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NSW Long Term Water Plans: Background Information

A description of the development of the 9 LTWPs in NSW

Part B: Objectives and targets

Department of Planning and Environment

Cover photo: Common Reed and adjacent lagoons, Monkeygar Swamp, Southern Macquarie Marshes. John Spencer/DPE

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Overview of the background information document

NSW Long Term Water Plans (LTWPs) bring together information from a range of planning material, scientific literature and expert opinion. This varied and complex information has been interpreted and analysed to produce new information products and tools to support development of the plans. The purpose of this background information document is to:

- describe the information sources that informed the development of the LTWPs
- describe how this information was interpreted and analysed
- outline the rationale behind the analyses, methods, assumptions and decisions that have underpinned the LTWPs
- provide a reference for future revision of the LTWPs.

The background information document has been divided into 4 parts for ease of use:

Part A: Introduction

1. Background to the development of NSW Long Term Water Plans
2. Priority environmental assets

Part B: Objectives and targets – this document

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3. Introduction to Part B

The Basin-wide environmental watering strategy (BWS) (MDBA 2014) supports the implementation of the Basin Plan through the development of a series of long-term objectives to be evaluated against expected outcomes for river flows and connectivity, vegetation, native fish and waterbirds. Building from the work to identify priority environmental assets (Part A), this section describes how environmental objectives and targets were developed for native fish, native vegetation, waterbirds, priority ecosystem functions, and other species (including frogs and platypus).

4. Native fish objectives and targets

4.1 Background

Native fish have evolved in a highly variable system that is characterised by extreme environmental conditions (Baumgartner et al. 2014; Humphries et al. 1999). From diverse wetting and drying cycles, to fluctuating temperatures, these conditions provide important seasonal cues for native fish, with hydrological variability playing an integral role in influencing the structure and diversity of aquatic communities (Baumgartner et al. 2014; Rolls et al. 2013). A variety of life-history and recruitment styles have been developed by different fish species in response to the range of environmental conditions experienced across the NSW Murray–Darling Basin (MDB). Given the BWS aims to protect and improve native fish populations, there is a need to cater for these differences across various spatial and temporal scales.

Alteration of the natural flow regime across the MDB has had significant impacts on the hydrological, hydraulic and ecological conditions that native fish rely on for recruitment success and survival (DPI 2015a). The 9 catchments in the NSW MDB are hydrologically connected either by in-channel flows or across floodplains and are therefore interdependent (DPI 2015a). To achieve the best outcomes for native fish populations, manipulation of the flow regime to target fish objectives should aim to achieve cumulative benefits within and across catchments. Native fish ecological objectives were developed with consideration of adjoining sites, reaches and streams by utilising information about the fish communities present within each catchment.

4.2 Approach to developing native fish objectives

4.2.1 Identifying native fish assets

Priority native fish assets were identified by collating and analysing information from a range of sources including the NSW Department of Primary Industries (DPI) Aquatic Ecosystem Research (AER) database (the database includes a range of site specific data and information from various fish related projects in NSW from 1970s through to the present depending on the project and location), Australian Museum records (as cited in Morris et al. 2001), fish community status (FCS) models, and threatened and common species distribution models.

To assist in understanding the current condition of native fish assets across the NSW MDB, the DPI AER database was analysed to determine fish community health as part of the Fish Community Status and Threatened Species Distribution (FCSandTSD) project. The FCSandTSD project consolidated data collected over 20 years of biological surveys and combined this with spatial distribution models to provide a delineation and spatial recognition of the condition of fish communities and threatened species across NSW (DPI 2015b). The overall FCS was derived from the 3 condition indicators of Expectedness, Nativeness and Recruitment, with outcomes partitioned into 5 equal bands to rate the condition of the fish community: Very Good, Good, Moderate, Poor or Very Poor (DPI 2015b; Appendix 3.2).

The Expectedness indicator represents the proportion of native species that are now found within NSW, compared to that which was historically expected based on expert opinion. It is derived from 2 input metrics: the observed native species richness over the expected species richness at each site, and the total native species richness observed within the zone over the total number of species predicted to have existed within the zone historically (DPI 2015b). The Nativeness indicator represents the proportion of native versus alien fishes within the river and is derived from 3 input metrics: proportion native biomass, proportion native abundance and proportion native species (DPI 2015b). The Recruitment indicator represents the recent reproductive activity of the native fish community within each altitude zone. The Recruitment indicator is derived from 3 input metrics: the proportion of native species showing evidence of recruitment at a minimum of one site within a zone, the average proportion of sites within a zone at which each species captured was recruiting, and the average proportion of total abundance of each species that are new recruits (DPI 2015b).

To improve understanding of the distribution of native fish species across the NSW MDB, eliminating any potential issues associated with relying on just site record data and strengthening spatial identification of native fish assets, generalised additive modelling (GAM) analysis was used to model relationships between the fish assemblage metrics/indicators/index with environmental and River Style® attributes of stream segments (DPI 2015b). Modelling of the current geographic distribution of each listed threatened freshwater fish species or population was undertaken using MaxEnt 3.3.3 (a widely used species distribution modelling program that utilises presence records to generate probabilities of occurrence based on a suite of environmental variables quantified across the area of interest) with >33% probability of occurrence used to predict presence of threatened species for the FCSandTSD project (DPI 2015b; Appendix 3.3). This work was extended to common species of the NSW MDB to model the current geographic distribution of each native fish species (DPI unpublished data).

