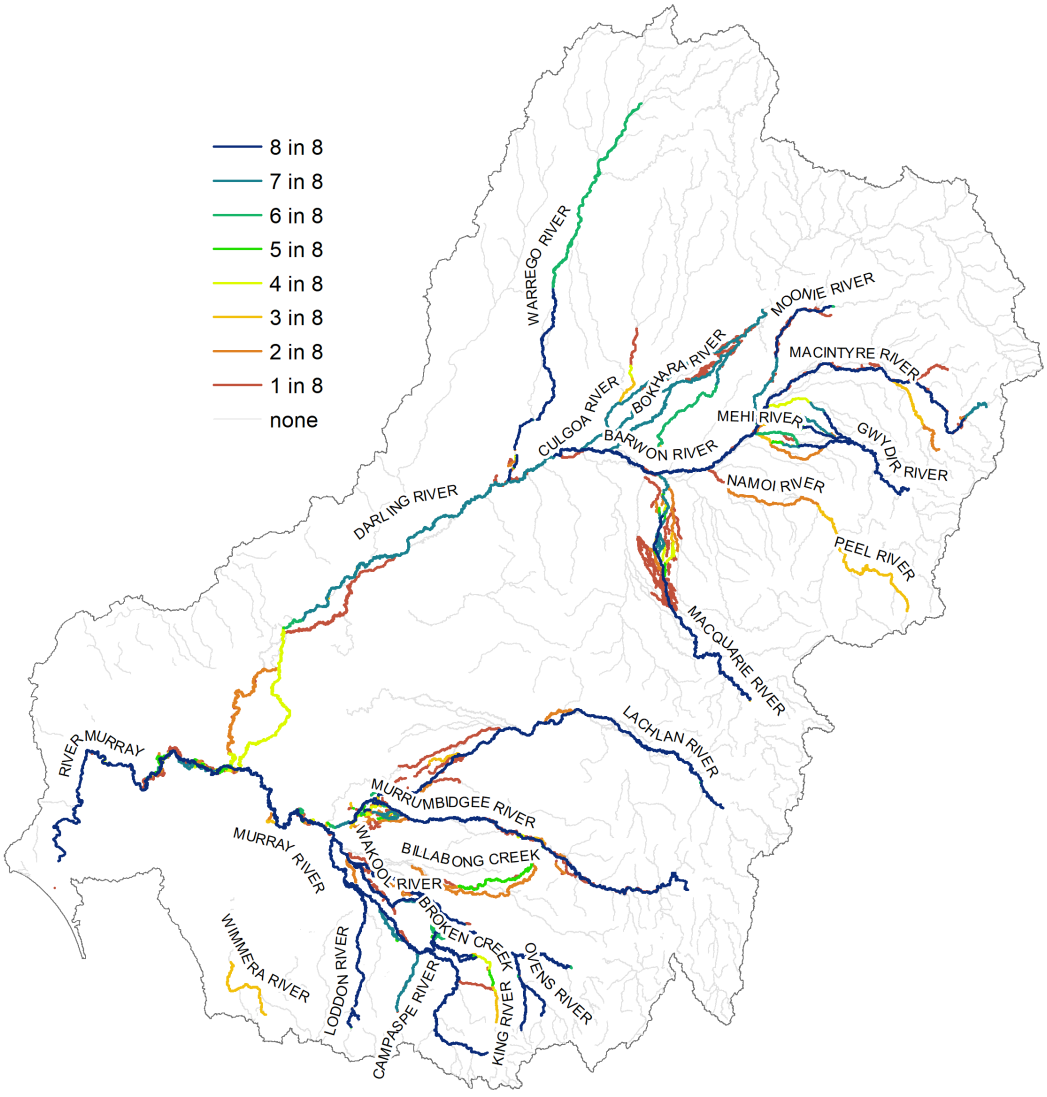


Figure 5.10 Map of annual frequency (from 1 in 8 years to 8 in 8 years) of Commonwealth environmental water in rivers in the Murray–Darling Basin, 2014–22

5.3 Outcomes for Ramsar Sites

For the period 2014–22, Commonwealth environmental water was delivered to support environmental outcomes in 11 Ramsar Sites in the Basin (Table 5.1, Figure 4.4), noting that Commonwealth environmental water is often delivered in partnership with water held by the MDBA (e.g. The Living Murray Program) as well as water from state jurisdictions.

Table 5.1 Years in which Commonwealth environmental water was delivered to Ramsar Sites in the Basin, 2014–22
Marked with 'X'. Dashes indicate no Commonwealth environmental water was delivered.

Ramsar Site	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
Northern Basin								
Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses	X	X	X	X	X	–	X	X
Narran Lake Nature Reserve	–	–	X	–	–	X	X	X
Paroo River Wetlands	–	–	–	–	–	–	–	–
The Macquarie Marshes	X	X	X	X	X	X	X	X
Southern Basin								
Banrock Station Wetland Complex	–	X	–	X	X	X	X	X
Barmah Forest*	–	X	–	X	X	X	X	X
Currawinya Lakes	–	–	–	–	–	–	–	–
Fivebough and Tuckerbil Swamps	–	–	–	X	X	X	X	–
Ginini Flats Wetland Complex	–	–	–	–	–	–	–	–
Gunbower Forest	–	X	X	X	X	X	X	X
Hattah–Kulkyne Lakes	X	X	–	X	–	–	–	–
Kerang Wetlands	–	–	–	–	–	–	–	–
Lake Albacutya	–	–	–	–	–	–	–	–
NSW Central Murray Forests	X	X	X	X	X	X	X	X
Riverland	X	X	X	X	X	X	X	X
The Coorong, and Lakes Alexandrina and Albert Wetland	X	X	X	X	X	X	X	X

Each Ramsar Site has a written ecological character description (ECD) that defines the critical CPS need to be maintained to preserve ecological character. Hydrology is listed as a critical component for all Basin Ramsar Sites. Examples of other critical CPS not assessed further in this evaluation include vegetation composition, waterbird species and population sizes, native fish populations, and rare or threatened species. The following summaries examine the recent 2014–22 history of Commonwealth environmental water inundation extent for each site. This is insufficient to determine whether ecological character is maintained but does inform a qualitative assessment of the potential contribution of managing Commonwealth environmental water towards hydrological aspects of ecological character. A comprehensive analysis of ecological character is beyond the scope of this evaluation but is recommended for inclusion in the next iteration of CEWH long-term monitoring, evaluation and research currently being planned as 'Flow-MER 2.0'.

5.3.1 Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses

The Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses Ramsar Site received Commonwealth environmental water in 7 of the 8 years 2014–22 (Figure 5.11, Figure 5.12). The exception in 2019–20 was when flows were constrained to the channel to protect river assets after 3 successive years of dry conditions. In early 2020, there was above-average rainfall that provided a natural water source to revive the cooch grass meadows (CEWO 2020). The Ramsar Site consists of 4 isolated sub-units with Commonwealth environmental water primarily supporting Goddard's Lease and Old Dromana (Figure 5.11) to flood freshwater meadows dominated by water cooch and areas of tall marsh (Figure 5.12). The Gwydir River System Selected Area reports in detail on the outcomes from Commonwealth environmental water management at this site. This site does not have an ECD that defines the critical CPS.

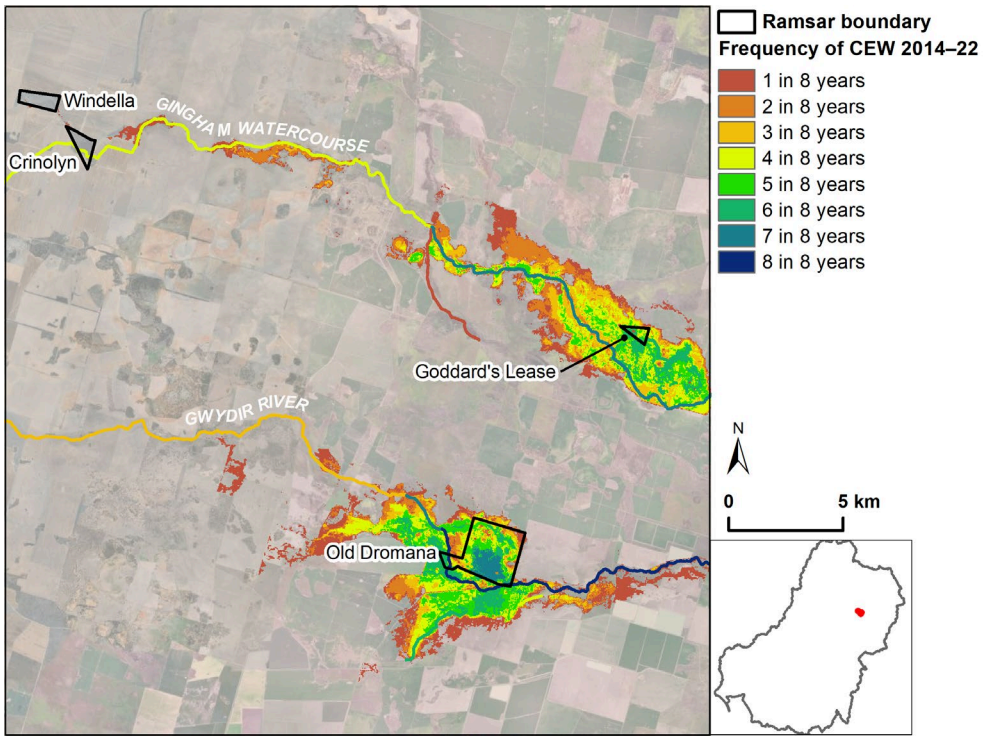


Figure 5.11 Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

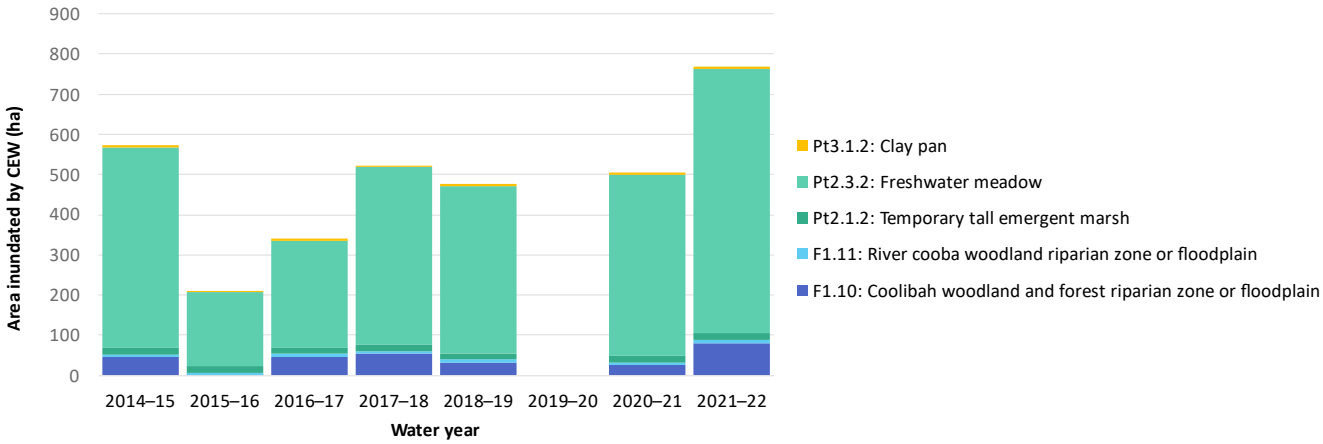


Figure 5.12 Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.2 Narran Lake Nature Reserve (Narran Lakes)

The Narran Lake Nature Reserve Ramsar Site received Commonwealth environmental water in 4 of the 8 years 2014–22 (Figure 5.13, Figure 5.14). Substantial inundation of lignum floodplain in 2019–20 was followed up with water allocations in 2020–21 to improve lignum health and build resilience in the system to support waterbird breeding and recruitment (MDBA 2021). Supporting regular breeding of colonial waterbirds (in no less than 1 in 8 years) is listed as a critical service that characterises this site (Butcher et al. 2011). The prior preparation appears to have been successful, with breeding commencing at the site after natural flooding in 2021–22. Commonwealth environmental water was then added to maintain water at colonies to provide breeding habitat and foraging areas for juveniles (Brandis et al. 2022).

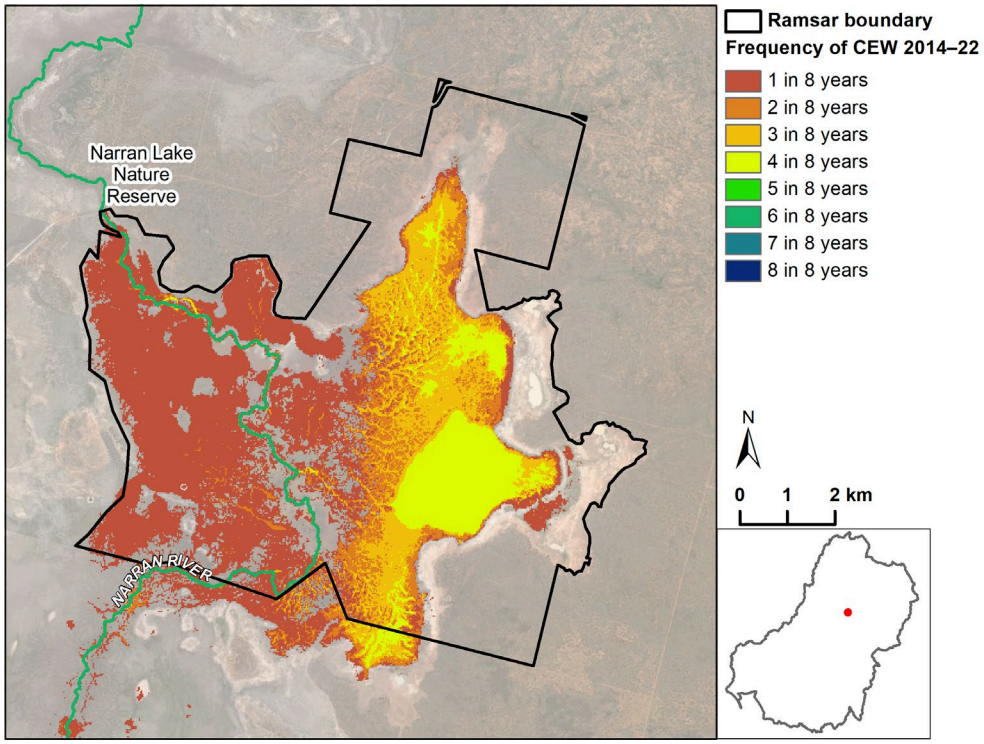


Figure 5.13 Narran Lake Nature Reserve Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

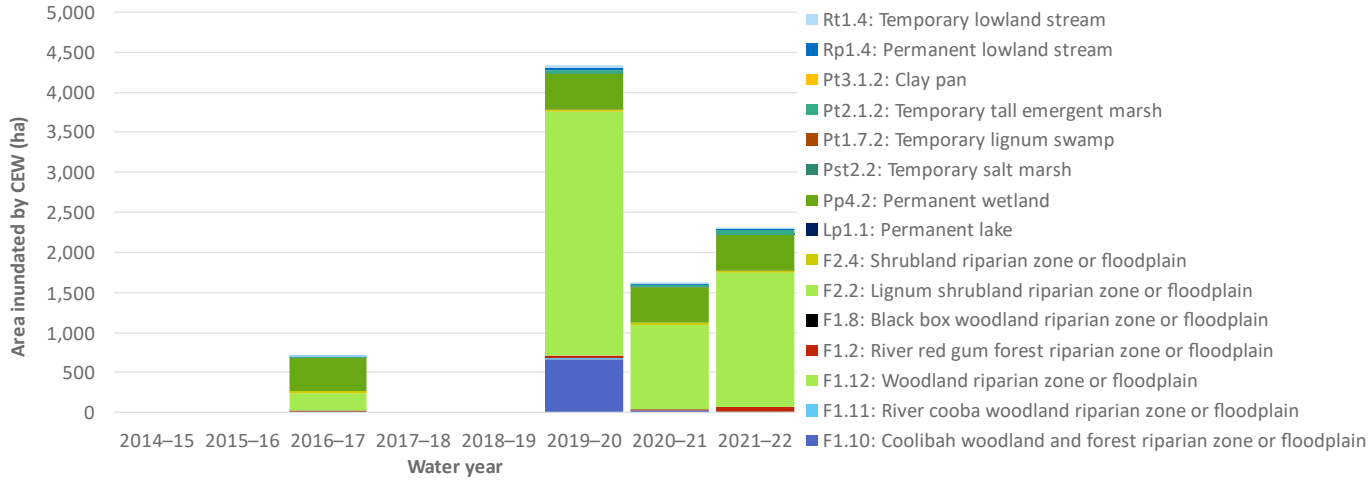


Figure 5.14 Narran Lake Nature Reserve Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.3 The Macquarie Marshes

Commonwealth environmental water contributed (along with jurisdictional water) to inundation of The Macquarie Marshes Ramsar Site in 7 of the 8 years 2014–22 (Figure 5.15, Figure 5.16). No inundation is shown for 2019–20 (Figure 5.15); however, in this period approximately 4 GL was accessed through supplementary licences on the Macquarie River allowing some in-channel flows to replenish refuge pools and flow through to the marshes. Extensive inundation in 2021–22 was the result of watering actions following natural flooding events to maintain waterbird breeding colonies and provide waterbird foraging habitat.

Water management in the Macquarie Marshes is typically planned and executed for the larger extent of the marshes, and not just the 3 units that make up the Ramsar Site. Much of the southern marsh that is regularly inundated by Commonwealth environmental water is outside of the Ramsar Site boundary (Figure 5.15).

The Ramsar critical CPS for the site include indicators that are the focus of much of the jurisdictional monitoring, including the extent of tall marsh, lignum and river red gum, waterbird counts and colonial waterbird breeding.

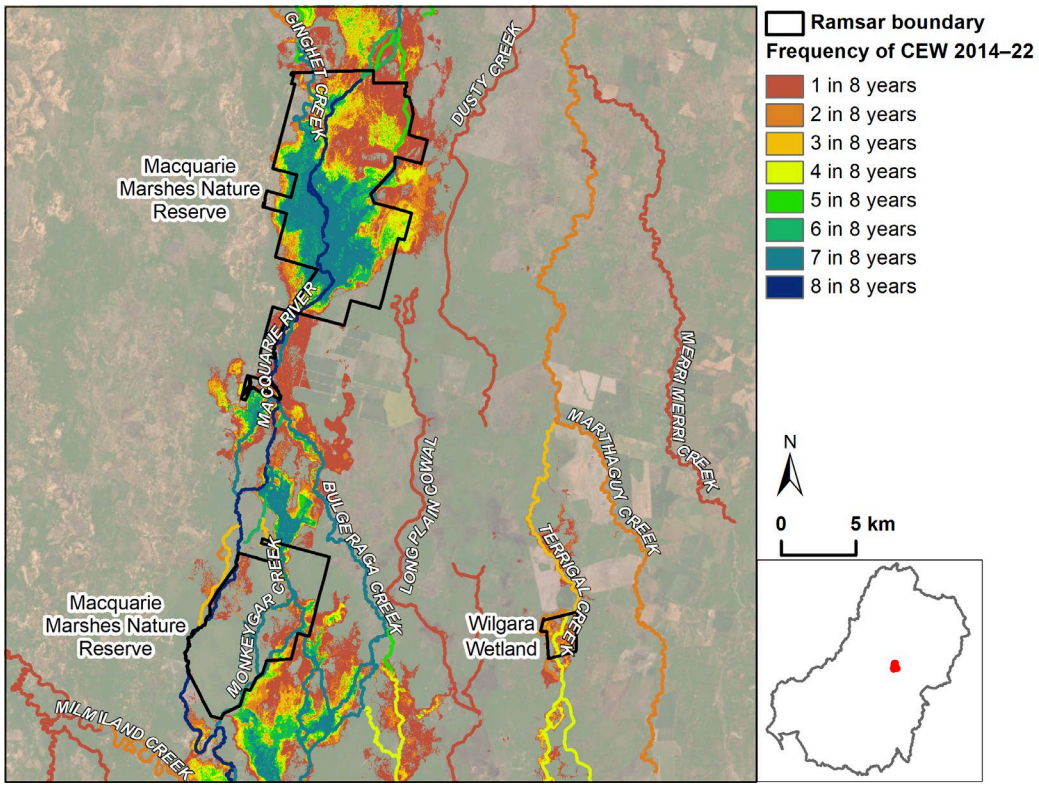


Figure 5.15 The Macquarie Marshes Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

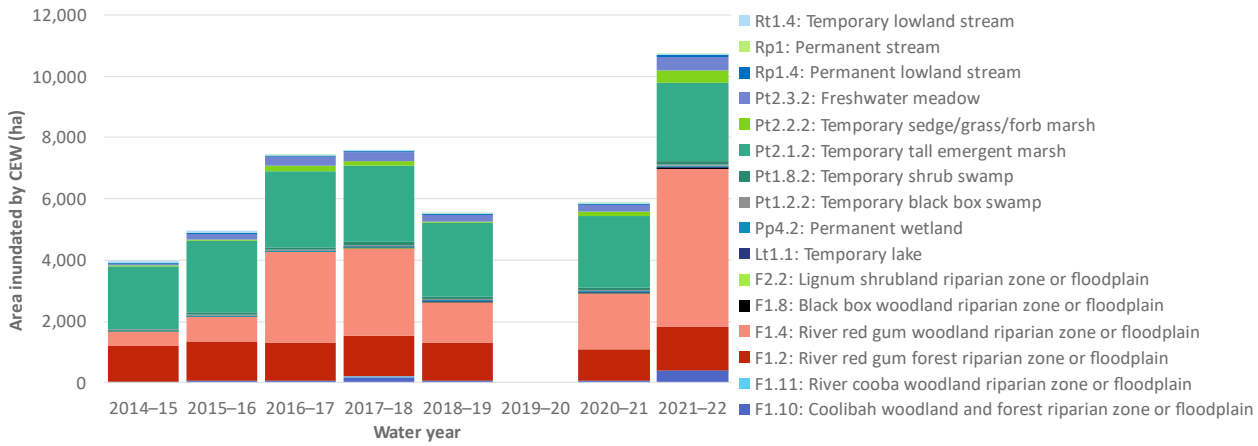


Figure 5.16 The Macquarie Marshes Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.4 Banrock Station Wetland Complex

At the time of listing in 2002, Banrock Lagoon was managed as a permanent wetland, but it is now managed for a wetting and drying cycle each year – wetting during spring primarily to sustain dominant vegetation associations, with a drawdown over summer and autumn (Butcher et al. 2009). Commonwealth environmental water was delivered to support the hydrological character of the Banrock Station Wetland Complex Ramsar Site in 7 of the 8 years 2014–22 to maintain this cycle (Figure 5.17, Figure 5.18). The frequently inundated patches on the eastern bank of the Murray River are patches of lignum floodplain outside the Ramsar Site boundary. Areas of permanent wetland are watered in the central basin to support threatened southern bell frog (*Litoria raniformis*). A regulator installed in Wiggley Reach in 2020 allows Commonwealth environmental water to be delivered to black box floodplain that supports the threatened regent parrot (*Polytelis anthopeplus*).

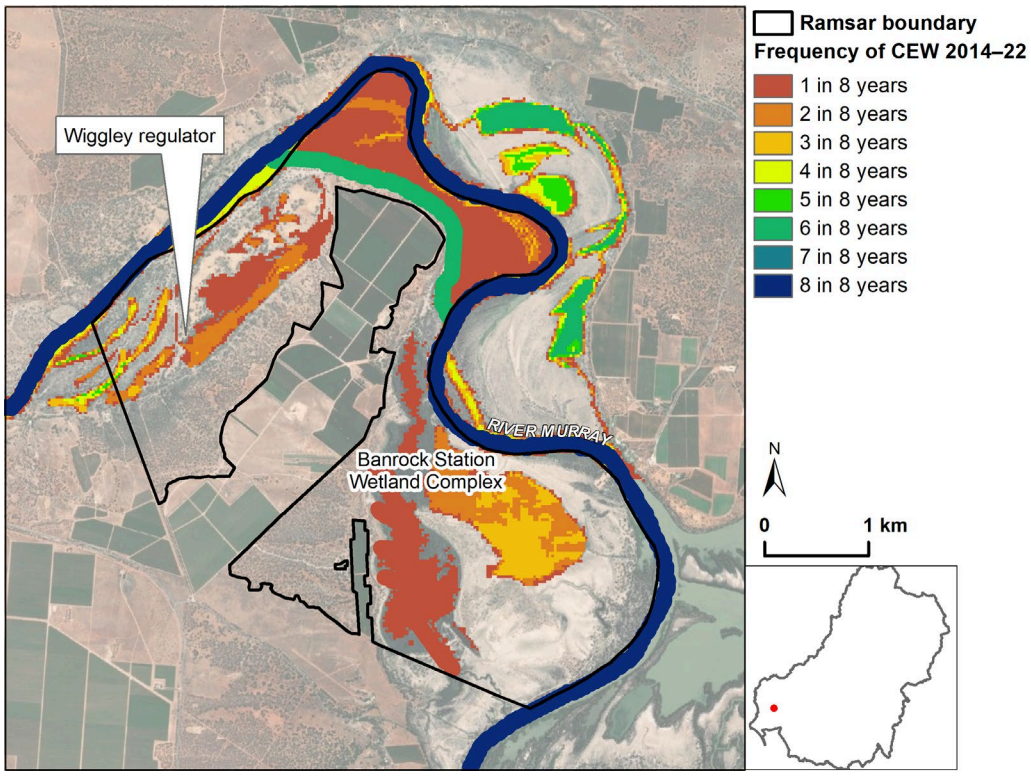


Figure 5.17 Banrock Station Wetland Complex Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

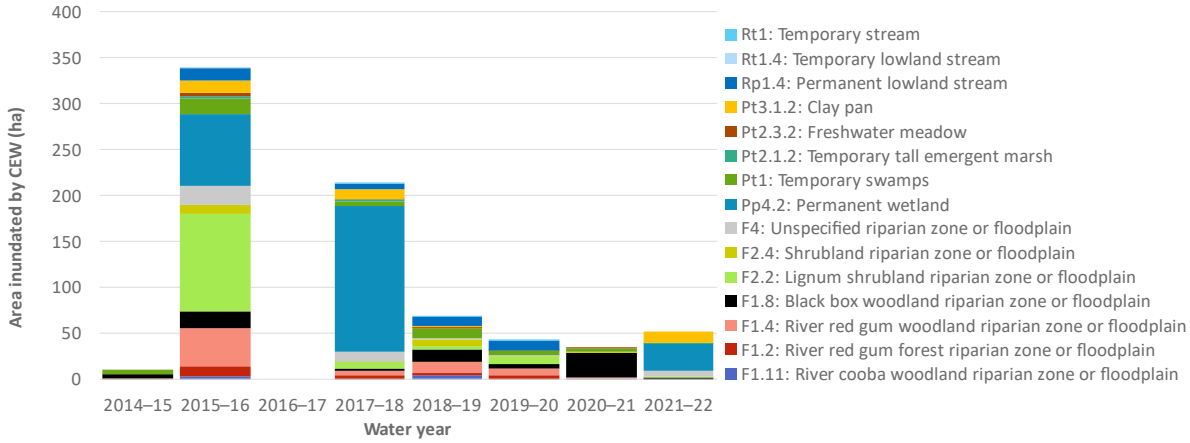


Figure 5.18 Banrock Station Wetland Complex Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.5 Barmah Forest

Barmah Forest Ramsar Site received Commonwealth environmental water in 6 of the 8 years 2014–22 (Figure 5.19, Figure 5.20). During the 2 years that Commonwealth environmental water was not delivered, there were 2 natural floods in 2014–15, and 'other' environmental water (state and MDBA The Living Murray) was used to inundate the site in 2016–17 (Hale et al. 2020). The annual flooding is thought to mimic the natural regime for the site as high winter–spring flows are constricted by the narrow channel of the Barmah choke, causing river water to back up and divert through channels in the floodplain. It is estimated that under pre-regulation scenarios, the site would have naturally flooded in 19 of the past 20 years (SCBEWC 2021). The extensive inundation in 2021–22 (Figure 5.20) is the result of a large environmental water allocation of 414 GL (including 220 GL of Commonwealth environmental water) that was delivered to the site when it was already 45% inundated by naturally occurring high flows (SCBEWC 2023).

The ECD for the Barmah Forest Ramsar Site (Hale and Butcher 2011) notes that, at the time of listing, the hydrological regime may have been insufficient to maintain the character of the site in the long term, emphasising that regular managed inundation by water for the environment in dry periods is critical to maintaining and restoring the site.

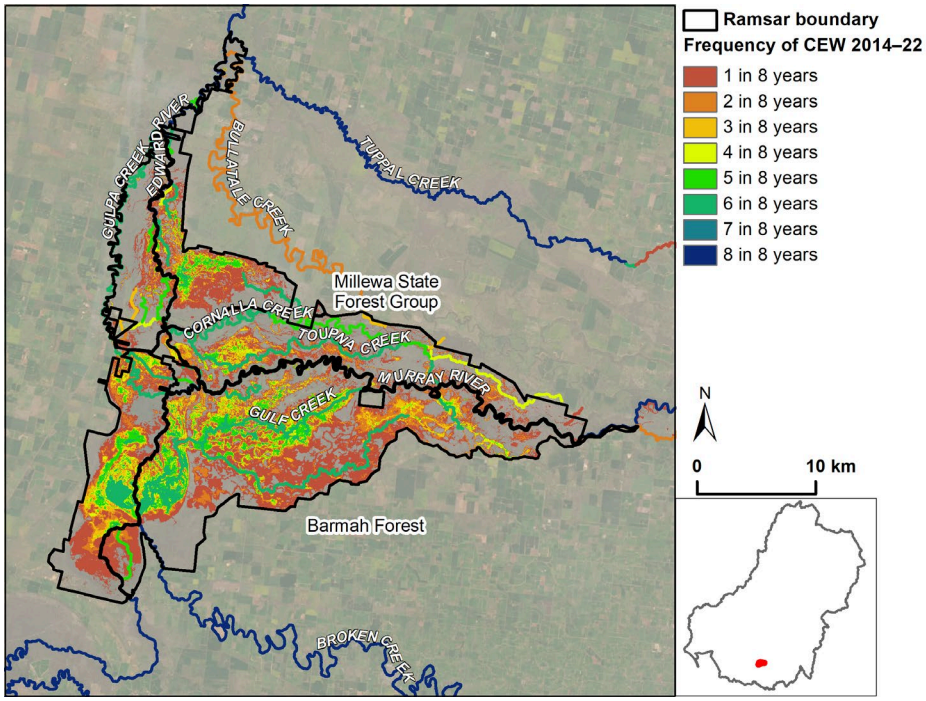


Figure 5.19 Barmah Forest Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

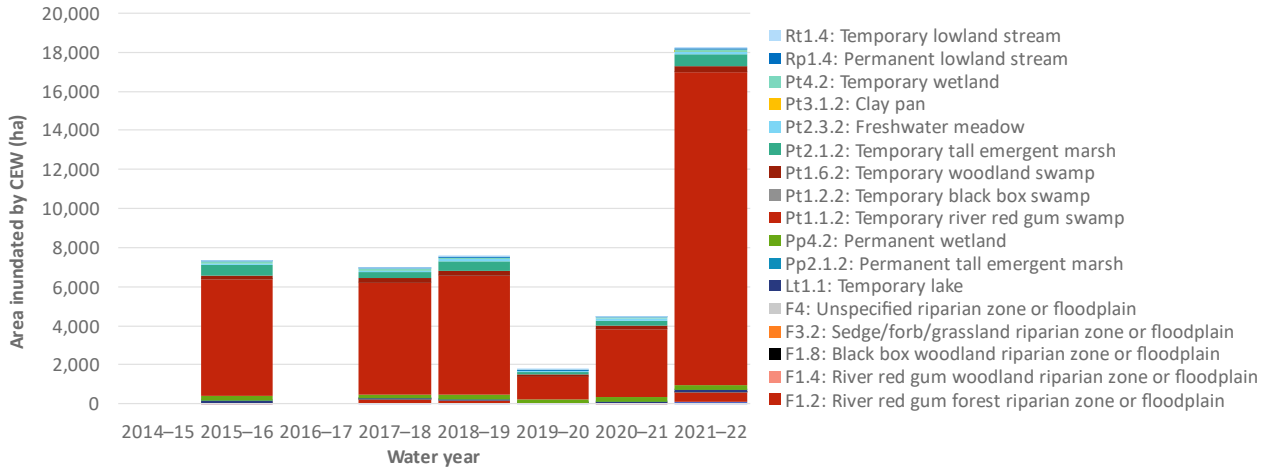


Figure 5.20 Barmah Forest Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.6 Fivebough and Tuckerbil Swamps

Fivebough and Tuckerbil Swamps Ramsar Site received Commonwealth environmental water in 4 of the 8 years 2014–22 (Figure 5.21, Figure 5.22). Fivebough Swamp is a permanent shallow wetland that was 'topped up' after 2 dry years in 2018–19 and 2020–21 using Commonwealth environmental water to support its value as a significant waterbird drought refuge and waterbird feeding and breeding site. Tuckerbil Swamp is a brackish, seasonal shallow wetland maintained by water for the environment more frequently (4 of the last 8 years; Figure 5.21) to support migratory waterbirds and threated waterbird species, including brolga (*Grus rubicunda*), Australasian bittern (*Botaurus poiciloptilus*) and Australian painted snipe (*Rostratula australis*). The swamps were inundated by natural flooding in 2021–22.

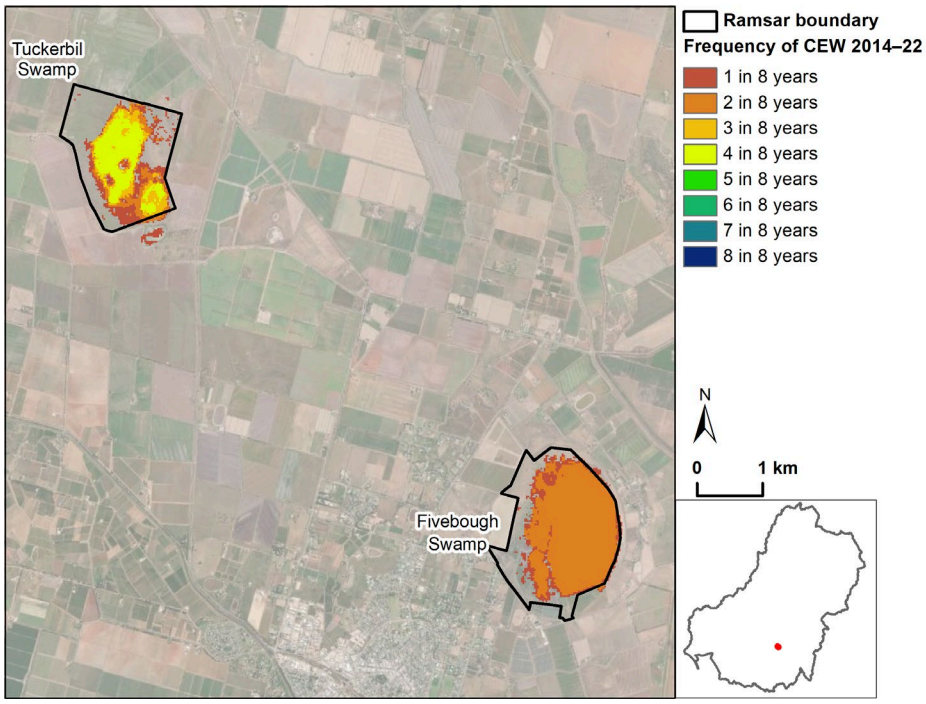


Figure 5.21 Fivebough and Tuckerbil Swamps Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

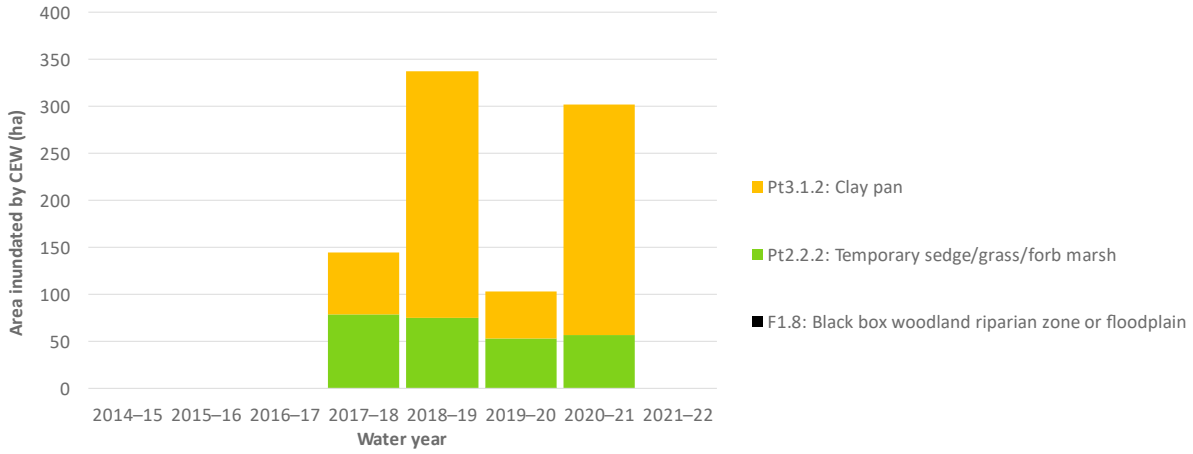


Figure 5.22 Fivebough and Tuckerbil Swamps Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.7 Gunbower Forest

A small number of wetlands and the channel of Gunbower Creek within the Gunbower Forest Ramsar Site are regularly inundated (Figure 5.23) by annual allocations of Commonwealth environmental water that commenced in 2015–16 to maintain native fish habitat and breeding in Gunbower Creek. The Ramsar critical CPS include the ongoing presence of Murray cod (*Maccullochella peelii peelii*) and silver perch (*Bidyanus bidyanus*) in Gunbower Creek, and small-bodied fish in wetland within the site, including Australian smelt (*Retropinna semoni*), carp gudgeons (*Hypseleotris* spp.), dwarf flat-headed gudgeon (*Philypnodon macrostomus*), flat-headed gudgeon (*Philypnodon grandiceps*), fly-specked hardyhead (*Craterocephalus stercusmuscarum)*, and Murray–Darling rainbowfish (*Melanotaenia fluviatilis*). The Ramsar critical CPS for Gunbower Forest also include waterbird breeding and maintaining the extent and condition of river red gum floodplain, but these were not a target of Commonwealth environmental water during the monitoring period, 2014–22.

Wetland inundation by environmental water has not been mapped at this site but occurred in 2021–22 within some smaller wetlands connected to Gunbower Creek in the northern end of the site (SCBEWC 2023).

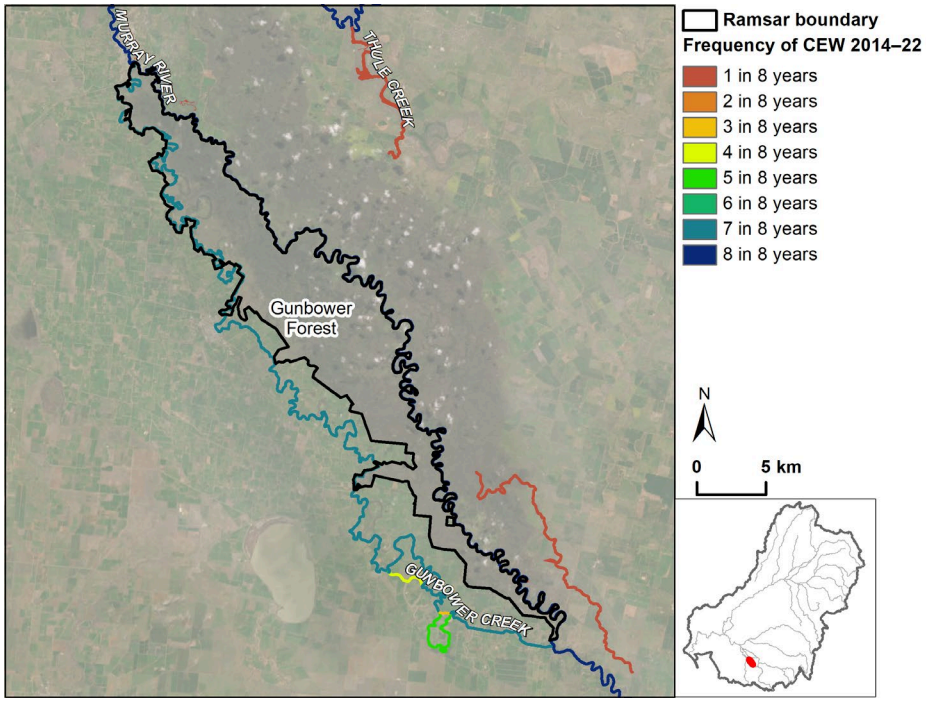


Figure 5.23 Gunbower Forest Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

5.3.8 Hattah–Kulkyne Lakes

In recent history, Hattah Lakes would connect to the Murray River via Chalka Creek when flows in the Murray River at Euston exceeded 36 700 ML/day (Butcher and Hale 2011). The ecological character of the site is now highly dependent on managed water for the environment. Construction of a permanent pump station, regulators and environmental levees were completed as part of The Living Murray Program in 2014–15 when LTIM monitoring began. The pump infrastructure was used to deliver Commonwealth environmental water in 4 of the 8 years 2014–22. Watering ceased in 2019–20 to begin a planned 'dry phase' (Figure 5.24, Figure 5.25), and recent reporting from The Living Murray Program indicates the lakes were dry in 2021–22 (Palmer et al. 2021). In the intervening years of 2016–17 and 2018–19, the floodplain was watered with contributions from The Living Murray. Mapping of other sources of environmental water in LTIM was not considered reliable or sufficiently comprehensive and was discontinued in Flow-MER. Expanding the scope of this evaluation to include all water is recommended to provide a more accurate characterisation of the hydrological regime and therefore the contribution of Commonwealth environmental water as part of that regime. The lakes were partially filled by Victorian environmental water in 2021 aligned to high natural flows in the Murray River and they drained back to the Murray over the summer (2021–22) (https://www.vewh.vic.gov.au/rivers-and-wetlands/northern-region/hattah-lakes).