To adequately sample key threatened species populations (assets) with particularly fragmented and restricted distributions, fish sampling zones had to be designed to ensure targeted sampling occurred at the scales these populations exist at within the MDB. This facilitated more precise estimates of abundance and distribution than would otherwise be possible and increased the likelihood of collecting meaningful data on these typically very rare and patchily distributed assets.

All of this information, including AER database records, threatened fish species or population modelled distribution (>33% probability of occurrence), and common species modelled distribution (>33% probability of occurrence) was compiled to determine native fish asset lists for management zones across the NSW MDB. Using this prioritisation process, DPI Fisheries identified 361 Basin Plan Environmental Outcome Monitoring zones (BPEOM zones) across the 9 NSW surface water resource plan areas (WRPAs), encompassing riverine, reservoir, lake and floodplain wetland habitat types. These BPEOM zones predominantly overlapped with LTWP planning units; however, by stratifying sampling plans according to BPEOM zone, we satisfied the monitoring requirements of all spatial scales within the continuum of the Basin Plan reporting hierarchy: NSW MDB, surface WRPA, catchment, LTWP planning unit and asset scales. This allowed monitoring outputs to report at spatial scales tailored to the needs of adaptive management.

For key species with range expansion outcomes listed in the BWS, the AER database was interrogated to determine catchments with existing core populations (relative to other catchments across the NSW MDB) where range extension targets should be prioritised, while historical records and expert opinion were used to identify potential catchments where additional population targets should be prioritised (Table B.1). To further refine range expansion outcomes and related targets at the catchment scale, a weighted average modelled distribution of key species with >50% probability of occurrence was used to identify priority systems and/or water management zones. The refinement of this range expansion outcome meant that even though a key species may form part of the asset list for a catchment it might not necessarily have an associated range expansion outcome, with these associated targets focused in areas that the best available information indicates would deliver the most effective outcome for native fish at a catchment scale whilst contributing to the broader Basin-scale outcome.

Table B.1 Priority catchments and related targeted BWS key species for range expansion targets based on AER database records, threatened species distribution modelling, and expert opinion

Priority catchment	Targeted BWS key native fish species
Barwon–Darling	Freshwater catfish; silver perch
Border Rivers	Freshwater catfish; olive perchlet; southern purple spotted gudgeon
Gwydir	Freshwater catfish; olive perchlet; southern purple spotted gudgeon
Lachlan	Flathead galaxias; Macquarie perch; olive perchlet; southern pygmy perch; trout cod
Macquarie–Castlereagh	Flathead galaxias; freshwater catfish; olive perchlet; southern purple spotted gudgeon; river blackfish; trout cod
Murray–Lower Darling	Flathead galaxias; freshwater catfish; Murray hardyhead; olive perchlet; southern purple spotted gudgeon; silver perch; southern pygmy perch; trout cod
Murrumbidgee	Flathead galaxias; Macquarie perch; olive perchlet; southern purple spotted gudgeon; river blackfish; silver perch; southern pygmy perch; trout cod
Namoi	Freshwater catfish; river blackfish; silver perch

4.3 Setting native fish objectives and targets

4.3.1 Expected outcomes

The BWS builds on the Basin Plan and is intended to help environmental water holders, Basin state governments and waterway managers plan and manage environmental watering at a Basin scale and over the long term to meet the environmental objectives. This includes making the best use of all water including held, planned, environmental and consumptive water, to achieve these objectives. Complementing the outcomes of the BWS are ecological objectives and targets in the NSW water resource plans (WRPs) and LTWPs. For native fish, the overall expected outcome from implementation of the Basin Plan is a diverse community with sustainable populations occupying a greater proportion of their historic distribution than is currently the case. The following broad outcomes are expected by 2024:

- no loss of native species currently present within the MDB
- improved population structure of key species through regular recruitment
- increased movement of key species
- expanded distribution of key species and populations in the northern and southern MDB.

Key species and candidate sites have been nominated in the BWS to focus expanded distribution outcomes across the MDB (Appendix 4.1). For these key species, increasing the distribution of native fish relies on expansion of existing populations and/or the establishment of new populations, facilitated by improved water management and flows. The number of populations to extend and establish for key species across the MDB has been quantified in the BWS (anywhere from 1–5 depending on the species), and whilst candidate sites have been suggested, further refinement of how many populations will be targeted for expansion/establishment in each relevant catchment needs to be determined using the best available information so a feasible system-scale target is set that can contribute to Basin-wide outcomes without compromising the achievability of jurisdictional LTWPs.