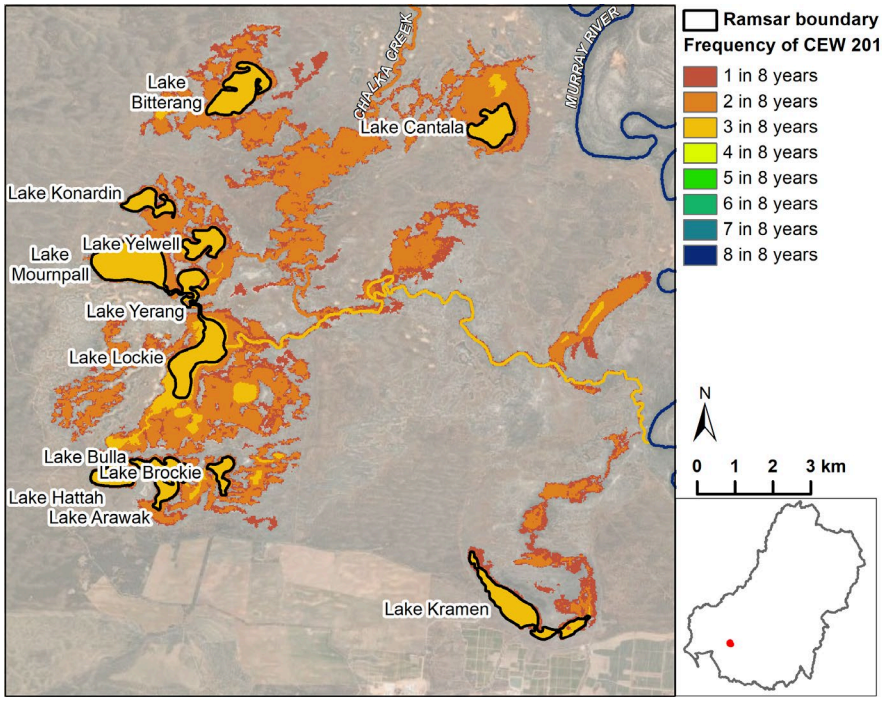


Figure 5.24 Hattah–Kulkyne Lakes Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

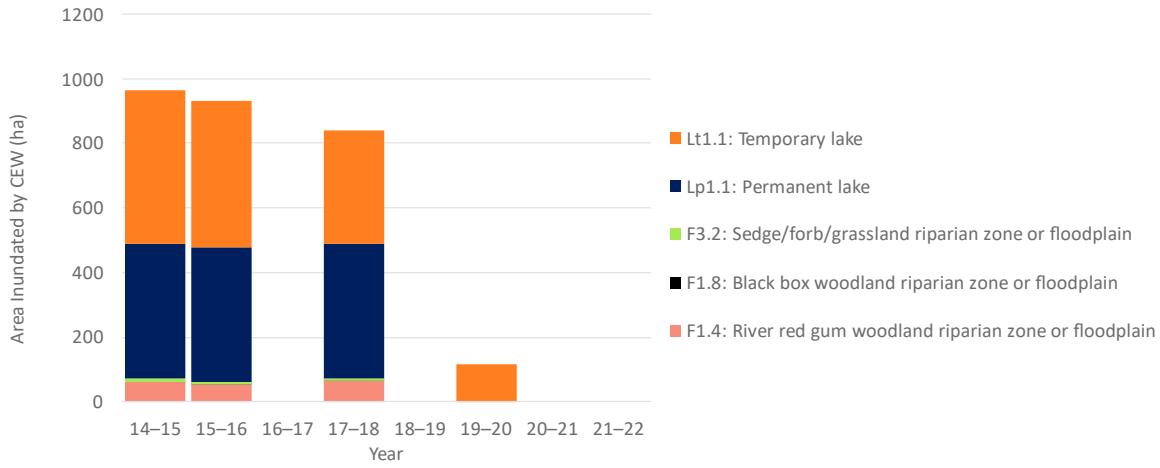


Figure 5.25 Hattah–Kulkyne Lakes Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.9 NSW Central Murray Forests

The NSW Central Murray Forests Ramsar Site received Commonwealth environmental water in 6 of the 8 years 2014–22 (Figure 5.26, Figure 5.27). The site consists of 3 large river red gum forest groups: Millewa, Koondrook–Perricoota and Werai. The majority of environmental water is delivered via the Murray River, typically inundating approximately 4,000 ha or more of the Millewa section in conjunction with the Barmah Forest Ramsar Site on the opposite bank of the Murray River. In 2021–22, 414 GL (including 220 GL of Commonwealth environmental water) was delivered via the Murray when the site was already inundated by naturally occurring high flows resulting in 16,000 ha or 50% of the Millewa block being inundated. In 2016–17, the Barmah and Millewa sites were watered with 155 GL from The Living Murray Program to provide the annual inundation cycle that is planned for the Barmah–Millewa Forests together.

Wholesale inundation of the Millewa group is likely to contribute to the maintenance of the ecological character of the site. The ECD for the site (Harrington and Hale 2011) defines ecological character at large spatial scales based on the current measured extent of marshes and river red gum forest in each of the forest blocks. For example, there should always be more than 20,000 ha of river red gum forest in the Millewa group and loss of forest extent would represent a change in character. Hydrological requirements defining the character of the site are defined using recurrence intervals of floods in the Murray River. For example, maintaining channels and low-lying areas in the Millewa group requires a minimum of 5 high flows of more than 12,500 ML/day for 70-day durations downstream of Yarrawonga in any 10-year period.

Outside of the Barmah–Millewa, Commonwealth environmental water was only used at Pollock Swamp in the Koondrook group, a 700 ha nature reserve at the western end of the Ramsar Site (approximately 1% of the Ramsar Site area). A new program commenced annual pumping from the Murray in 2018–19 of 2–3.5 GL of Commonwealth environmental water to restore approximately 100 ha of shallow wallaby grass and river red gum swamp. This project is likely to have successful outcomes, but at this local scale is a small contribution towards maintaining the ecological character of the Ramsar Site where critical CPS are defined at much larger scales. The remainder of the extensive Koondrook Forest Group (34,524 ha) and the Werai Forest Group (11,421 ha) have not received Commonwealth environmental water since monitoring began in 2014.

Inundation frequency map. Other details as per caption.

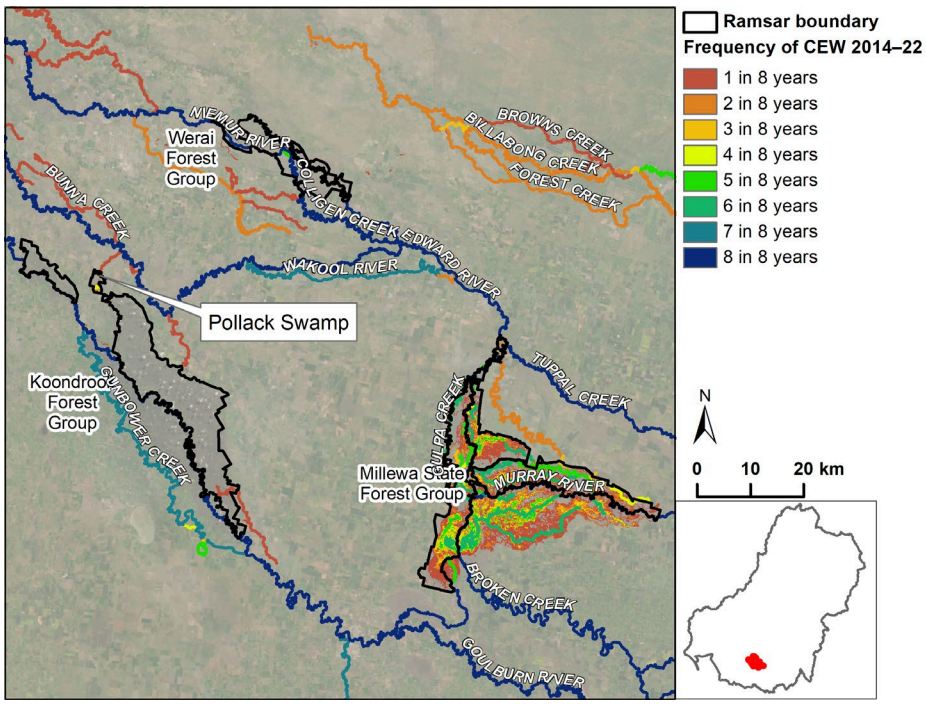


Figure 5.26 NSW Central Murray Forests Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

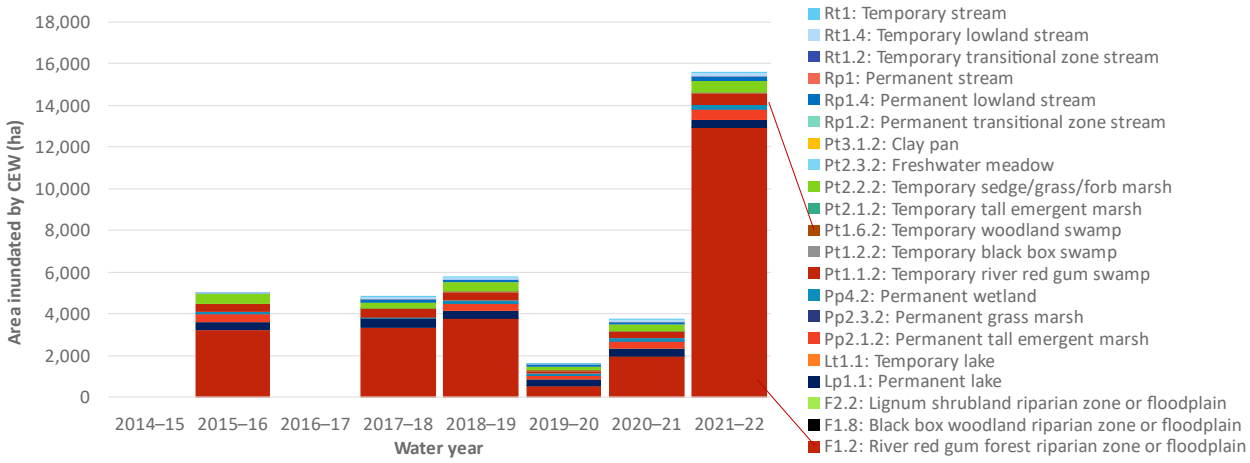


Figure 5.27 NSW Central Murray Forests Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.10 Riverland

The Riverland Ramsar Site received Commonwealth environmental water in all 8 years 2014–22, inundating the site to varying degrees (Figure 5.28, Figure 5.29). The site is a large floodplain of the Murray River that includes the Chowilla and Calperum wetlands and has many interconnecting channels and anabranches. Water is managed strategically through regulators and pumping to protecting waterbird habitat and water-dependent vegetation, including stands of black box higher on the floodplain. The ECD defines hydrological character by the water requirements of different wetland types (Newall et al. 2009), creating a direct line of sight to the Basin ANAE mapping to use in evaluating the contribution of environmental water to maintenance of the Ramsar Site ecological character. For example, Figure 5.29 shows that Commonwealth environmental water is supporting a high diversity of ecosystem types at the site and appears to be used to protect the more permanent habitats, with larger areas of inundation of permanent wetland, permanent lake, permanent saline wetland and the permanent lowland river (the Murray River).

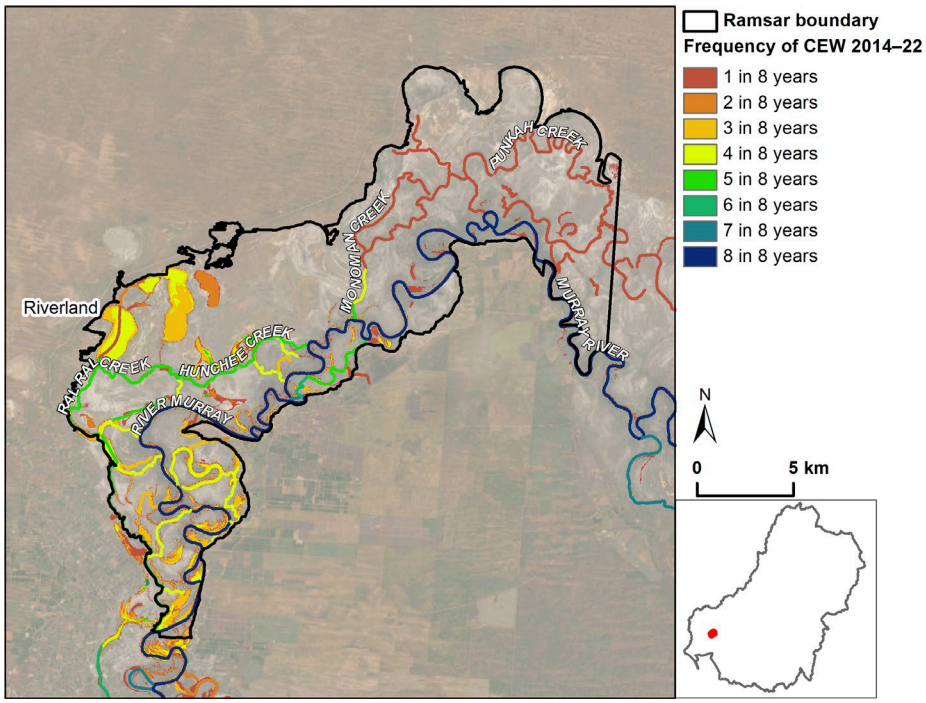


Figure 5.28 Riverland Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

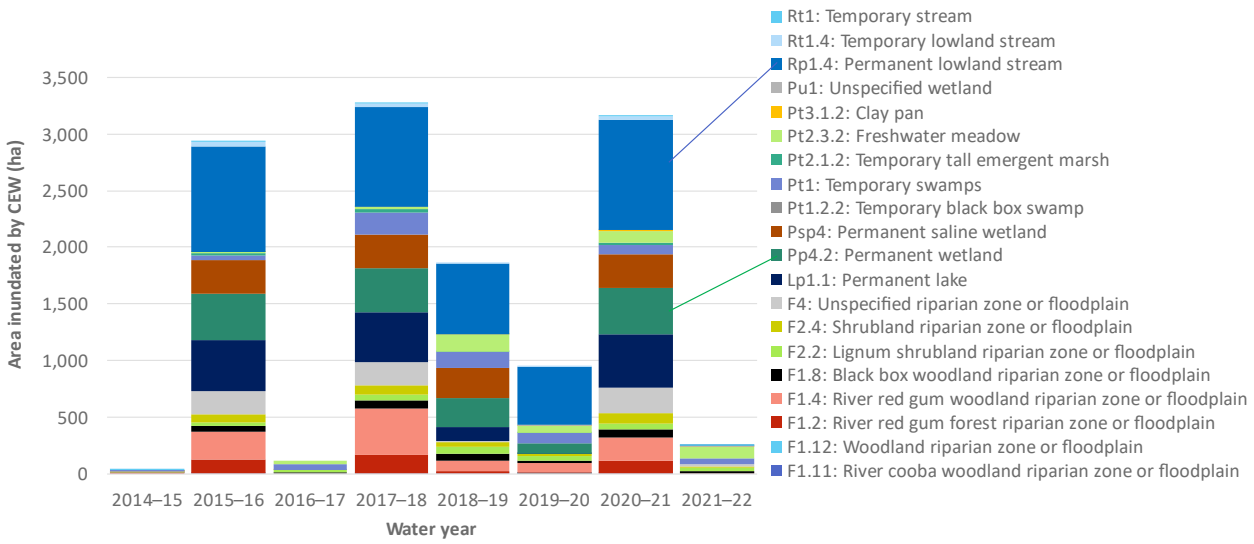


Figure 5.29 Riverland Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

5.3.11 The Coorong, and Lakes Alexandrina and Albert Wetland

The Coorong, and Lakes Alexandrina and Albert Wetland Ramsar Site received Commonwealth environmental water in all 8 years, either as allocations or end-of-system flows (Figure 5.30). Some attempts were made during LTIM to model changes in the large lake area in response to the relatively small quantities of environmental water received; however, the models were not sensitive enough to detect changes in inundation of wetland habitat that fringes the lakes. Flow-MER therefore uses the same inundated extent to represent the CLLMM in every year, and the composition of CLLMM ecosystem types supported by Commonwealth environmental water is mostly static (Figure 5.31), except for some small fringing areas that receive targeted allocations of water. For example, there was environmental watering of the Tolderol Game Reserve 2019–20 and 2020–21 and the Milang Snipe Sanctuary 2016–17 to 2021–22 to support migratory waders (Figure 5.30).

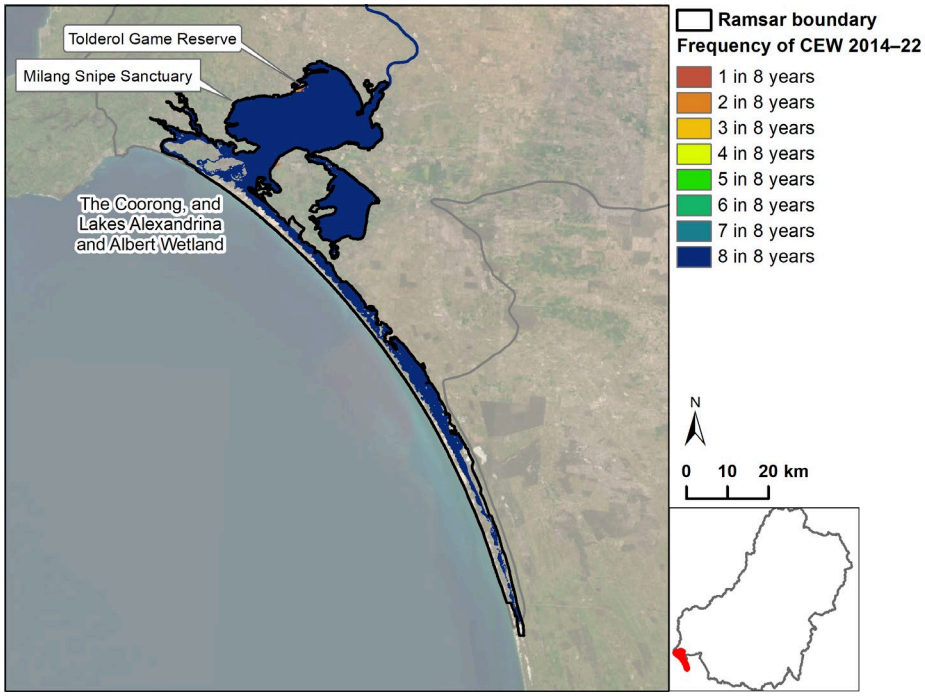


Figure 5.30 The Coorong, and Lakes Alexandrina and Albert Wetland Ramsar Site – frequency of inundation by Commonwealth environmental water (CEW), 2014–22

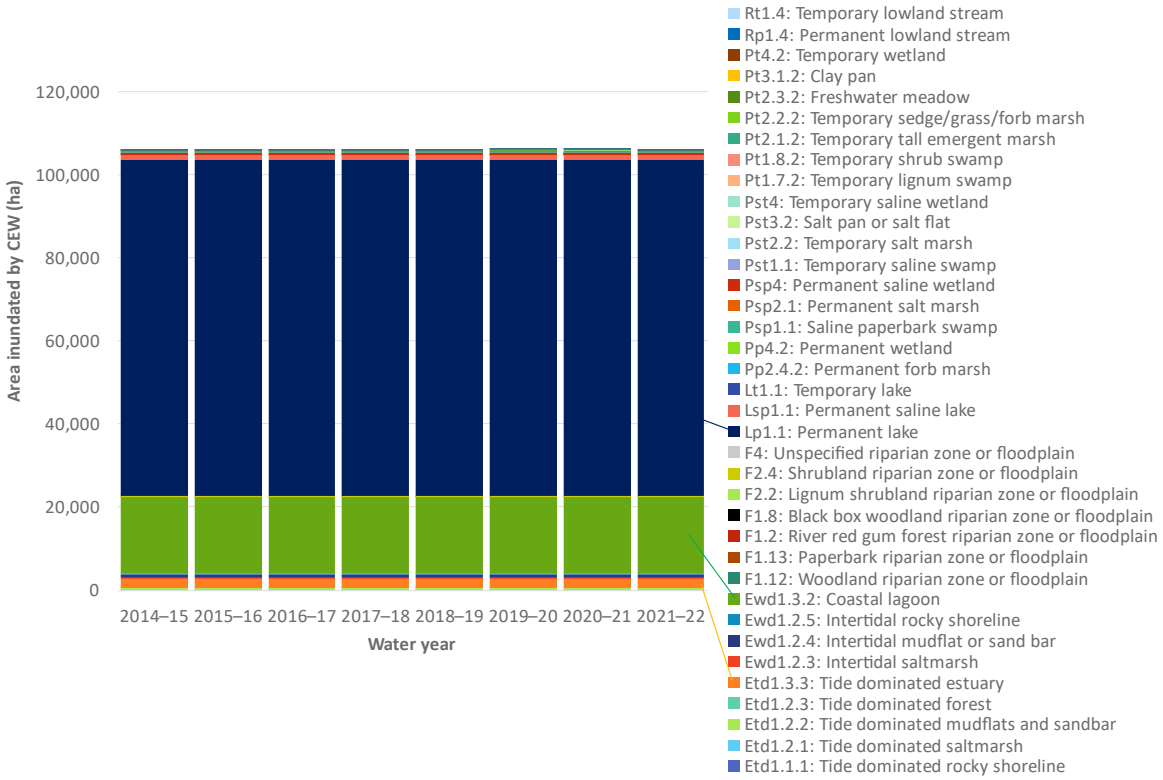


Figure 5.31 The Coorong, and Lakes Alexandrina and Albert Wetland Ramsar Site – diversity of Australian National Aquatic Ecosystem (ANAE) ecosystem types inundated by Commonwealth environmental water (CEW), 2014–22

6 Contribution to Basin Plan objectives

The Ecosystem Diversity evaluation examines the contribution of Commonwealth environmental water to the Basin Plan objective of *Protection and restoration of water-dependent ecosystems* (Basin Plan, section 8.05), at the Basin scale. It achieves this through analysing the spatial and temporal patterns of Commonwealth environmental water delivered to ecosystem types across waterways, floodplains, lakes and wetlands on the managed floodplain that together are broadly representative of aquatic ecosystems in the Basin (established by Brooks 2021b). While the Commonwealth Environmental Water Outcomes Framework (CEWH 2013) does not include 1-year or 5-year expected outcomes for ecosystem diversity, the approach adopted provides a foundation from which expected outcomes for ecosystem diversity may be developed in the future.

More specifically (summarised in Table 6.1):

Basin Plan objective at paragraph 8.05(3)(b): to ensure that representative populations and communities of native biota are protected and, if necessary, restored

- The representativeness of ecosystem types on the managed floodplain was established by Brooks (2021b). Of the Basin ecosystem types, 97% occur on the managed floodplain. The relative abundance (by area) of ecosystem types was similar when comparing the managed floodplain to the whole Basin.
- In 2021–22, there were 55 ANAE ecosystem types representing 86% of the ecosystem diversity on the managed floodplain that were recipients of Commonwealth environmental water. They cover a combined area of 279,958 ha with an additional 22,170 km of river representing the 'populations and communities of water-dependent native biota' that are assumed to have been supported or 'protected' by the environmental water they received. The evaluation is unable to examine if ecosystems were 'restored'.
- The 8-year watering history, 2014–22, included a similar diversity of ecosystem types through the years, but a wide difference in the total extent. The current 2021–22 year was an outlier, with numerous watering actions building on widespread natural flooding to inundate up to twice the area than previously achieved. Ecosystems that continue to not be watered are the naturally wet bogs, springs and paperbark swamps or saline systems where delivery of fresh water is likely not appropriate.

Basin Plan objective at paragraph 8.05(2)(a): to protect and restore a subset of all water-dependent ecosystems of the Murray–Darling Basin, including by ensuring that declared Ramsar wetlands that depend on Basin water resources maintain their ecological character

- Commonwealth environmental water was delivered to 9 Ramsar Sites in 2021–22, supporting a total of 173,874 ha of 52 different ecosystem types within the Ramsar estate. This areal extent is dominated by the 81,144 ha of lakes Alexandrina and Albert and 18,435 ha of the Coorong. Excluding these three waterbodies in the CLLMM, Commonwealth environmental water directly supported 75,611 ha of Ramsar ecosystems. Some evidence for supporting Ramsar Site critical CPS were identified (e.g. protecting and/or maintaining frequency of inundation to support vegetation which in turn supports breeding and foraging habitat for waterbirds); however, a detailed investigation to determine if Ramsar Site ecological character was maintained (the Basin Plan objective) was beyond the scope of this evaluation.

Table 6.1 Observations associated with diversity objectives listed in the Commonwealth's (Murray–Darling) *Basin Plan 2012* section 8.05

Basin Plan objectives	Basin outcomes	Long-term expected outcomes	1-year expected outcomes	Measured and predicted 1-year outcomes 2021–22	Measured and predicted long-term outcomes 2014–22
Biodiversity (Basin Plan s 8.05)	Ecosystem diversity	None identified	None identified	• 184,000 ha of mapped lakes and wetland supported • 22,170 km of rivers supported • 72,190 ha of floodplain inundated • 23,768 ha of estuary supported with fresh water • 55 Basin ANAE ecosystem types supported • No negative impacts identified	• 239,662 ha of lakes, and wetlands supported • 157,907 ha of floodplain supported • 26,245 km of waterways supported • 23,768 ha of estuary supported • 57 Basin ANAE ecosystem types supported • No negative impacts identified
Ramsar Sites maintained	Ecological character maintained		None identified	• Water delivered to 9 Ramsar Sites, supporting a subset of critical components, processes and services	• Not assessed

7 Basin annual watering priorities 2021–22

The *Basin annual environmental watering priorities 2021–22* (MDBA 2021) provide annual guidance to jurisdictions and the Commonwealth Environmental Water Holder (CEWH) for implementing the Basin Plan via the Strategy (MDBA 2019). This high-level evaluation of Ecosystem Diversity potentially supported by Commonwealth environmental water does not assemble direct evidence for improved ecosystem condition; however, observations can be made that highlight the management response in implementing the Strategy (Table 7.1). These are limited to outcomes for the 'River flows and connectivity' and 'Native vegetation' themes of the Strategy that could be inferred from the distribution of water management interacting with ANAE ecosystem types.

Table 7.1 Ecosystem diversity outcomes from Commonwealth environmental water in 2021–22 that align with Strategy annual priorities for 'River flows and connectivity' and 'Native vegetation' themes

Annual priority 2021–22	Ecosystem diversity outcome 2021–22
River flows and connectivity	
Rolling priority: Support lateral and longitudinal connectivity along the river system Annual priority: Build ecosystem resilience by providing or enhancing connectivity	Longitudinal connectivity through 22,170 km of rivers, predominantly lowland rivers connecting laterally with 72,190 ha of floodplain representing 10 different floodplain vegetation communities
Rolling priority: Support freshwater connectivity through the Coorong, Lower Lakes and Murray Mouth	End-of-system flows including 816 GL of Commonwealth environmental water connecting through 103,451 ha of the Lower Lakes inundating 65 ha of floodplain around the lakes and 23,768 ha of estuary habitat in the Coorong and Murray Mouth
Native vegetation	
Rolling priorities: • Allow opportunities for growth of non-woody wetland vegetation • Allow opportunities for growth of non-woody riparian vegetation that fringes or occurs within main river corridors	Commonwealth environmental water delivered to 31,410 ha of meadow and marsh upstream of the Lower Lakes and another 9,259 ha of marsh around the Lower Lakes 737 ha of sedge/forb/grassland riparian zone or floodplain inundated
Rolling priority: Maintain the extent, improve the condition and promote recruitment of forests and woodlands	Commonwealth environmental water delivered to 69,888 ha of woody wetlands (swamps) and inundated 71,303 ha of woody floodplain vegetation
Rolling priority: Maintain the extent and improve the condition of lignum shrublands Annual priority: Support riparian vegetation and lignum in key wetlands of the northern Basin	13,021 ha of lignum floodplain inundated, and another 298 ha of temporary lignum swamp received Commonwealth environmental water
Rolling priority: Expand the extent and improve the condition of Moira grass in Barmah–Millewa Forest	Possible, given that 98 ha of freshwater meadow was inundated within the Barmah Forest Ramsar Site; however, specific monitoring of Moira grass was not assessed

Annual priority 2021–22	Ecosystem diversity outcome 2021–22
Annual priority: Extend inundation duration on key sites at Macquarie Marshes	Indirect evidence as watering actions were delivered to maintain water at breeding colonies; however, inundation mapping in Flow-MER does not measure duration nor estimate a counterfactual in the absence of environmental water
Annual priority: Support inundation of the Warrego floodplain	2,858 ha of floodplain and 2,716 ha wetlands inundated by Commonwealth environmental water in the Warrego Valley
Annual priority: Support inundation of the Lower Balonne floodplain	Commonwealth environmental water inundated 8,387 ha of the Narran Lakes complex, including 2,376 ha of the Narran Lakes Nature Reserve Ramsar Site
Annual priority: Increase inundation higher on the floodplain to support parched and stressed forests and woodlands	1,892 ha of black box floodplain that is typically located higher on the floodplain was inundated by Commonwealth environmental water; however, levels of water stress were not assessed

8 Informing adaptive management

Each annual evaluation contributes to our understanding of how the ecosystems of the Murray–Darling Basin respond in the short and long term to delivery of Commonwealth environmental water. This chapter provides our reflections on how this increased understanding can inform the next cycle of Commonwealth environmental water planning and its delivery, and improve our approach to Basin-scale evaluation.

> *Adaptive management* includes (a) setting clear objectives; (b) linking knowledge (including local knowledge), management evaluation and feedback over a period of time; (c) identifying and testing uncertainties; (d) using management as a tool to learn about the relevant system and change its management; (c) improving knowledge; (f) having regard to the social, economic and technical aspects of management. Basin Plan, part 3, subsection 1.07(1)

8.1 Informing the planning and management of water to protect and restore ecosystem diversity in the Basin

The 8 years of continued evaluation of ecosystem diversity supported by Commonwealth environmental water is clarifying:

- the spatial pattern of watering actions in the landscape among valleys at the Basin scale
- distribution of Commonwealth environmental water to the different ecosystem types to ensure ecosystems receiving water are representative of Basin ecosystems
- watering frequencies at ecosystem and wetland-complex scales.

Previous work has demonstrated that the Basin ecosystems on the managed floodplain **are** representative of ecosystem types in the whole Basin (Brooks 2021b).

The 8-year evaluation of watering frequencies for ecosystems on the managed floodplain has not found any strong evidence to recommend changes to the CEWH's water management. The evaluation shows that watering is responsive to climatic conditions from year to year and sufficiently agile to align with Strategy annual priorities, noting that measuring environmental benefits of those watering actions in terms of improvement in ecosystem condition was beyond the scope of this evaluation. Watering frequencies broadly align with expected needs of vegetation groups, with permanent lowland rivers, freshwater meadow and permanent tall marsh ecosystem types being watered more frequently than most swamps, and palustrine wetlands being watered more frequently than floodplains. At the Basin scale, the 8-year evaluation of watering frequencies indicates the CEWH's current water allocation and delivery appears fit for purpose and should continue.

These Basin-scale generalisations will not always be true within individual valleys and wetland complexes where local stressors – including land use, water harvesting, local rainfall and antecedent flood history – interact to determine levels of water stress in local ecosystems. Research underway in Flow-MER to interpret and spatially map ecosystem condition at these local scales will allow a finer grained evaluation of watering extent and frequency on ecosystem condition.

8.2 Improving our approach to Basin-scale evaluation

The evaluation has iteratively improved throughout the last 8 years, due to improvements in CEWH acquittal reporting, enhancements in the methods and consistency of documenting inundation from Commonwealth environmental water, and 3 major leaps forward in the mapping of water-dependent ecosystems in the Basin via updates to the ANAE mapping. These improvements contribute greatly to our ability to assess the extent (by area and river length) of aquatic ecosystems receiving Commonwealth environmental water.

The ability of this evaluation to re-analyse the long-term datasets back to 2014–15 to incorporate new and improved knowledge is an example of adaptive management in action, enabled by the long-term monitoring and evaluation plan that the CEWH began with LTIM and continued into Flow-MER.

8.2.1 Updating the managed floodplain

The MDBA, CEWH and other cultural and jurisdictional water managers should be actively involved in defining the extent of the managed floodplain so it can continue to improve and inform evaluation of outcomes from environmental water management. The managed floodplain extent is an important spatial dataset in this Basin-scale evaluation because it allows the observed extent of ecosystem diversity supported by Commonwealth environmental water to be framed with the context of the proportion of the total Basin area that is in scope for management by water recovered under the Basin Plan; approximately 40,000 km^2 that contains 51% of the 7.8 million hectares of water-dependent ecosystems mapped in the Basin. The managed floodplain was expanded in 2022 by the author using evidence from LTIM and Flow-MER inundation mapping to add 274,202 ha of aquatic ecosystem area to the mapped extent. The mapping was not revised again in the current year due to concerns by the author that widespread natural flooding may be carrying Commonwealth environmental water into areas that are not within scope for water management in a more typical year. Addition of these extreme 2021–22 flood inundation extents into the managed floodplain data set might then set up unrealistic expectations for water managers on areas to manage and for the magnitude of inundation that can be expected from water delivery. The Flow-MER forum in August 2023 will be a good opportunity for water managers to consider the 2021–22 inundation mapping further to determine whether any significant overestimation of the extent of influence of Commonwealth environmental water is occurring.

Notable omissions in the managed floodplain mapping include wetland complexes that receive water from jurisdictional water holders in South Australia and in Victoria, most notably the entire Kerang Wetlands Ramsar Site. These jurisdictional assets could be added to the managed floodplain map by aligning the wetland asset mapping of the ANAE to watering information reported to MDBA annually since 2013–14 as a requirement of the Basin Plan Schedule 12, Matter 8. This would require cooperation from the jurisdictional governments to locate all the assets that are identified by free-form text names in the reporting without maps or location coordinates.

Updates to the managed floodplain mapping by the Flow-MER project are published (CEWO 2022b); however, it is important that changes being made (or not made) in response to issues discussed above are considered and coordinated. There is a role for the MDBA (as custodian) and CEWH to play in actively coordinating updates and publishing an official map for use by all Basin programs.

8.2.2 A unified register of all environmental water management

(adapted from Brooks 2021b)

Commonwealth environmental water is strategically managed in collaboration with other water holders in the Basin. The current focus of this evaluation on Commonwealth environmental water without considering natural flooding and other sources of supplementary water for the environment means our understanding of wetland and floodplain water regimes is incomplete.

Evaluation of all sources of water for the environment will improve interpretation of outcomes from cooperative actions and may lead to more targeted adaptive management advice regarding long-term watering regimes towards which multiple agencies are contributing. This is certainly true for some Ramsar Sites, including Barmah Forest and Hattah–Kulkyne Lakes, where cooperation between the states sees Commonwealth environmental water delivered in years when state water is not, and vice versa. Including all water enables the magnitude of observed outcomes to be interpreted relative to the magnitude of the intervention. This will foster a more comprehensive evaluation that is better placed to inform adaptive management by assessing the appropriateness, effectiveness, efficiency and impact of water management in total, and also the contribution of Commonwealth environmental water. Expanding the scope of this evaluation to include all water is recommended for the next iteration of monitoring, evaluation and research currently being planned as 'Flow-MER 2.0'.

A number of recent initiatives are making spatio-temporal mapping of surface hydrological regimes more available, for example:

- Geoscience Australia has used its Wetland Insights Tool to estimate percentage cover for bare ground, dry vegetation, green vegetation, wet vegetation and open water in all ANAE ecosystems on the managed floodplain that are more than 1 ha in size (approximately 270,000 ecosystems). These data are currently being further processed to quantify inundation events and extended dry intervals. The new information will be available in the second half of 2022.
- Through the MDBA Ecosystem Functions Project, CSIRO has integrated some remote-sensing data and tools to improve measurement of flooded extent and depth. This is being trialled in a Flow-MER research project to quantify flooding regimes for a number of Basin assets.

A common feature of these approaches is they generate a hydrograph at asset scale that can quantify the extent and duration of inundation events, but they are ignorant of whether events are natural floods or managed releases of water from CEWH or jurisdictions. Attribution to describe the origin of inundation is currently difficult because water management information is fragmented across jurisdictions. The MDBA collates Basin Plan implementation reports as required under schedule 12 of the Basin Plan (e.g. Basin Plan implementation reports 2021–22), but these reports are not compiled across jurisdictions annually and often contain information that conflicts with CEWH acquittal reporting because they are submitted before the acquittal reporting is complete.

An agreed resource for all environmental water information in the Basin would strengthen evaluation of all environmental water. A definitive and agreed 'one-stop shop' describing the timing, duration and extent of all environmental water management along with the objectives, observed outcomes and any unintended consequences would empower evaluation with a more realistic hydrological context for understanding outcomes, and a more direct line of sight to inform the collaborative planning process. Inter-agency communication will likely need to improve for the resource to be collated in a timely manner, ideally within the water year to provide opportunity for evaluation to inform near-term water planning in subsequent years.

8.2.3 Expected outcomes for ecosystem diversity

Neither CEWH nor the Strategy currently define expected outcomes for ecosystem diversity. It is hoped that ecosystem objectives can be developed in the near future, beginning with detailing requirements for timing, extent and frequency to maintain and promote condition that influences diversity and resilience. The evaluation can then move beyond a scorecard of when, where and how much water was delivered to determine where water planning and delivery is achieving outcomes and how to inform management to improve the maintenance and restoration of ecosystem diversity in the Basin. Recent work by Cherie Campbell for the MDBA's project Assessing vulnerability for use in determining Basin-scale environmental watering priorities (Commonwealth of Australia 2023) developed some thinking and preliminary thresholds to quantify water stress and vegetation condition for some vegetated ANAE types to inform the setting of Strategy annual priorities. These thresholds provide a starting point to develop further with CEWH science and delivery teams to contribute to Commonwealth environmental water planning and interpretation of outcomes in acquittal reporting. Establishing a small working group, including a CEWH delivery representative, should be a priority for 2023–24.

8.2.4 Transition of Flow-MER research into evaluation

The Flow-MER scaling research project has been examining the use of diversity indices, including Shannon diversity and evenness that can be applied to ANAE types to quantify landscape diversity at different scales. The project is also looking at spectral diversity in satellite imagery as an alternative way of quantifying landscape ecosystem diversity. These methods can now be brought into the evaluation space to quantify diversity that considers the abundance and spatial arrangement of different ecosystem types in the Basin. This may change our perspective on diversity in watered areas that are dominated by single ecosystem types (e.g. temporary river red-gum swamps) and may help identify new areas of high diversity to protect and areas of low diversity to focus restoration objectives. This project has also developed a very simple framework using area-weighted aggregation of ecosystem measures using ANAE polygons as building blocks to scale up to larger wetland complexes and valley scales.

The Flow-MER ecosystem condition research project is testing this framework for remote-sensed measures of water inundation (timing, frequency and extent) and different vegetation condition metrics that quantify ecosystem condition – evapotranspiration, Landsat's Normalized Difference Vegetation Index (NDVI), greenness and MDBA's Tree Stand Condition. Integrating these with watering needs and the expected outcomes discussed above will enable a spatially explicit evaluation to compare measured ecosystem responses to the expected outcomes from water management. This will provide stronger evidence to improve water management than can be achieved by the current interpretation of annual water extent and frequency.

Part II Methods

This part of the report includes additional detail and documentation of some of the technical analyses that underpin the evaluation provided in Part I.

9 GIS workflows for calculating areas supported by Commonwealth environmental water

This evaluation uses 3 geographical information system (GIS) workflows, which are outlined in the sections that follow.

9.1 Calculating the area of ecosystems inundated by Commonwealth environmental water

The area of ecosystems inundated by Commonwealth environmental water is the fraction of the wetland area that intersects the Commonwealth environmental water inundation extent. The inundated area is used in this evaluation for floodplains and rivers to quantify the proportion of the floodplain that was influenced by Commonwealth environmental water.

1. Intersect:
    a. Basin ANAE classification mapping
    b. Commonwealth environmental water inundation
    c. LTIM valleys.
2. Calculate polygon area in hectares for the intersected areas using equal area GDA94 Australian Albers projection.
3. Sum the area of inundated ANAE wetland types per valley.

For rivers, the inundated length of river channel is obtained directly from the inundation mapping and aggregated for each valley.

9.2 Calculating the area of ecosystems influenced by Commonwealth environmental water

The area of ecosystems influenced by Commonwealth environmental water is defined as the sum of the areas of mapped features that are partially or fully overlapped by the mapped extent of Commonwealth environmental water inundation. The influenced area is used for depressional wetlands and lakes to incorporate fringing water-dependent vegetation growing in wet soils adjacent to waterbodies and the wet areas where inundation mapping from satellite imagery underestimates the area of water obscured by thick vegetation as occurs in reed beds (tall emergent marsh), meadows and sedgelands.

1. Select by location all ANAE wetland polygons that intersect the Commonwealth environmental water inundation raster.
2. Add to the selection any additional ANAE wetland polygons that intersect the Commonwealth environmental water inundation ‘watercourses watered’ line mapping.
3. Intersect the selected wetlands with the valley boundaries.
4. Calculate polygon area in hectares using equal area GDA94 Australian Albers projection for each ecosystem polygon.
5. Sum the area of each ANAE wetland type per valley.

9.3 Calculating the length of waterways with Commonwealth environmental water

The length of waterways with Commonwealth environmental water is defined as the sum of the Geofabric segment line length designated as holding Commonwealth environmental water during the water year (1 July to 30 June). The distribution of Commonwealth environmental water in channels mapped by LTIM in 2014–19 was updated to the current v3.2 Geofabric mapping (BOM 2020) to ensure the mapping of Commonwealth environmental water was comparable and consistent among all years of monitoring evaluated in Flow-MER.

1. Select the Basin ANAE Geofabric v3.2 Network Streams that have line segments overlapping the Basin inundation 'watercourses watered' mapping.
2. Intersect the selection with the LTIM valleys.
3. Calculate the length of inundated segments for each riverine ecosystem type in kilometres using equal area GDA94 Australian Albers projection.
4. Calculate summary statistics to sum the length of each river ecosystem type per valley.

Appendix A ANAE wetland types by valley influenced by Commonwealth environmental water 2021–22

Lake and wetland types influenced by Commonwealth environmental water are represented by the entire wetland when any portion of the wetland was recorded as having been inundated. The contribution of Commonwealth environmental water to supporting wetland ecosystem diversity within each valley is presented in Table A.1 excluding the Coorong, Lower Lakes and Murray Mouth area which is presented in Table 4.5. The percentage of managed floodplain can exceed 100% when the inundation extends beyond the currently mapped boundary of the managed floodplain (last updated by Brooks 2022). These may be places that will be added to the managed floodplain in future updates.

Table A.1 Area of each Australian National Aquatic Ecosystem (ANAE) lake and wetland ecosystem type and the contribution of Commonwealth environmental water (CEW) to support wetland ecosystem diversity within each valley 2021–22 (shaded blue)

The percentage of managed floodplain can exceed 100% when the inundation extends beyond the currently mapped boundary of the managed floodplain.

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Avoca	Pt3.1.2: Clay pan	18,395	16,127	0	0
Avoca	Pt1.2.2: Temporary black box swamp	5,108	703	0	0
Avoca	Pt2.3.2: Freshwater meadow	715	684	0	0
Avoca	Pt1.6.2: Temporary woodland swamp	803	651	0	0
Avoca	Pt1.1.2: Temporary river red gum swamp	143	130	0	0
Avoca	Lp1.1: Permanent lake	61	26	0	0
Avoca	Lst1.1: Temporary saline lake	19,829	0	0	0
Avoca	Lt1.1: Temporary lake	4,232	0	0	0
Avoca	Lst1.2: Temporary saline lake with aquatic bed	1,821	0	0	0
Avoca	Pst1.1: Temporary saline swamp	1,541	0	0	0
Avoca	Pst2.2: Temporary salt marsh	1,174	0	0	0
Avoca	Pst3.2: Salt pan or salt flat	309	0	0	0
Avoca	Psp2.1: Permanent salt marsh	209	0	0	0
Avoca	Pt4.2: Temporary wetland	208	0	0	0
Avoca	Lsp1.1: Permanent saline lake	137	0	0	0
Avoca	Pp4.2: Permanent wetland	50	0	0	0
Avoca	Pst4: Temporary saline wetland	50	0	0	0
Avoca	Pt1.8.2: Temporary shrub swamp	41	0	0	0
Avoca	Pt1.7.2: Temporary lignum swamp	40	0	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Barwon Darling	Lp1.1: Permanent lake	31,697	9,212	184	2.0
Barwon Darling	Lt1.1: Temporary lake	57,628	2,782	66	2.4
Barwon Darling	Pp4.2: Permanent wetland	2,015	508	34	6.7
Barwon Darling	Pt2.2.2: Temporary sedge/grass/forb marsh	16,658	567	9	1.6
Barwon Darling	Pt1.1.2: Temporary river red gum swamp	378	372	4	1.0
Barwon Darling	Pt1.3.2: Temporary coolibah swamp	57	15	2	13.6
Barwon Darling	Pt1.2.2: Temporary black box swamp	2,957	141	<1	<0.1
Barwon Darling	Pt3.1.2: Clay pan	175	86	0	0
Barwon Darling	Pt2.3.2: Freshwater meadow	941	46	0	0
Barwon Darling	Pt1.6.2: Temporary woodland swamp	16,305	19	0	0
Barwon Darling	Pt1.8.2: Temporary shrub swamp	11,009	1	0	0
Barwon Darling	Pp2.2.2: Permanent sedge/grass/forb marsh	5	0	0	0
Barwon Darling	Pst2.2: Temporary salt marsh	3	0	0	0
Border Rivers	Pt1.1.2: Temporary river red gum swamp	726	251	141	56.2
Border Rivers	Lp1.1: Permanent lake	937	382	113	29.6
Border Rivers	Lt1.1: Temporary lake	645	392	104	26.6
Border Rivers	Pp4.2: Permanent wetland	660	272	34	12.5
Border Rivers	Pt3.1.2: Clay pan	219	62	17	27.4
Border Rivers	Pt2.3.2: Freshwater meadow	1,924	760	13	1.7
Border Rivers	Pt1.6.2: Temporary woodland swamp	2,486	241	12	5.1
Border Rivers	Pt4.2: Temporary wetland	3,006	396	4	1.0
Border Rivers	Pt1.8.2: Temporary shrub swamp	11	10	3	34.4
Border Rivers	Pst1.1: Temporary saline swamp	2	2	2	112.8
Border Rivers	Pt2.2.2: Temporary sedge/grass/forb marsh	809	232	0	0
Border Rivers	Pt1.3.2: Temporary coolibah swamp	494	229	0	0
Border Rivers	Lp1.2: Permanent lake with aquatic bed	227	187	0	0
Border Rivers	Pp2.2.2: Permanent sedge/grass/forb marsh	1,233	54	0	0
Border Rivers	Pp2.3.2: Permanent grass marsh	26	26	0	0
Border Rivers	Pt1.2.2: Temporary black box swamp	13	7	0	0
Border Rivers	Lt1.2: Temporary lake with aquatic bed	12	3	0	0
Border Rivers	Pp3: Peat bog or fen marsh	504	0	0	0
Border Rivers	Pt2.1.2: Temporary tall emergent marsh	96	0	0	0
Broken	Pt2.3.2: Freshwater meadow	269	181	181	100.2
Broken	Pt3.1.2: Clay pan	2,971	253	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Broken	Pt1.6.2: Temporary woodland swamp	431	153	0	0
Broken	Pt1.1.2: Temporary river red gum swamp	1,922	132	0	0
Broken	Pp4.2: Permanent wetland	45	43	0	0
Broken	Lp1.1: Permanent lake	3,305	16	0	0
Broken	Lt1.1: Temporary lake	104	1	0	0
Broken	Pt1.7.2: Temporary lignum swamp	192	0	0	0
Broken	Pt2.1.2: Temporary tall emergent marsh	97	0	0	0
Broken	Pt1.2.2: Temporary black box swamp	92	0	0	0
Broken	Pt2.2.2: Temporary sedge/grass/forb marsh	77	0	0	0
Campaspe	Pt3.1.2: Clay pan	1,805	499	0	0
Campaspe	Pt1.1.2: Temporary river red gum swamp	397	160	0	0
Campaspe	Lt1.1: Temporary lake	49	14	0	0
Campaspe	Pt1.6.2: Temporary woodland swamp	168	0	0	0
Campaspe	Pt2.1.2: Temporary tall emergent marsh	38	0	0	0
Campaspe	Lp1.1: Permanent lake	12	0	0	0
Campaspe	Pt2.3.2: Freshwater meadow	10	0	0	0
Campaspe	Pp4.2: Permanent wetland	4	0	0	0
Campaspe	Pt1.7.2: Temporary lignum swamp	2	0	0	0
Campaspe	Pps5: Permanent spring	0	0	0	0
Castlereagh	Pt2.2.2: Temporary sedge/grass/forb marsh	10,560	4,623	0	0
Castlereagh	Lt1.1: Temporary lake	456	93	0	0
Castlereagh	Pt2.1.2: Temporary tall emergent marsh	16	16	0	0
Castlereagh	Pp4.2: Permanent wetland	16	2	0	0
Castlereagh	Pt1.2.2: Temporary black box swamp	30	2	0	0
Castlereagh	Pt1.8.2: Temporary shrub swamp	49	0	0	0
Castlereagh	Pt1.6.2: Temporary woodland swamp	35	0	0	0
Castlereagh	Pt3.1.2: Clay pan	30	0	0	0
Castlereagh	Pp2.2.2: Permanent sedge/grass/forb marsh	7	0	0	0
Castlereagh	Lp1.1: Permanent lake	5	0	0	0
Castlereagh	Pt1.1.2: Temporary river red gum swamp	1	0	0	0
Castlereagh	Pt2.3.2: Freshwater meadow	1	0	0	0
Central Murray	Pt1.1.2: Temporary river red gum swamp	39,313	37,164	24,477	65.9
Central Murray	Pt2.1.2: Temporary tall emergent marsh	1,191	1,055	721	68.4
Central Murray	Pp2.1.2: Permanent tall emergent marsh	1,183	1,103	707	64.1

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Central Murray	Pt2.2.2: Temporary sedge/grass/forb marsh	5,568	1,152	614	53.3
Central Murray	Pp4.2: Permanent wetland	8,985	4,465	568	12.7
Central Murray	Lp1.1: Permanent lake	4,117	3,571	407	11.4
Central Murray	Pt1.6.2: Temporary woodland swamp	1,429	653	377	57.8
Central Murray	Pt4.2: Temporary wetland	144	125	124	99.2
Central Murray	Pt2.3.2: Freshwater meadow	1,528	541	99	18.2
Central Murray	Pt1.2.2: Temporary black box swamp	4,370	1,936	86	4.4
Central Murray	Lt1.1: Temporary lake	13,094	2,563	78	3.0
Central Murray	Pt3.1.2: Clay pan	10,850	1,256	26	2.1
Central Murray	Pp2.4.2: Permanent forb marsh	136	117	6	5.1
Central Murray	Pp2.3.2: Permanent grass marsh	75	75	2	3.2
Central Murray	Pt1.7.2: Temporary lignum swamp	1,576	492	0	0
Central Murray	Psp4: Permanent saline wetland	642	321	0	0
Central Murray	Lsp1.1: Permanent saline lake	462	251	0	0
Central Murray	Pt1.8.2: Temporary shrub swamp	584	62	0	0
Central Murray	Pp2.2.2: Permanent sedge/grass/forb marsh	37	34	0	0
Central Murray	Pst2.2: Temporary salt marsh	2,123	0	0	0
Central Murray	Pst4: Temporary saline wetland	2,099	0	0	0
Central Murray	Lst1.1: Temporary saline lake	1,286	0	0	0
Central Murray	Pst3.2: Salt pan or salt flat	732	0	0	0
Central Murray	Pst1.1: Temporary saline swamp	38	0	0	0
Condamine Balonne	Lp1.1: Permanent lake	6,498	5,670	5,280	93.1
Condamine Balonne	Pp4.2: Permanent wetland	3,763	1,614	455	28.2
Condamine Balonne	Pt1.1.2: Temporary river red gum swamp	1,121	342	119	34.9
Condamine Balonne	Pt1.7.2: Temporary lignum swamp	111	7	103	1477.0
Condamine Balonne	Pt3.1.2: Clay pan	1,934	88	67	76.5
Condamine Balonne	Pt2.1.2: Temporary tall emergent marsh	38,343	34,048	51	0.2
Condamine Balonne	Pt1.3.2: Temporary coolibah swamp	2,425	424	44	10.5
Condamine Balonne	Pt2.3.2: Freshwater meadow	4,355	447	13	3.0
Condamine Balonne	Lt1.1: Temporary lake	11,632	917	12	1.3
Condamine Balonne	Pt1.6.2: Temporary woodland swamp	13,236	5,608	12	0.2
Condamine Balonne	Pst2.2: Temporary salt marsh	986	0	3	NA
Condamine Balonne	Pt4.2: Temporary wetland	6,404	1,574	1	<0.1
Condamine Balonne	Pt1.8.2: Temporary shrub swamp	29,273	26,396	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Condamine Balonne	Pt1.2.2: Temporary black box swamp	4,683	4,673	0	0
Condamine Balonne	Pp2.1.2: Permanent tall emergent marsh	2,522	2,481	0	0
Condamine Balonne	Lst1.1: Temporary saline lake	1,624	1,312	0	0
Condamine Balonne	Pt2.2.2: Temporary sedge/grass/forb marsh	8,417	262	0	0
Condamine Balonne	Lt1.2: Temporary lake with aquatic bed	684	73	0	0
Condamine Balonne	Lp1.2: Permanent lake with aquatic bed	1,648	10	0	0
Condamine Balonne	Pp2.3.2: Permanent grass marsh	23	4	0	0
Condamine Balonne	Pps5: Permanent spring	5	0	0	0
Condamine Balonne	Pt1.5.2: Temporary paperbark swamp	95	0	0	0
Condamine Balonne	Lsp1.1: Permanent saline lake	3	0	0	0
Condamine Balonne	Pp2.2.2: Permanent sedge/grass/forb marsh	2	0	0	0
Condamine Balonne	Pst4: Temporary saline wetland	1	0	0	0
Edward/Kolety–Wakool	Pt3.1.2: Clay pan	3,645	1,034	45	4.3
Edward/Kolety–Wakool	Pp4.2: Permanent wetland	800	722	7	0.9
Edward/Kolety–Wakool	Pt2.3.2: Freshwater meadow	597	138	6	4.1
Edward/Kolety–Wakool	Pt1.7.2: Temporary lignum swamp	168	57	6	9.8
Edward/Kolety–Wakool	Pt1.6.2: Temporary woodland swamp	421	203	3	1.6
Edward/Kolety–Wakool	Pt1.2.2: Temporary black box swamp	1,585	1,099	2	0.2
Edward/Kolety–Wakool	Pt1.1.2: Temporary river red gum swamp	1,321	1,042	1	0.1
Edward/Kolety–Wakool	Lt1.1: Temporary lake	985	337	0	0
Edward/Kolety–Wakool	Pt2.2.2: Temporary sedge/grass/forb marsh	410	191	0	0
Edward/Kolety–Wakool	Pt1.8.2: Temporary shrub swamp	280	128	0	0
Edward/Kolety–Wakool	Lp1.1: Permanent lake	130	109	0	0
Edward/Kolety–Wakool	Pt2.1.2: Temporary tall emergent marsh	47	44	0	0
Edward/Kolety–Wakool	Pp2.3.2: Permanent grass marsh	19	19	0	0
Edward/Kolety–Wakool	Psp4: Permanent saline wetland	6	6	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Edward/Kolety–Wakool	Pst1.1: Temporary saline swamp	5	5	0	0
Edward/Kolety–Wakool	Pp2.1.2: Permanent tall emergent marsh	4	4	0	0
Goulburn	Pt1.1.2: Temporary river red gum swamp	5,526	2,127	0	0
Goulburn	Pt3.1.2: Clay pan	10,284	300	0	0
Goulburn	Pt2.1.2: Temporary tall emergent marsh	886	292	0	0
Goulburn	Pt2.2.2: Temporary sedge/grass/forb marsh	172	144	0	0
Goulburn	Pp4.2: Permanent wetland	234	118	0	0
Goulburn	Lp1.1: Permanent lake	1,087	92	0	0
Goulburn	Lt1.1: Temporary lake	1,598	79	0	0
Goulburn	Pt1.6.2: Temporary woodland swamp	851	41	0	0
Goulburn	Pp2.1.2: Permanent tall emergent marsh	4	4	0	0
Goulburn	Pt2.3.2: Freshwater meadow	801	0	0	0
Goulburn	Pt1.7.2: Temporary lignum swamp	632	0	0	0
Goulburn	Pp2.4.2: Permanent forb marsh	571	0	0	0
Goulburn	Lst1.2: Temporary saline lake with aquatic bed	238	0	0	0
Goulburn	Pt1.2.2: Temporary black box swamp	82	0	0	0
Goulburn	Lsp1.1: Permanent saline lake	46	0	0	0
Goulburn	Lst1.1: Temporary saline lake	25	0	0	0
Goulburn	Pt4.2: Temporary wetland	19	0	0	0
Goulburn	Pt1.8.2: Temporary shrub swamp	3	0	0	0
Goulburn	Pst4: Temporary saline wetland	2	0	0	0
Goulburn	Pps5: Permanent spring	0	0	0	0
Gwydir	Pt2.3.2: Freshwater meadow	9,232	6,906	2,998	43.4
Gwydir	Pt2.1.2: Temporary tall emergent marsh	372	372	206	55.3
Gwydir	Lt1.1: Temporary lake	914	58	11	19.5
Gwydir	Pt3.1.2: Clay pan	236	53	0	0
Gwydir	Lp1.1: Permanent lake	77	35	0	0
Gwydir	Pt1.6.2: Temporary woodland swamp	183	24	0	0
Gwydir	Pp4.2: Permanent wetland	241	20	0	0
Gwydir	Pt2.2.2: Temporary sedge/grass/forb marsh	475	17	0	0
Gwydir	Pt1.1.2: Temporary river red gum swamp	13	10	0	0
Gwydir	Pp2.2.2: Permanent sedge/grass/forb marsh	1,257	9	0	0
Gwydir	Pt1.8.2: Temporary shrub swamp	92	7	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Gwydir	Pt1.2.2: Temporary black box swamp	4	4	0	0
Gwydir	Pp1.1.2: Permanent paperbark swamp	1	1	0	0
Gwydir	Pt1.3.2: Temporary coolibah swamp	9	1	0	0
Gwydir	Pt4.2: Temporary wetland	392	0	0	0
Gwydir	Pp3: Peat bog or fen marsh	167	0	0	0
Kiewa	Pt3.1.2: Clay pan	265	170	0	0
Kiewa	Pt1.6.2: Temporary woodland swamp	81	55	0	0
Kiewa	Lp1.1: Permanent lake	37	33	0	0
Kiewa	Pt2.2.2: Temporary sedge/grass/forb marsh	26	16	0	0
Kiewa	Pt1.1.2: Temporary river red gum swamp	21	9	0	0
Kiewa	Pt2.1.2: Temporary tall emergent marsh	3	3	0	0
Kiewa	Pp4.2: Permanent wetland	720	0	0	0
Kiewa	Pps5: Permanent spring	0	0	0	0
Lachlan	Pp2.1.2: Permanent tall emergent marsh	3,449	3,449	3,449	100.0
Lachlan	Pt1.1.2: Temporary river red gum swamp	2,207	1,636	435	26.6
Lachlan	Pt2.1.2: Temporary tall emergent marsh	618	572	410	71.6
Lachlan	Pt2.2.2: Temporary sedge/grass/forb marsh	43,855	10,768	205	1.9
Lachlan	Pt3.1.2: Clay pan	14,941	10,984	10	<0.1
Lachlan	Lt1.1: Temporary lake	32,350	11,136	0	0
Lachlan	Pt2.3.2: Freshwater meadow	13,398	6,423	0	0
Lachlan	Lp1.1: Permanent lake	7,385	6,232	0	0
Lachlan	Pt1.2.2: Temporary black box swamp	15,306	4,660	0	0
Lachlan	Pt1.7.2: Temporary lignum swamp	22,242	3,148	0	0
Lachlan	Pp4.2: Permanent wetland	2,871	2,437	0	0
Lachlan	Pt1.8.2: Temporary shrub swamp	16,488	1,843	0	0
Lachlan	Pt4.2: Temporary wetland	348	241	0	0
Lachlan	Pp2.2.2: Permanent sedge/grass/forb marsh	84	75	0	0
Lachlan	Pst2.2: Temporary salt marsh	224	17	0	0
Lachlan	Pt1.6.2: Temporary woodland swamp	3,318	12	0	0
Lachlan	Pp2.3.2: Permanent grass marsh	21	0	0	0
Lachlan	Pps5: Permanent spring	7	0	0	0
Loddon	Pt1.2.2: Temporary black box swamp	5,591	1,395	0	0
Loddon	Pt3.1.2: Clay pan	12,235	676	0	0
Loddon	Pt1.1.2: Temporary river red gum swamp	1,176	156	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Loddon	Pt2.3.2: Freshwater meadow	3,515	82	0	0
Loddon	Pt1.7.2: Temporary lignum swamp	3,989	37	0	0
Loddon	Pt1.6.2: Temporary woodland swamp	1,423	9	0	0
Loddon	Lp1.1: Permanent lake	6,384	0	0	0
Loddon	Lst1.1: Temporary saline lake	1,478	0	0	0
Loddon	Pst1.1: Temporary saline swamp	1,379	0	0	0
Loddon	Lsp1.1: Permanent saline lake	1,252	0	0	0
Loddon	Lt1.1: Temporary lake	417	0	0	0
Loddon	Pp4.2: Permanent wetland	196	0	0	0
Loddon	Lsp1.2: Permanent saline lake with aquatic bed	181	0	0	0
Loddon	Pt1.8.2: Temporary shrub swamp	109	0	0	0
Loddon	Pst3.2: Salt pan or salt flat	109	0	0	0
Loddon	Pst4: Temporary saline wetland	55	0	0	0
Loddon	Lt1.2: Temporary lake with aquatic bed	55	0	0	0
Loddon	Pt2.1.2: Temporary tall emergent marsh	54	0	0	0
Loddon	Psp2.1: Permanent salt marsh	37	0	0	0
Loddon	Pst2.2: Temporary salt marsh	28	0	0	0
Loddon	Pps5: Permanent spring	3	0	0	0
Lower Darling	Lt1.1: Temporary lake	187,365	63,780	0	0
Lower Darling	Pt2.2.2: Temporary sedge/grass/forb marsh	45,439	9,103	0	0
Lower Darling	Pt1.2.2: Temporary black box swamp	1,920	1,107	0	0
Lower Darling	Pt1.1.2: Temporary river red gum swamp	879	873	0	0
Lower Darling	Pt1.8.2: Temporary shrub swamp	69,574	532	0	0
Lower Darling	Pt3.1.2: Clay pan	1,351	125	0	0
Lower Darling	Lp1.1: Permanent lake	9,743	115	0	0
Lower Darling	Pp4.2: Permanent wetland	1,761	84	0	0
Lower Darling	Pt2.3.2: Freshwater meadow	8,087	59	0	0
Lower Darling	Pt1.6.2: Temporary woodland swamp	4,424	40	0	0
Lower Darling	Pst2.2: Temporary salt marsh	1,718	10	0	0
Lower Darling	Lst1.1: Temporary saline lake	509	0	0	0
Lower Darling	Pst4: Temporary saline wetland	161	0	0	0
Lower Darling	Pt4.2: Temporary wetland	53	0	0	0
Lower Darling	Pp2.3.2: Permanent grass marsh	26	0	0	0
Lower Darling	Pt2.1.2: Temporary tall emergent marsh	1	0	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Lower Murray	Lt1.1: Temporary lake	27,494	828	825	99.6
Lower Murray	Pt1: Temporary swamps	3,744	3,216	421	13.1
Lower Murray	Pp4.2: Permanent wetland	4,370	3,622	393	10.8
Lower Murray	Pt2.3.2: Freshwater meadow	4,441	3,392	334	9.8
Lower Murray	Pt3.1.2: Clay pan	5,116	1,435	202	14.1
Lower Murray	Pt1.1.2: Temporary river red gum swamp	524	386	50	13.1
Lower Murray	Lp1.1: Permanent lake	21,721	20,995	38	0.2
Lower Murray	Pp2.3.2: Permanent grass marsh	102	102	23	22.3
Lower Murray	Pt2.1.2: Temporary tall emergent marsh	3,321	574	21	3.7
Lower Murray	Pt1.8.2: Temporary shrub swamp	2,970	503	17	3.4
Lower Murray	Psp4: Permanent saline wetland	1,364	1,291	16	1.3
Lower Murray	Pt1.2.2: Temporary black box swamp	413	210	12	5.8
Lower Murray	Pt1.7.2: Temporary lignum swamp	2,651	2,154	12	0.6
Lower Murray	Pp2.4.2: Permanent forb marsh	34	31	10	31.3
Lower Murray	Pu1: Unspecified wetland	63	60	3	5.5
Lower Murray	Lst1.1: Temporary saline lake	1,547	307	0	0
Lower Murray	Pst2.2: Temporary salt marsh	4,474	246	0	0
Lower Murray	Pt1.6.2: Temporary woodland swamp	818	38	0	0
Lower Murray	Pp2.1.2: Permanent tall emergent marsh	10	10	0	0
Lower Murray	Pt2.2.2: Temporary sedge/grass/forb marsh	1,077	0	0	0
Lower Murray	Pst4: Temporary saline wetland	437	0	0	0
Lower Murray	Pt4.2: Temporary wetland	83	0	0	0
Lower Murray	Pst3.2: Salt pan or salt flat	63	0	0	0
Lower Murray	Pps5: Permanent spring	2	0	0	0
Macquarie	Pt2.2.2: Temporary sedge/grass/forb marsh	34,725	11,223	9,032	80.5
Macquarie	Pt1.1.2: Temporary river red gum swamp	5,784	5,149	5,192	100.8
Macquarie	Pt2.1.2: Temporary tall emergent marsh	5,546	5,290	5,185	98.0
Macquarie	Pt2.3.2: Freshwater meadow	8,382	2,269	3,560	156.9
Macquarie	Pt1.8.2: Temporary shrub swamp	1,705	726	700	96.4
Macquarie	Pp4.2: Permanent wetland	1,584	917	637	69.4
Macquarie	Lt1.1: Temporary lake	9,214	71	252	354.4
Macquarie	Pt1.6.2: Temporary woodland swamp	2,639	323	50	15.5
Macquarie	Pt1.2.2: Temporary black box swamp	1,901	56	41	73.8
Macquarie	Lp1.1: Permanent lake	833	60	33	55.1

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Macquarie	Pt3.1.2: Clay pan	1,901	23	32	137.3
Macquarie	Pt1.3.2: Temporary coolibah swamp	1,435	1,404	0	0
Macquarie	Pp2.2.2: Permanent sedge/grass/forb marsh	28	0	0	0
Macquarie	Pps5: Permanent spring	15	0	0	0
Macquarie	Pst2.2: Temporary salt marsh	13	0	0	0
Macquarie	Pp3: Peat bog or fen marsh	4	0	0	0
Mitta Mitta	Pt1.6.2: Temporary woodland swamp	570	227	0	0
Mitta Mitta	Lp1.1: Permanent lake	88	73	0	0
Mitta Mitta	Pt3.1.2: Clay pan	581	54	0	0
Mitta Mitta	Pp4.2: Permanent wetland	1,013	0	0	0
Mitta Mitta	Pt2.3.2: Freshwater meadow	626	0	0	0
Mitta Mitta	Pt1.8.2: Temporary shrub swamp	450	0	0	0
Mitta Mitta	Pt4.2: Temporary wetland	56	0	0	0
Mitta Mitta	Pt1.1.2: Temporary river red gum swamp	5	0	0	0
Murrumbidgee	Pt1.8.2: Temporary shrub swamp	23,159	2,721	2,317	85.1
Murrumbidgee	Pt3.1.2: Clay pan	17,324	6,701	1,696	25.3
Murrumbidgee	Pt2.2.2: Temporary sedge/grass/forb marsh	45,553	8,311	1,604	19.3
Murrumbidgee	Pt1.1.2: Temporary river red gum swamp	7,380	6,516	636	9.8
Murrumbidgee	Pt2.1.2: Temporary tall emergent marsh	589	306	268	87.7
Murrumbidgee	Pp4.2: Permanent wetland	8,893	3,168	260	8.2
Murrumbidgee	Pt1.7.2: Temporary lignum swamp	1,501	183	178	97.0
Murrumbidgee	Pt1.2.2: Temporary black box swamp	4,874	987	162	16.4
Murrumbidgee	Lp1.1: Permanent lake	1,479	1,059	157	14.8
Murrumbidgee	Lt1.1: Temporary lake	30,458	2,113	122	5.8
Murrumbidgee	Pt2.3.2: Freshwater meadow	29,915	1,400	84	6.0
Murrumbidgee	Pt1.6.2: Temporary woodland swamp	1,623	105	39	36.9
Murrumbidgee	Pp2.3.2: Permanent grass marsh	36	23	23	99.5
Murrumbidgee	Pp2.1.2: Permanent tall emergent marsh	181	0	17	n/a
Murrumbidgee	Pt4.2: Temporary wetland	1,500	84	10	11.6
Murrumbidgee	Pp3: Peat bog or fen marsh	1,420	187	0	0
Murrumbidgee	Pp2.2.2: Permanent sedge/grass/forb marsh	15	6	0	0
Murrumbidgee	Pps5: Permanent spring	19	0	0	0
Namoi	Lp1.1: Permanent lake	5,122	4,585	0	0
Namoi	Pp4.2: Permanent wetland	11,301	1,131	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Namoi	Pt1.1.2: Temporary river red gum swamp	1,618	794	0	0
Namoi	Pt2.2.2: Temporary sedge/grass/forb marsh	3,600	763	0	0
Namoi	Pt1.2.2: Temporary black box swamp	1,771	334	0	0
Namoi	Pt3.1.2: Clay pan	5,326	297	0	0
Namoi	Pt4.2: Temporary wetland	2,909	277	0	0
Namoi	Pt1.6.2: Temporary woodland swamp	3,427	127	0	0
Namoi	Lt1.1: Temporary lake	2,604	93	0	0
Namoi	Pt2.3.2: Freshwater meadow	752	51	0	0
Namoi	Pt1.8.2: Temporary shrub swamp	568	29	0	0
Namoi	Pt1.3.2: Temporary coolibah swamp	609	0	0	0
Namoi	Pp2.2.2: Permanent sedge/grass/forb marsh	247	0	0	0
Namoi	Pt1.7.2: Temporary lignum swamp	16	0	0	0
Namoi	Pp3: Peat bog or fen marsh	15	0	0	0
Ovens	Pt3.1.2: Clay pan	1,814	357	0	0
Ovens	Pt1.1.2: Temporary river red gum swamp	472	187	0	0
Ovens	Pt1.6.2: Temporary woodland swamp	1,003	158	0	0
Ovens	Pt2.1.2: Temporary tall emergent marsh	67	67	0	0
Ovens	Pt2.2.2: Temporary sedge/grass/forb marsh	60	37	0	0
Ovens	Pp2.1.2: Permanent tall emergent marsh	36	36	0	0
Ovens	Lp1.1: Permanent lake	80	30	0	0
Ovens	Pp4.2: Permanent wetland	164	24	0	0
Ovens	Pt2.3.2: Freshwater meadow	963	0	0	0
Ovens	Lt1.1: Temporary lake	4	0	0	0
Ovens	Pps5: Permanent spring	0	0	0	0
Paroo	Pt2.2.2: Temporary sedge/grass/forb marsh	100,113	71,869	0	0
Paroo	Lt1.1: Temporary lake	48,834	31,963	0	0
Paroo	Lp1.1: Permanent lake	23,697	19,683	0	0
Paroo	Pt1.6.2: Temporary woodland swamp	32,561	19,441	0	0
Paroo	Pt1.8.2: Temporary shrub swamp	24,086	17,956	0	0
Paroo	Pt2.1.2: Temporary tall emergent marsh	14,554	10,156	0	0
Paroo	Lsp1.1: Permanent saline lake	7,064	5,789	0	0
Paroo	Pt1.2.2: Temporary black box swamp	8,428	4,464	0	0
Paroo	Pp4.2: Permanent wetland	4,506	3,721	0	0
Paroo	Pt2.3.2: Freshwater meadow	7,494	3,603	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Paroo	Pt1.3.2: Temporary coolibah swamp	2,399	2,328	0	0
Paroo	Pt1.7.2: Temporary lignum swamp	4,321	1,812	0	0
Paroo	Pst2.2: Temporary salt marsh	4,515	1,361	0	0
Paroo	Pp2.1.2: Permanent tall emergent marsh	586	586	0	0
Paroo	Pp2.2.2: Permanent sedge/grass/forb marsh	294	204	0	0
Paroo	Pst4: Temporary saline wetland	77	50	0	0
Paroo	Pt1.1.2: Temporary river red gum swamp	113	40	0	0
Paroo	Lst1.1: Temporary saline lake	468	37	0	0
Paroo	Pt3.1.2: Clay pan	31	31	0	0
Paroo	Pt4.2: Temporary wetland	494	13	0	0
Paroo	Pps5: Permanent spring	7	1	0	0
Upper Murray	Pt3.1.2: Clay pan	1,401	321	0	0
Upper Murray	Pt2.2.2: Temporary sedge/grass/forb marsh	542	282	0	0
Upper Murray	Pt1.1.2: Temporary river red gum swamp	304	275	0	0
Upper Murray	Pp4.2: Permanent wetland	416	51	0	0
Upper Murray	Pt1.6.2: Temporary woodland swamp	143	46	0	0
Upper Murray	Lp1.1: Permanent lake	92	26	0	0
Upper Murray	Pt4.2: Temporary wetland	50	12	0	0
Upper Murray	Pp3: Peat bog or fen marsh	1,197	0	0	0
Upper Murray	Pp2.2.2: Permanent sedge/grass/forb marsh	1,173	0	0	0
Upper Murray	Pps5: Permanent spring	63	0	0	0
Upper Murray	Lt1.1: Temporary lake	50	0	0	0
Upper Murray	Pt2.1.2: Temporary tall emergent marsh	7	0	0	0
Upper Murray	Pp2.1.2: Permanent tall emergent marsh	5	0	0	0
Upper Murray	Pt2.3.2: Freshwater meadow	0	0	0	0
Warrego	Pt2.2.2: Temporary sedge/grass/forb marsh	11,167	10,013	1,515	15.1
Warrego	Lp1.1: Permanent lake	4,431	1,374	1,134	82.6
Warrego	Lt1.1: Temporary lake	2,329	1,741	39	2.2
Warrego	Pp4.2: Permanent wetland	3,232	106	15	14.3
Warrego	Pt1.3.2: Temporary coolibah swamp	845	748	9	1.2
Warrego	Pp2.2.2: Permanent sedge/grass/forb marsh	13	13	3	1.5
Warrego	Pt2.1.2: Temporary tall emergent marsh	4,447	2,947	0	0
Warrego	Pt1.6.2: Temporary woodland swamp	4,619	2,759	0	0
Warrego	Pt1.8.2: Temporary shrub swamp	3,698	1,727	0	0

Valley	ANAE lake and wetland type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Warrego	Pt2.3.2: Freshwater meadow	1,396	205	0	0
Warrego	Pt3.1.2: Clay pan	654	201	0	0
Warrego	Pst2.2: Temporary salt marsh	244	176	0	0
Warrego	Pp2.1.2: Permanent tall emergent marsh	21	17	0	0
Warrego	Pt4.2: Temporary wetland	265	15	0	0
Warrego	Pt1.1.2: Temporary river red gum swamp	12	3	0	0
Warrego	Pst1.1: Temporary saline swamp	2	2	0	0
Warrego	Pps5: Permanent spring	2	0	0	0
Warrego	Psp2.1: Permanent salt marsh	2	0	0	0
Wimmera	Lt1.2: Temporary lake with aquatic bed	8,300	8,101	0	0
Wimmera	Pt3.1.2: Clay pan	4,404	260	0	0
Wimmera	Pst3.2: Salt pan or salt flat	1,634	253	0	0
Wimmera	Lst1.2: Temporary saline lake with aquatic bed	180	180	0	0
Wimmera	Pt1.6.2: Temporary woodland swamp	3,362	120	0	0
Wimmera	Pt2.3.2: Freshwater meadow	3,777	100	0	0
Wimmera	Pt1.1.2: Temporary river red gum swamp	4,713	41	0	0
Wimmera	Pp4.2: Permanent wetland	148	37	0	0
Wimmera	Lt1.1: Temporary lake	25,070	6	0	0
Wimmera	Lp1.1: Permanent lake	1,541	1	0	0
Wimmera	Pt1.8.2: Temporary shrub swamp	5,801	0	0	0
Wimmera	Pst4: Temporary saline wetland	3,120	0	0	0
Wimmera	Pst1.1: Temporary saline swamp	2,424	0	0	0
Wimmera	Pt1.2.2: Temporary black box swamp	1,929	0	0	0
Wimmera	Pt4.2: Temporary wetland	1,477	0	0	0
Wimmera	Lst1.1: Temporary saline lake	1,132	0	0	0
Wimmera	Pst2.2: Temporary salt marsh	405	0	0	0
Wimmera	Lp1.2: Permanent lake with aquatic bed	192	0	0	0
Wimmera	Pt1.5.2: Temporary paperbark swamp	183	0	0	0
Wimmera	Pt1.7.2: Temporary lignum swamp	174	0	0	0
Wimmera	Pt2.1.2: Temporary tall emergent marsh	121	0	0	0
Wimmera	Psp1.1: Saline paperbark swamp	31	0	0	0
Wimmera	Lsp1.1: Permanent saline lake	24	0	0	0
Wimmera	Psp4: Permanent saline wetland	16	0	0	0

Appendix B ANAE floodplain types by valley inundated by Commonwealth environmental water 2021–22

For floodplains, the area inundated by out-of-channel delivery of Commonwealth environmental water is presented in Table B.1 (column labelled CEW area (ha)). The percentage of managed floodplain can exceed 100% when the inundation extends beyond the currently mapped boundary of the managed floodplain (last updated by Brooks 2022). These may be places to be added to the managed floodplain in future updates.

Table B.1 Area of each Australian National Aquatic Ecosystem (ANAE) floodplain ecosystem type and the contribution of Commonwealth environmental water (CEW) to support floodplain ecosystem diversity within each valley 2021–22 (shaded blue)

The percentage of managed floodplain can exceed 100% when the inundation extends beyond the currently mapped boundary of the managed floodplain.

Valley	ANAE floodplain type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Avoca	F1.12: Woodland riparian zone or floodplain	415	301	0	0
Avoca	F1.4: River red gum woodland riparian zone or floodplain	379	167	0	0
Avoca	F1.8: Black box woodland riparian zone or floodplain	2,354	99	0	0
Avoca	F2.2: Lignum shrubland riparian zone or floodplain	68	4	0	0
Avoca	F1.6: Black box forest riparian zone or floodplain	891	0	0	0
Avoca	F4: Unspecified riparian zone or floodplain	182	0	0	0
Avoca	F2.4: Shrubland riparian zone or floodplain	2	0	0	0
Barwon Darling	F1.2: River red gum forest riparian zone or floodplain	50,564	24,831	1,054	4.2
Barwon Darling	F1.10: Coolibah woodland and forest riparian zone or floodplain	263,304	36,098	212	0.6
Barwon Darling	F1.8: Black box woodland riparian zone or floodplain	254,690	17,111	4	<0.1
Barwon Darling	F1.12: Woodland riparian zone or floodplain	3,399	39	1	2.1
Barwon Darling	F2.2: Lignum shrubland riparian zone or floodplain	20,125	2,034	1	<0.1
Barwon Darling	F2.4: Shrubland riparian zone or floodplain	34,184	3,608	0	0
Barwon Darling	F1.4: River red gum woodland riparian zone or floodplain	3,204	0	0	0
Barwon Darling	F1.11: River cooba woodland riparian zone or floodplain	63	0	0	0
Border Rivers	F1.2: River red gum forest riparian zone or floodplain	29,958	15,101	1,868	12.4

Valley	ANAE floodplain type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Border Rivers	F1.4: River red gum woodland riparian zone or floodplain	369	228	43	18.7
Border Rivers	F1.10: Coolibah woodland and forest riparian zone or floodplain	105,878	20,166	22	0.1
Border Rivers	F3.2: Sedge/forb/grassland riparian zone or floodplain	12,750	2,974	8	0.3
Border Rivers	F1.12: Woodland riparian zone or floodplain	3,837	568	5	0.9
Border Rivers	F2.2: Lignum shrubland riparian zone or floodplain	2,339	310	<1	<0.1
Border Rivers	F1.11: River cooba woodland riparian zone or floodplain	2,259	152	0	0
Border Rivers	F1.8: Black box woodland riparian zone or floodplain	3,094	5	0	0
Border Rivers	F2.4: Shrubland riparian zone or floodplain	1,246	4	0	0
Border Rivers	F4: Unspecified riparian zone or floodplain	191	0	0	0
Broken	F1.4: River red gum woodland riparian zone or floodplain	2,386	1,782	0	0
Broken	F4: Unspecified riparian zone or floodplain	90	83	0	0
Broken	F1.12: Woodland riparian zone or floodplain	676	34	0	0
Broken	F1.8: Black box woodland riparian zone or floodplain	60	2	0	0
Broken	F2.2: Lignum shrubland riparian zone or floodplain	2	0	0	0
Broken	F1.2: River red gum forest riparian zone or floodplain	1	0	0	0
Campaspe	F1.4: River red gum woodland riparian zone or floodplain	744	527	0	0
Campaspe	F4: Unspecified riparian zone or floodplain	35	13	0	0
Campaspe	F1.12: Woodland riparian zone or floodplain	1,157	4	0	0
Campaspe	F1.2: River red gum forest riparian zone or floodplain	2	2	0	0
Campaspe	F2.2: Lignum shrubland riparian zone or floodplain	1	0	0	0
Castlereagh	F1.10: Coolibah woodland and forest riparian zone or floodplain	40,762	7,065	0	0
Castlereagh	F1.2: River red gum forest riparian zone or floodplain	6,955	4,122	0	0
Castlereagh	F1.8: Black box woodland riparian zone or floodplain	36,699	2,138	0	0
Castlereagh	F1.12: Woodland riparian zone or floodplain	2,883	441	0	0
Castlereagh	F2.2: Lignum shrubland riparian zone or floodplain	100	0	0	0
Castlereagh	F1.11: River cooba woodland riparian zone or floodplain	57	0	0	0
Central Murray	F1.2: River red gum forest riparian zone or floodplain	139,157	60,996	13,848	22.7
Central Murray	F1.12: Woodland riparian zone or floodplain	6,399	2,425	135	5.6
Central Murray	F3.2: Sedge/forb/grassland riparian zone or floodplain	1,034	372	16	4.4

Valley	ANAE floodplain type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Central Murray	F1.8: Black box woodland riparian zone or floodplain	104,016	15,556	14	<0.1
Central Murray	F4: Unspecified riparian zone or floodplain	7,001	829	13	1.5
Central Murray	F1.4: River red gum woodland riparian zone or floodplain	18,003	7,455	8	0.1
Central Murray	F2.2: Lignum shrubland riparian zone or floodplain	7,034	656	0	0
Central Murray	F1.6: Black box forest riparian zone or floodplain	1,383	379	0	0
Central Murray	F2.4: Shrubland riparian zone or floodplain	322	26	0	0
Condamine Balonne	F2.2: Lignum shrubland riparian zone or floodplain	58,747	11,391	1,969	17.3
Condamine Balonne	F2.4: Shrubland riparian zone or floodplain	15,153	3,136	728	23.2
Condamine Balonne	F3.2: Sedge/forb/grassland riparian zone or floodplain	43,303	2,985	707	23.7
Condamine Balonne	F1.10: Coolibah woodland and forest riparian zone or floodplain	789,650	66,816	554	0.8
Condamine Balonne	F1.2: River red gum forest riparian zone or floodplain	49,652	5,828	84	1.4
Condamine Balonne	F1.11: River cooba woodland riparian zone or floodplain	5,206	279	4	1.5
Condamine Balonne	F1.8: Black box woodland riparian zone or floodplain	207,679	15,455	1	<0.1
Condamine Balonne	F1.4: River red gum woodland riparian zone or floodplain	13,508	3,175	<1	<0.1
Condamine Balonne	F1.12: Woodland riparian zone or floodplain	18,786	1,434	<1	<0.1
Condamine Balonne	F4: Unspecified riparian zone or floodplain	267	78	0	0
Condamine Balonne	F1.13: Paperbark riparian zone or floodplain	5	0	0	0
Edward/Kolety–Wakool	F1.8: Black box woodland riparian zone or floodplain	73,167	3,782	147	3.9
Edward/Kolety–Wakool	F1.2: River red gum forest riparian zone or floodplain	65,502	24,202	101	0.4
Edward/Kolety–Wakool	F2.2: Lignum shrubland riparian zone or floodplain	3,641	181	2	0.9
Edward/Kolety–Wakool	F2.4: Shrubland riparian zone or floodplain	48	3	0	0
Goulburn	F1.4: River red gum woodland riparian zone or floodplain	11,384	6,024	0	0
Goulburn	F1.2: River red gum forest riparian zone or floodplain	5,800	4,525	0	0
Goulburn	F1.12: Woodland riparian zone or floodplain	13,175	1,668	0	0

Valley	ANAE floodplain type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Goulburn	F4: Unspecified riparian zone or floodplain	507	143	0	0
Goulburn	F1.8: Black box woodland riparian zone or floodplain	129	24	0	0
Goulburn	F3.2: Sedge/forb/grassland riparian zone or floodplain	20	19	0	0
Goulburn	F2.2: Lignum shrubland riparian zone or floodplain	26	0	0	0
Gwydir	F1.10: Coolibah woodland and forest riparian zone or floodplain	157,616	11,904	1,817	15.3
Gwydir	F1.11: River cooba woodland riparian zone or floodplain	4,429	1,895	66	3.5
Gwydir	F2.2: Lignum shrubland riparian zone or floodplain	613	145	60	41.6
Gwydir	F1.8: Black box woodland riparian zone or floodplain	19,280	401	0	0
Gwydir	F1.2: River red gum forest riparian zone or floodplain	9,653	6,123	0	0
Gwydir	F1.12: Woodland riparian zone or floodplain	4,546	646	0	0
Gwydir	F2.4: Shrubland riparian zone or floodplain	203	0	0	0
Kiewa	F1.4: River red gum woodland riparian zone or floodplain	1,094	949	0	0
Kiewa	F1.12: Woodland riparian zone or floodplain	1,422	373	0	0
Kiewa	F4: Unspecified riparian zone or floodplain	1	1	0	0
Lachlan	F1.2: River red gum forest riparian zone or floodplain	80,067	60,521	2,157	3.6
Lachlan	F1.8: Black box woodland riparian zone or floodplain	129,174	54,714	133	0.2
Lachlan	F2.4: Shrubland riparian zone or floodplain	321,807	105,911	59	<0.1
Lachlan	F2.2: Lignum shrubland riparian zone or floodplain	10,168	2,713	44	1.6
Lachlan	F1.11: River cooba woodland riparian zone or floodplain	3	3	0	0
Lachlan	F1.12: Woodland riparian zone or floodplain	173	0	0	0
Loddon	F1.12: Woodland riparian zone or floodplain	1,827	599	0	0
Loddon	F1.4: River red gum woodland riparian zone or floodplain	1,744	453	0	0
Loddon	F1.8: Black box woodland riparian zone or floodplain	6,900	282	0	0
Loddon	F2.2: Lignum shrubland riparian zone or floodplain	5,785	116	0	0
Loddon	F1.2: River red gum forest riparian zone or floodplain	77	60	0	0
Loddon	F4: Unspecified riparian zone or floodplain	124	31	0	0
Loddon	F1.6: Black box forest riparian zone or floodplain	30	0	0	0
Loddon	F2.4: Shrubland riparian zone or floodplain	17	0	0	0
Loddon	F3.2: Sedge/forb/grassland riparian zone or floodplain	1	0	0	0
Lower Darling	F1.8: Black box woodland riparian zone or floodplain	226,762	18,869	0	0

Valley	ANAE floodplain type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Lower Darling	F1.2: River red gum forest riparian zone or floodplain	16,358	11,410	0	0
Lower Darling	F2.4: Shrubland riparian zone or floodplain	8,918	518	0	0
Lower Darling	F2.2: Lignum shrubland riparian zone or floodplain	1,186	60	0	0
Lower Darling	F1.4: River red gum woodland riparian zone or floodplain	907	12	0	0
Lower Darling	F1.12: Woodland riparian zone or floodplain	12	0	0	0
Lower Murray	F2.2: Lignum shrubland riparian zone or floodplain	19,396	7,801	197	2.5
Lower Murray	F1.8: Black box woodland riparian zone or floodplain	57,121	12,638	179	1.4
Lower Murray	F1.4: River red gum woodland riparian zone or floodplain	34,349	10,224	88	0.9
Lower Murray	F4: Unspecified riparian zone or floodplain	9,020	3,184	73	2.3
Lower Murray	F1.2: River red gum forest riparian zone or floodplain	10,055	6,682	43	0.6
Lower Murray	F2.4: Shrubland riparian zone or floodplain	12,131	2,700	15	0.6
Lower Murray	F3.2: Sedge/forb/grassland riparian zone or floodplain	4,415	473	6	1.2
Lower Murray	F1.12: Woodland riparian zone or floodplain	1,285	110	<1	0.2
Lower Murray	F1.11: River cooba woodland riparian zone or floodplain	278	130	0	0
Lower Murray	F1.6: Black box forest riparian zone or floodplain	8	8	0	0
Macquarie	F1.4: River red gum woodland riparian zone or floodplain	40,760	32,784	14,513	44.3
Macquarie	F1.2: River red gum forest riparian zone or floodplain	37,037	18,708	5,962	31.9
Macquarie	F1.10: Coolibah woodland and forest riparian zone or floodplain	157,953	24,284	3,528	14.5
Macquarie	F1.8: Black box woodland riparian zone or floodplain	305,561	31,163	743	2.4
Macquarie	F1.11: River cooba woodland riparian zone or floodplain	2,763	2,188	680	31.1
Macquarie	F2.2: Lignum shrubland riparian zone or floodplain	11,230	535	276	51.6
Macquarie	F2.4: Shrubland riparian zone or floodplain	1,715	471	32	6.8
Macquarie	F1.12: Woodland riparian zone or floodplain	2,542	10	0	0
Mitta Mitta	F1.12: Woodland riparian zone or floodplain	3,459	295	0	0
Mitta Mitta	F1.4: River red gum woodland riparian zone or floodplain	82	11	0	0
Mitta Mitta	F2.4: Shrubland riparian zone or floodplain	14	0	0	0
Murrumbidgee	F2.2: Lignum shrubland riparian zone or floodplain	79,708	19,991	10,365	51.8
Murrumbidgee	F2.4: Shrubland riparian zone or floodplain	45,248	9,911	3,517	35.5
Murrumbidgee	F1.2: River red gum forest riparian zone or floodplain	105,109	70,231	2,500	3.6

Valley	ANAE floodplain type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Murrumbidgee	F1.8: Black box woodland riparian zone or floodplain	122,839	28,804	666	2.3
Murrumbidgee	F1.11: River cooba woodland riparian zone or floodplain	25	5	1	10.3
Murrumbidgee	F1.12: Woodland riparian zone or floodplain	115	107	0	0
Murrumbidgee	F1.4: River red gum woodland riparian zone or floodplain	2	2	0	0
Murrumbidgee	F1.10: Coolibah woodland and forest riparian zone or floodplain	23	0	0	0
Namoi	F1.10: Coolibah woodland and forest riparian zone or floodplain	85,657	4,679	0	0
Namoi	F1.2: River red gum forest riparian zone or floodplain	5,842	3,039	0	0
Namoi	F1.12: Woodland riparian zone or floodplain	7,708	453	0	0
Namoi	F1.11: River cooba woodland riparian zone or floodplain	1,391	41	0	0
Namoi	F2.2: Lignum shrubland riparian zone or floodplain	2,240	33	0	0
Namoi	F1.8: Black box woodland riparian zone or floodplain	15,387	2	0	0
Namoi	F2.4: Shrubland riparian zone or floodplain	227	0	0	0
Namoi	F1.13: Paperbark riparian zone or floodplain	14	0	0	0
Ovens	F1.4: River red gum woodland riparian zone or floodplain	4,621	3,714	0	0
Ovens	F1.12: Woodland riparian zone or floodplain	5,982	2,490	0	0
Ovens	F1.2: River red gum forest riparian zone or floodplain	1,921	1,748	0	0
Ovens	F4: Unspecified riparian zone or floodplain	92	33	0	0
Paroo	F1.10: Coolibah woodland and forest riparian zone or floodplain	132,400	114,013	0	0
Paroo	F1.8: Black box woodland riparian zone or floodplain	97,104	49,058	0	0
Paroo	F1.4: River red gum woodland riparian zone or floodplain	99,862	41,702	0	0
Paroo	F2.2: Lignum shrubland riparian zone or floodplain	58,163	35,279	0	0
Paroo	F1.12: Woodland riparian zone or floodplain	40,896	26,551	0	0
Paroo	F2.4: Shrubland riparian zone or floodplain	18,863	14,382	0	0
Paroo	F1.2: River red gum forest riparian zone or floodplain	4,359	2,752	0	0
Paroo	F4: Unspecified riparian zone or floodplain	1,197	805	0	0
Paroo	F1.13: Paperbark riparian zone or floodplain	871	267	0	0
Paroo	F1.11: River cooba woodland riparian zone or floodplain	30	22	0	0
Upper Murray	F1.2: River red gum forest riparian zone or floodplain	1,583	919	0	0
Upper Murray	F1.12: Woodland riparian zone or floodplain	1,229	383	0	0

Valley	ANAE floodplain type	Total area (ha)	Area on managed floodplain (ha)	CEW area (ha)	Percentage of managed floodplain (%)
Upper Murray	F1.4: River red gum woodland riparian zone or floodplain	569	143	0	0
Upper Murray	F4: Unspecified riparian zone or floodplain	54	24	0	0
Upper Murray	F2.4: Shrubland riparian zone or floodplain	349	19	0	0
Upper Murray	F2.2: Lignum shrubland riparian zone or floodplain	9	0	0	0
Warrego	F1.10: Coolibah woodland and forest riparian zone or floodplain	374,028	207,009	2,223	1.1
Warrego	F1.2: River red gum forest riparian zone or floodplain	5,958	4,901	298	6.1
Warrego	F1.4: River red gum woodland riparian zone or floodplain	59,817	35,235	123	0.3
Warrego	F2.2: Lignum shrubland riparian zone or floodplain	13,759	3,888	108	2.8
Warrego	F1.11: River cooba woodland riparian zone or floodplain	394	343	101	29.5
Warrego	F1.8: Black box woodland riparian zone or floodplain	46,974	28,905	5	<0.1
Warrego	F1.12: Woodland riparian zone or floodplain	17,528	3,182	<1	<0.1
Warrego	F4: Unspecified riparian zone or floodplain	514	31	0	0
Warrego	F2.4: Shrubland riparian zone or floodplain	137	14	0	0
Warrego	F1.13: Paperbark riparian zone or floodplain	7	3	0	0
Warrego	F3.2: Sedge/forb/grassland riparian zone or floodplain	1,260	0	0	0
Wimmera	F1.12: Woodland riparian zone or floodplain	13,281	1,534	0	0
Wimmera	F1.4: River red gum woodland riparian zone or floodplain	4,186	1,078	0	0
Wimmera	F1.8: Black box woodland riparian zone or floodplain	4,221	368	0	0
Wimmera	F1.6: Black box forest riparian zone or floodplain	866	63	0	0
Wimmera	F4: Unspecified riparian zone or floodplain	539	62	0	0
Wimmera	F2.4: Shrubland riparian zone or floodplain	615	0	0	0
Wimmera	F2.2: Lignum shrubland riparian zone or floodplain	142	0	0	0
Wimmera	F3.2: Sedge/forb/grassland riparian zone or floodplain	1	0	0	0

Appendix C ANAE river channel types by valley influenced by Commonwealth environmental water 2021–22

The lengths of river and stream channels of differing ANAE type with Commonwealth environmental water in 2021–22 are presented in Table C.1 as an indicator of the contribution of Commonwealth environmental water towards riverine ecosystem diversity within each valley. River length measurement is highly dependent on the resolution of the mapping, with higher resolution capturing more twists and turns in the river that increase the measured river length along the flow path. ANAE river mapping is based on the Geofabric v3.2 Network Streams which are derived from a 1 arc-second digital elevation model (DEM) with an approximate resolution of 30 m (BOM 2020). The percentage of managed floodplain can exceed 100% when Commonwealth environmental water flows in channels outside of the currently mapped boundary of the managed floodplain (last updated by Brooks 2022). These may be places to be added to the managed floodplain in future updates.

Table C.1 Length of Australian National Aquatic Ecosystem (ANAE) river and stream ecosystem types influenced by Commonwealth environmental water (CEW) within each valley 2021–22 (shaded blue)

The percentage of managed floodplain can exceed 100% when the inundation extends beyond the currently mapped boundary of the managed floodplain.

Valley	ANAE river and stream types	Total length (km)	Length on managed floodplain (km)	CEW length (km)	Percentage of managed floodplain (%)
Avoca	Rt1.4: Temporary lowland stream	1,370	346	0	0
Avoca	Rt1.2: Temporary transitional zone stream	1,950	18	0	0
Avoca	Rt1.1: Temporary high energy upland stream	139	0	0	0
Barwon Darling	Rp1.4: Permanent lowland stream	3,434	2,319	1,874	80.8
Barwon Darling	Rt1.4: Temporary lowland stream	16,232	559	82	14.7
Barwon Darling	Rp1.2: Permanent transitional zone stream	85	13	13	96.4
Barwon Darling	Rp1.1: Permanent high energy upland stream	4	4	4	108.0
Barwon Darling	Rt1.2: Temporary transitional zone stream	11,089	8	0	0
Barwon Darling	Rt1.1: Temporary high energy upland stream	12	0	0	0
Border Rivers	Rt1.4: Temporary lowland stream	10,762	1,945	771	39.7
Border Rivers	Rp1.4: Permanent lowland stream	1,135	863	679	78.7
Border Rivers	Rp1.2: Permanent transitional zone stream	675	236	89	37.7
Border Rivers	Rt1.2: Temporary transitional zone stream	12,764	342	72	21.0
Border Rivers	Rt1.1: Temporary high energy upland stream	10,265	56	19	33.2
Border Rivers	Rt1.3: Temporary low energy upland stream	310	18	13	74.9
Border Rivers	Rp1.3: Permanent low energy upland stream	708	109	0	0

Valley	ANAE river and stream types	Total length (km)	Length on managed floodplain (km)	CEW length (km)	Percentage of managed floodplain (%)
Border Rivers	Rp1.1: Permanent high energy upland stream	1,151	45	0	0
Broken	Rp1.4: Permanent lowland stream	338	297	281	94.6
Broken	Rt1.4: Temporary lowland stream	984	147	110	74.8
Broken	Rp1.2: Permanent transitional zone stream	33	33	3	9.6
Broken	Rt1.2: Temporary transitional zone stream	1,056	8	1	15.0
Broken	Rp1.1: Permanent high energy upland stream	9	3	0	0
Broken	Rt1.1: Temporary high energy upland stream	439	2	0	0
Broken	Rt1.3: Temporary low energy upland stream	1	0	0	0
Campaspe	Rp1.4: Permanent lowland stream	130	110	110	99.9
Campaspe	Rp1.2: Permanent transitional zone stream	50	4	2	54.6
Campaspe	Rt1.2: Temporary transitional zone stream	1,915	50	0	0
Campaspe	Rt1.3: Temporary low energy upland stream	63	25	0	0
Campaspe	Rt1.4: Temporary lowland stream	566	23	0	0
Campaspe	Rt1.1: Temporary high energy upland stream	570	6	0	0
Campaspe	Rp1.3: Permanent low energy upland stream	3	0	0	0
Campaspe	Rp1.1: Permanent high energy upland stream	2	0	0	0
Castlereagh	Rp1.4: Permanent lowland stream	488	354	0	0
Castlereagh	Rp1.2: Permanent transitional zone stream	449	174	0	0
Castlereagh	Rt1.4: Temporary lowland stream	2,726	77	0	0
Castlereagh	Rt1.2: Temporary transitional zone stream	4,204	34	0	0
Castlereagh	Rt1.1: Temporary high energy upland stream	2,346	0	0	0
Castlereagh	Rt1.3: Temporary low energy upland stream	85	0	0	0
Castlereagh	Rp1.1: Permanent high energy upland stream	25	0	0	0
Castlereagh	Rp1.3: Permanent low energy upland stream	20	0	0	0
Central Murray	Rp1.4: Permanent lowland stream	2,715	2,419	1,837	75.9
Central Murray	Rt1.4: Temporary lowland stream	3,659	1,148	422	36.7
Central Murray	Rt1.2: Temporary transitional zone stream	2,720	33	9	28.8
Central Murray	Rp1.2: Permanent transitional zone stream	120	18	9	47.7
Central Murray	Rt1.1: Temporary high energy upland stream	493	1	0	0
Central Murray	Rp1.1: Permanent high energy upland stream	1	0	0	0
Central Murray	Rt1.3: Temporary low energy upland stream	0	0	0	0
Condamine Balonne	Rt1.4: Temporary lowland stream	14,853	1,860	1,258	67.6
Condamine Balonne	Rp1.4: Permanent lowland stream	1,563	1,377	891	64.7
Condamine Balonne	Rt1.2: Temporary transitional zone stream	29,029	663	23	3.5

Valley	ANAE river and stream types	Total length (km)	Length on managed floodplain (km)	CEW length (km)	Percentage of managed floodplain (%)
Condamine Balonne	Rp1.2: Permanent transitional zone stream	467	465	5	1.1
Condamine Balonne	Rt1.3: Temporary low energy upland stream	963	89	0	0
Condamine Balonne	Rt1.1: Temporary high energy upland stream	8,197	32	0	0
Condamine Balonne	Rp1.1: Permanent high energy upland stream	25	25	0	0
Condamine Balonne	Rp1.3: Permanent low energy upland stream	16	16	0	0
Edward/Kolety–Wakool	Rp1.4: Permanent lowland stream	1,642	1,392	1,070	76.9
Edward/Kolety–Wakool	Rt1.4: Temporary lowland stream	1,554	437	227	52.0
Edward/Kolety–Wakool	Rp1.2: Permanent transitional zone stream	6	5	2	43.0
Edward/Kolety–Wakool	Rt1.2: Temporary transitional zone stream	8	3	0	0
Goulburn	Rp1.4: Permanent lowland stream	868	437	408	93.3
Goulburn	Rp1.2: Permanent transitional zone stream	397	60	3	4.5
Goulburn	Rp1.1: Permanent high energy upland stream	113	1	1	71.1
Goulburn	Rt1.4: Temporary lowland stream	2,168	96	0	0
Goulburn	Rt1.2: Temporary transitional zone stream	5,887	18	0	0
Goulburn	Rt1.1: Temporary high energy upland stream	4,527	9	0	0
Goulburn	Rt1.3: Temporary low energy upland stream	24	0	0	0
Goulburn	Rp1.3: Permanent low energy upland stream	23	0	0	0
Gwydir	Rp1.4: Permanent lowland stream	1,144	968	683	70.6
Gwydir	Rt1.4: Temporary lowland stream	856	61	55	89.8
Gwydir	Rp1.2: Permanent transitional zone stream	3,000	270	12	4.5
Gwydir	Rt1.2: Temporary transitional zone stream	1,028	14	<1	0.6
Gwydir	Rp1.1: Permanent high energy upland stream	637	113	0	0
Gwydir	Rp1.3: Permanent low energy upland stream	3,295	20	0	0
Gwydir	Rt1.1: Temporary high energy upland stream	6,935	16	0	0
Gwydir	Rt1.3: Temporary low energy upland stream	68	0	0	0
Kiewa	Rp1.4: Permanent lowland stream	97	97	0	0
Kiewa	Rp1.2: Permanent transitional zone stream	29	21	0	0
Kiewa	Rt1.1: Temporary high energy upland stream	1,033	10	0	0
Kiewa	Rt1.4: Temporary lowland stream	84	8	0	0
Kiewa	Rt1.2: Temporary transitional zone stream	378	7	0	0
Kiewa	Rp1.1: Permanent high energy upland stream	46	6	0	0
Kiewa	Rt1.3: Temporary low energy upland stream	9	0	0	0

Valley	ANAE river and stream types	Total length (km)	Length on managed floodplain (km)	CEW length (km)	Percentage of managed floodplain (%)
Kiewa	Rp1.3: Permanent low energy upland stream	1	0	0	0
Lachlan	Rp1.4: Permanent lowland stream	3,334	1,656	1,326	80.0
Lachlan	Rt1.4: Temporary lowland stream	11,645	2,435	516	21.2
Lachlan	Rp1.2: Permanent transitional zone stream	1,826	150	18	11.9
Lachlan	Rt1.2: Temporary transitional zone stream	15,080	37	1	3.0
Lachlan	Rp1.1: Permanent high energy upland stream	1,621	3	<1	3.5
Lachlan	Rp1.3: Permanent low energy upland stream	676	44	0	0
Lachlan	Rt1.1: Temporary high energy upland stream	12,660	26	0	0
Lachlan	Rt1.3: Temporary low energy upland stream	210	0	0	0
Loddon	Rp1.4: Permanent lowland stream	602	363	361	99.3
Loddon	Rp1.2: Permanent transitional zone stream	5	4	4	108.6
Loddon	Rt1.4: Temporary lowland stream	3,320	51	0	0
Loddon	Rt1.2: Temporary transitional zone stream	4,024	42	0	0
Loddon	Rt1.1: Temporary high energy upland stream	374	1	0	0
Loddon	Rt1.3: Temporary low energy upland stream	8	0	0	0
Lower Darling	Rp1.4: Permanent lowland stream	1,534	1,217	953	78.3
Lower Darling	Rt1.4: Temporary lowland stream	2,626	322	69	21.4
Lower Darling	Rp1.2: Permanent transitional zone stream	24	5	4	82.2
Lower Darling	Rt1.2: Temporary transitional zone stream	1,141	2	<1	12.9
Lower Darling	Rt1.1: Temporary high energy upland stream	0	0	0	0
Lower Murray	Rp1.4: Permanent lowland stream	1,334	1,096	864	78.8
Lower Murray	Rt1.4: Temporary lowland stream	4,826	890	69	7.8
Lower Murray	Rt1.2: Temporary transitional zone stream	13,283	30	3	8.5
Lower Murray	Rp1.2: Permanent transitional zone stream	22	3	1	34.5
Lower Murray	Rt1.1: Temporary high energy upland stream	1,275	1	0	0
Lower Murray	Rt1.3: Temporary low energy upland stream	42	0	0	0
Macquarie	Rp1.4: Permanent lowland stream	3,114	1,684	1,345	79.9
Macquarie	Rt1.4: Temporary lowland stream	10,363	747	1,207	161.6
Macquarie	Rp1.2: Permanent transitional zone stream	1,802	320	16	4.9
Macquarie	Rt1.2: Temporary transitional zone stream	13,506	78	<1	0.4
Macquarie	Rp1.1: Permanent high energy upland stream	1,877	38	<1	<0.1
Macquarie	Rp1.3: Permanent low energy upland stream	942	81	0	0
Macquarie	Rt1.1: Temporary high energy upland stream	18,603	48	0	0
Macquarie	Rt1.3: Temporary low energy upland stream	194	3	0	0

Valley	ANAE river and stream types	Total length (km)	Length on managed floodplain (km)	CEW length (km)	Percentage of managed floodplain (%)
Mitta Mitta	Rp1.4: Permanent lowland stream	130	98	0	0
Mitta Mitta	Rp1.2: Permanent transitional zone stream	111	34	0	0
Mitta Mitta	Rp1.1: Permanent high energy upland stream	188	19	0	0
Mitta Mitta	Rp1.3: Permanent low energy upland stream	79	15	0	0
Mitta Mitta	Rt1.1: Temporary high energy upland stream	3,960	11	0	0
Mitta Mitta	Rt1.2: Temporary transitional zone stream	435	4	0	0
Mitta Mitta	Rt1.4: Temporary lowland stream	25	1	0	0
Mitta Mitta	Rt1.3: Temporary low energy upland stream	37	0	0	0
Murrumbidgee	Rp1.4: Permanent lowland stream	3,424	2,255	1,948	86.4
Murrumbidgee	Rt1.4: Temporary lowland stream	7,284	1,460	865	59.3
Murrumbidgee	Rp1.2: Permanent transitional zone stream	1,257	94	17	18.0
Murrumbidgee	Rt1.2: Temporary transitional zone stream	12,784	43	5	10.9
Murrumbidgee	Rp1.3: Permanent low energy upland stream	1,094	214	0	0
Murrumbidgee	Rp1.1: Permanent high energy upland stream	2,956	71	0	0
Murrumbidgee	Rt1.1: Temporary high energy upland stream	14,155	35	0	0
Murrumbidgee	Rt1.3: Temporary low energy upland stream	195	0	0	0
Namoi	Rp1.4: Permanent lowland stream	899	569	0	0
Namoi	Rp1.2: Permanent transitional zone stream	1,594	210	0	0
Namoi	Rt1.4: Temporary lowland stream	5,022	58	0	0
Namoi	Rt1.2: Temporary transitional zone stream	10,593	29	0	0
Namoi	Rp1.1: Permanent high energy upland stream	1,015	14	0	0
Namoi	Rt1.1: Temporary high energy upland stream	10,759	11	0	0
Namoi	Rp1.3: Permanent low energy upland stream	421	2	0	0
Namoi	Rt1.3: Temporary low energy upland stream	33	0	0	0
Ovens	Rp1.4: Permanent lowland stream	344	276	230	83.2
Ovens	Rp1.2: Permanent transitional zone stream	180	73	30	41.6
Ovens	Rt1.4: Temporary lowland stream	880	151	0	0
Ovens	Rp1.1: Permanent high energy upland stream	78	32	0	0
Ovens	Rt1.2: Temporary transitional zone stream	2,139	19	0	0
Ovens	Rt1.1: Temporary high energy upland stream	2,714	13	0	0
Ovens	Rp1.3: Permanent low energy upland stream	3	2	0	0
Ovens	Rt1.3: Temporary low energy upland stream	2	0	0	0
Paroo	Rt1.4: Temporary lowland stream	21,399	5,315	0	0
Paroo	Rt1.2: Temporary transitional zone stream	11,842	297	0	0

Valley	ANAE river and stream types	Total length (km)	Length on managed floodplain (km)	CEW length (km)	Percentage of managed floodplain (%)
Paroo	Rp1.4: Permanent lowland stream	16	13	0	0
Paroo	Rt1.1: Temporary high energy upland stream	6	0	0	0
Upper Murray	Rp1.4: Permanent lowland stream	352	150	0	0
Upper Murray	Rp1.2: Permanent transitional zone stream	567	52	0	0
Upper Murray	Rp1.1: Permanent high energy upland stream	967	45	0	0
Upper Murray	Rt1.1: Temporary high energy upland stream	6,008	28	0	0
Upper Murray	Rp1.3: Permanent low energy upland stream	102	24	0	0
Upper Murray	Rt1.4: Temporary lowland stream	168	15	0	0
Upper Murray	Rt1.2: Temporary transitional zone stream	1,570	13	0	0
Upper Murray	Rt1.3: Temporary low energy upland stream	20	0	0	0
Warrego	Rt1.4: Temporary lowland stream	6,726	4,228	1,048	24.8
Warrego	Rt1.2: Temporary transitional zone stream	15,048	2,028	181	8.9
Warrego	Rp1.4: Permanent lowland stream	106	85	53	62.0
Warrego	Rt1.1: Temporary high energy upland stream	4,669	12	<1	0.6
Warrego	Rt1.3: Temporary low energy upland stream	1,291	112	0	0
Wimmera	Rt1.4: Temporary lowland stream	3,100	533	0	0
Wimmera	Rt1.2: Temporary transitional zone stream	3,340	20	0	0
Wimmera	Rt1.1: Temporary high energy upland stream	505	0	0	0
Wimmera	Rp1.4: Permanent lowland stream	16	0	0	0
Wimmera	Rt1.3: Temporary low energy upland stream	0	0	0	0

Appendix D ANAE wetland types influenced by Commonwealth environmental water 2014–22

Tables in this appendix provide the area (ha) (Table D.1, Table D.2 and Table D.3) or length (km) (Table D.4) of each ANAE ecosystem type supported by Commonwealth environmental water since monitoring began in 2014–15 during LTIM. Values have been calculated using the current version of the ANAE and inundation extent mapping that was updated by the Flow-MER project to be consistent among years. The data are grouped by ANAE system types as lakes (Table D.1), palustrine wetlands (Table D.2), floodplains (Table D.3) and river channels (Table D.4).

Table D.1 Area of Australian National Aquatic Ecosystem (ANAE) lake ecosystem types supported* by Commonwealth environmental water (CEW) (upstream of the Coorong, Lower Lakes and Murray Mouth), 2014–22

This information is presented graphically in Figure 5.1. *See Section 3.2 for the definition of area supported by CEW. † Refers to ecosystem types that received Commonwealth environmental water (CEW) in each year of the 8-year monitoring period (also shaded blue).

ANAE ecosystem type	Total area(ha)	Area on managed floodplain (ha)	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
Lt1.1: Temporary lake†	457,526	118,967	714	3,472	2,188	3,076	1,279	1,616	7,823	1,508
Lp1.1: Permanent lake†	130,559	73,379	6,745	3,993	7,972	15,001	3,392	7,561	8,970	7,346
Lt1.2: Temporary lake with aquatic bed	9,052	8,177	0	0	0	0	0	0	0	0
Lsp1.1: Permanent saline lake	8,988	6,041	0	0	0	0	0	0	0	0
Lst1.1: Temporary saline lake	27,898	1,656	0	0	0	307	0	0	0	0
Lp1.2: Permanent lake with aquatic bed	2,067	196	0	0	0	0	0	0	0	0
Lst1.2: Temporary saline lake with aquatic bed	2,238	180	0	0	0	0	0	0	0	0
Lsp1.2: Permanent saline lake with aquatic bed	181	0	0	0	0	0	0	0	0	0
TOTAL	**638,509**	**208,596**	**7,459**	**7,465**	**10,160**	**18,384**	**4,671**	**9,177**	**16,793**	**8,854**

Table D.2 Areas of Australian National Aquatic Ecosystem (ANAE) palustrine wetland types supported* by Commonwealth environmental water (upstream of the Coorong, Lower Lakes and Murray Mouth), ordered by their managed floodplain area, 2014–22

This information is presented graphically in Figure 5.3 *See Section 3.2 for the definition of area supported by CEW. † Refers to ecosystem types that received Commonwealth environmental water (CEW) in each year of the 8-year monitoring period (also shaded blue).

ANAE ecosystem type	Total area (ha)	Area on managed floodplain (ha)	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
Pt2.2.2: Temporary sedge/grass/forb marsh†	329,304	129,573	3,632	4,127	7,535	8,035	7,279	1,869	8,991	12,980
Pt1.1.2: Temporary river red gum swamp†	76,067	57,794	3,217	28,342	7,471	35,132	32,986	26,035	33,572	31,056
Pt2.1.2: Temporary tall emergent marsh†	70,414	55,742	5,575	6,041	5,282	6,615	6,565	1,484	7,044	6,863
Pt1.8.2: Temporary shrub swamp	189,953	52,643	0	2,259	1,287	2,120	1,431	1,334	3,030	3,037
Pt3.1.2: Clay pan†	117,887	41,393	649	3,145	1,585	1,494	1,029	518	2,448	2,094
Pt1.6.2: Temporary woodland swamp	96,360	31,054	34	355	0	412	375	377	378	493
Pt2.3.2: Freshwater meadow†	103,117	27,289	8,449	6,944	8,268	8,163	8,957	441	7,683	7,288
Pp4.2: Permanent wetland†	57,991	23,064	1,681	3,535	2,422	5,365	4,470	2,486	4,888	2,401
Pt1.2.2: Temporary black box swamp†	61,058	21,777	294	1,113	209	232	274	214	907	304
Pt1.7.2: Temporary lignum swamp†	37,613	7,891	440	38	1,058	600	8	39	185	298
Pp2.1.2: Permanent tall emergent marsh	8,001	7,690	3,449	4,156	0	3,451	4,156	4,156	4,156	4,173
Pt1.3.2: Temporary coolibah swamp	8,274	5,148	0	0	0	0	0	0	0	55
Pt1: Temporary swamps†	3,744	3,216	280	689	133	578	739	525	502	421
Pt4.2: Temporary wetland	17,407	2,737	0	120	0	140	124	113	124	139
Pst2.2: Temporary salt marsh	15,906	1,809	41	33	143	181	0	3	0	6
Psp4: Permanent saline wetland†	2,029	1,617	538	802	173	631	640	487	617	16
Pp2.2.2: Permanent sedge/grass/forb marsh	4,395	396	0	0	2	6	0	3	3	2
Pst3.2: Salt pan or salt flat	2,847	253	0	0	0	0	0	0	0	0
Pp2.3.2: Permanent grass marsh†	329	250	102	25	89	91	11	91	25	48
Pp3: Peat bog or fen marsh	3,307	187	0	0	0	0	0	0	0	0

ANAE ecosystem type	Total area (ha)	Area on managed floodplain (ha)	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
Pp2.4.2: Permanent forb marsh†	740	149	21	3	30	20	3	17	6	16
Pu1: Unspecified wetland	63	60	0	0	0	1	0	48	3	3
Pst4: Temporary saline wetland	6,003	50	0	0	0	0	0	0	0	0
Pst1.1: Temporary saline swamp	5,391	9	0	0	0	0	0	0	0	2
Pps5: Permanent spring	122	2	0	0	0	0	0	0	0	0
Pp1.1.2: Permanent paperbark swamp	1	1	0	0	0	0	0	0	0	0
Pt1.5.2: Temporary paperbark swamp	278	0	0	0	0	0	0	0	0	0
Psp2.1: Permanent salt marsh	248	0	0	0	0	0	0	0	0	0
Psp1.1: Saline paperbark swamp	31	0	0	0	0	0	0	0	0	0
TOTAL	**1,218,880**	**471,794**	**28,402**	**61,727**	**35,687**	**73,267**	**69,047**	**40,240**	**74,562**	**71,695**

Table D.3 Areas of Australian National Aquatic Ecosystem (ANAE) floodplain types supported* by Commonwealth environmental water (CEW), 2014–22 (upstream of the Coorong, Lower Lakes and Murray Mouth)

This information is presented graphically in Figure 5.6. *See Section 3.2 for the definition of area supported by CEW. † Refers to ecosystem types that received CEW in every year of the 8-year monitoring period (also shaded blue).

ANAE ecosystem type	Total area (ha)	Area on managed floodplain (ha)	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
F1.10: Coolibah woodland and forest riparian zone or floodplain†	2,107,271	492,035	2,149	649	1,315	1,324	2,334	677	785	8,356
F1.2: River red gum forest riparian zone or floodplain†	625,609	326,699	12,528	24,266	4,326	25,400	17,246	4,521	23,599	27,915
F1.8: Black box woodland riparian zone or floodplain†	1,713,211	279,375	5,992	10,417	1,643	3,198	3,248	1,200	5,366	1,892
F1.4: River red gum woodland riparian zone or floodplain†	297,969	145,664	3,651	2,322	5,989	9,752	3,624	334	4,385	14,775
F2.4: Shrubland riparian zone or floodplain†	461,201	140,679	1,042	7,026	2,279	140	534	836	3,510	4,351
F2.2: Lignum shrubland riparian zone or floodplain†	294,481	85,138	1,239	2,042	1,496	1,453	1,512	6,002	6,693	13,021

ANAE ecosystem type	Total area (ha)	Area on managed floodplain (ha)	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
F1.12: Woodland riparian zone or floodplain†	152,733	43,645	7	8	7	99	57	22	24	142
F3.2: Sedge/forb/grassland riparian zone or floodplain†	62,784	6,822	130	44	38	137	10	39	10	737
F4: Unspecified riparian zone or floodplain†	19,813	5,286	39	365	9	401	100	131	372	86
F1.11: River cooba woodland riparian zone or floodplain†	16,898	5,060	979	230	1,087	842	1,127	18	409	851
F1.6: Black box forest riparian zone or floodplain	3,179	450	9	0	0	0	2	0	0	0
F1.13: Paperbark riparian zone or floodplain	897	271	0	0	0	0	0	0	0	0
TOTAL	**5,756,046**	**1,531,124**	**27,765**	**47,369**	**18,189**	**42,746**	**29,794**	**13,780**	**45,153**	**72,126**

Table D.4 Lengths of Australian National Aquatic Ecosystem (ANAE) river ecosystem types supported* by Commonwealth environmental water (CEW) (upstream of the Coorong, Lower Lakes and Murray Mouth), 2014–22

This information is presented graphically in Figure 5.8. *See Section 3.2 for the definition of area supported by CEW. † Refers to ecosystem types that received Commonwealth environmental water (CEW) in every year of the 8-year monitoring period (also shaded blue).

ANAE ecosystem type	Total length in Basin (km)	Length on managed floodplain (km)	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22
Rt1.4: Temporary lowland stream	136,028	23,031	2,947	2,975	3,218	3,526	2,916	3,496	4,141	6,656
Rp1.4: Permanent lowland stream	28,888	20,036	11,785	12,412	13,525	13,762	10,725	11,567	13,562	14,912
Rt1.2: Temporary transitional zone stream	179,114	3,846	251	76	251	95	211	252	252	295
Rp1.2: Permanent transitional zone stream†	10,555	2,037	255	249	374	461	247	253	447	270
Rp1.3: Permanent low energy upland stream	4,726	621	0	0	0	0	0	0	0	0
Rp1.1: Permanent high energy upland stream†	11,106	321	5	5	5	6	5	5	6	5
Rt1.1: Temporary high energy upland stream†	110,649	318	17	17	17	18	1	17	17	19
Rt1.3: Temporary low energy upland stream	3,554	247	13	13	13	13	0	13	13	13
Total	**484,620**	**50,457**	**15,273**	**15,747**	**17,403**	**17,881**	**14,105**	**15,603**	**18,438**	**22,170**

Abbreviations and terms

Abbreviation / term	Description
2014–22	water years, 1 July 2014 to 30 June 2022
2021–22	water year, 1 July 2021 to 30 June 2022
ANAE	Australian National Aquatic Ecosystem
Basin Plan	(Murray–Darling) *Basin Plan 2012* made under subparagraph 44 (3)(b)(i) of the *Water Act 2007* Basin Plan 2012 (legislation.gov.au)
CEW	Commonwealth environmental water, also Commonwealth water for the environment
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CLLMM	Coorong, Lower Lakes and Murray Mouth
counterfactual	In the counterfactual approach, Commonwealth environmental water is removed from the observed streamflow time series, creating a hypothetical (counterfactual) daily streamflow time series with no Commonwealth environmental water. This approach is used to infer the effects of Commonwealth water for the environment as an experimental design with controls and/or before–after comparisons is not possible.
critical CPS	critical components, processes and services (used to define ecological character of Ramsar Sites)
CSIRO	Commonwealth Scientific and Industrial Research Organisation, csiro.au
ECD	ecological character description (with regard to Ramsar Sites)
estuarine ecosystems	Ecosystems near the river mouth that are influenced by salty ocean water
Flow-MER	The CEWH Monitoring, Evaluation and Research Program (2019–22)
influenced area	The entire area of a wetland that received environmental water including the inundated area and the adjacent terrestrial habitats that occur within the wetland boundary
inundated area	The area of a wetland or floodplain in direct contact with environmental water
lake ecosystems	Wetlands that are mostly open water and typically greater than 2 m in depth
LTIM	Long Term Intervention Monitoring Project (2014–15 to 2018–19)
managed floodplain	The area of the Basin that can be influenced by environmental water management as defined by the *Basin-wide environmental watering strategy* (MDBA 2019)
MDBA	Murray–Darling Basin Authority
palustrine wetlands	Shallow wetlands with a predominance of emergent vegetation (reeds, sedges, shrubs or trees)
riverine ecosystems	Flowing-water river and creek ecosystems. Applies also to temporary rivers that dry up to a sequence of pools that are not flowing
the Basin	Short form for the Murray–Darling Basin
the Strategy	Short form for the *Basin-wide environmental watering strategy* (MDBA 2019)

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