4.3.2 LTWP objectives and targets

The Basin-wide outcomes were transferred to NSW MDB catchments using the latest information on fish distribution to identify relevant broad fish community objectives and species-specific targets relating to improved fish outcomes. The process ensured that catchment-scale objectives and targets for native fish had a direct line of sight to the overarching BWS outcomes whilst being ecologically relevant to the management and monitoring activities within the catchment (Table B.2).

4.4 References

Baumgartner LJ, Conallin J, Wooden I, Campbell B, Gee R, Robinson WA and Mallen-Cooper M (2014) ‘Using flow guilds of freshwater fish in an adaptive management framework to simplify environmental flow delivery for semi-arid riverine systems’, *Fish and Fisheries*, 15(3):410–427, doi: 10.1111/faf.12023.

Humphries P, King A and Koehn J (1999) ‘Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray–Darling River system, Australia’, *Environmental Biology of Fishes*, 56:129–151.

Morris S, Pollard D, Gehrke P and Pogonoski J (2001) *Threatened and potentially threatened freshwater fishes of coastal New South Wales and the Murray–Darling Basin*, NSW Fisheries, Sydney.

DPI (NSW Department of Primary Industries) (2015a) *Fish and Flows in the Northern Basin: responses of fish to changes in flow in the Northern Murray–Darling Basin – Reach Scale Report*, final report prepared for the Murray–Darling Basin Authority, NSW Department of Primary Industries, Tamworth.

DPI (2015b) *NSW Fish Community Status Project*, final report prepared for the Commonwealth Government, NSW Department of Primary Industries, Wollongbar.

Rolls R, Growns I, Khan T, Wilson G, Ellison T, Prior A and Waring C (2013) ‘Fish recruitment in rivers with modified discharge depends on the interacting effects of flow and thermal regimes’, *Freshwater Biology*, 58:1804–1819.

Table B.2 Native fish BWS outcomes, LTWP objectives and targets, and the priority systems they apply to

BWS outcome	LTWP objective	LTWP target	Priority system
No loss of native species currently present in the MDB	No loss of native species present within the management zone	Prevalence of all known species continually detected over 5, 10 and 20-year timeframes, with an improvement in FCS by one category over a 20-year timeframe	All management zones to include this objective
Restored distribution and abundance of short-lived species to levels recorded pre-2007	Increased distribution and abundance of short-lived species relative to levels prior to Basin Plan implementation	Increased distribution (measured as prevalence) and abundance (measured as catch per unit effort (CPUE)) from pre-Basin Plan for known short-lived species, with no more than one year between detection of immature size classes	Management zones that contain relevant short-lived species in their asset lists, and where standardised fish community data exists and/or will exist (i.e. monitoring sites located in management zone) for short-lived species across the nominated temporal scales (pre-Basin Plan) will include this objective
Improved population structure (i.e. a range of size/age classes for all species and stable sex ratios where relevant) of moderate to long-lived species in key sites[1]	Improved population structure of moderate to long-lived species driven by sufficient frequency and magnitude of recruitment events	Population length–frequency data indicates presence of young of year, juveniles and adult size classes within the population with no more than 2 consecutive years without recruitment for moderate-lived species and no more than 4 consecutive years without recruitment for long-lived species, with at least one significant recruitment event, indicated by a size/age cohort (young of year) representing >30% of numbers of the population from standardised sample	Management zones that contain relevant moderate to long-lived species in their asset lists and where standardised fish community data exists and/or will exist (i.e. monitoring sites located in management zone) for moderate to long-lived species across the nominated temporal scales (pre-Basin Plan and post-Basin Plan) will include this objective

[1] This will require annual recruitment events in at least 8 out of 10 years at 80% of sites, with at least 4 of these being ‘strong’ recruitment events.

BWS outcome	LTWP objective	LTWP target	Priority system
A 10–15% increase of mature fish (of legal take size) for recreational target species (Murray cod and golden perch) in key populations	A 15% increase of mature fish (of legal take size) for recreational target species (Murray cod and golden perch) in key populations detected over 5, 10 and 20-year timeframes	Population length–frequency data indicates presence of legal take size classes within the population, with an increased abundance (measured as CPUE) from pre-Basin Plan for key populations of Murray cod and golden perch	Management zones where a weighted average modelled distribution of Murray cod and golden perch is >50% probability of occurrence was used to identify priority systems and/or water management zones that could potentially include this objective[2]
Annual detection of species and life stages representative of the whole fish community through key fish passages, and increase in passage of targeted species through key fish passages to be detected in 2019–2024 compared to passage rates detected in 2014–2019	Annual detection of species and life stages representative of the whole fish community through key fish passages, and increase in passage of targeted species through key fish passages to be detected in 2019–2024 compared to passage rates detected in 2014–2019	Increased movement of targeted species in 2019–2024 compared to passage rates detected in 2014–2019	Management zones to be selected by identifying 'key fish passages', which may include fishways, tributary connectivity and/or floodplain connectivity, as part of a NSW MDB review that will also consider associated monitoring and research activities related to fish movement detection. If a management zone is identified as having a key fish passage and related fish movement monitoring activities, then the relevant objective and targets will be included

[2] Assessment of this objective will need to consider the influence of angler take, which will require a separate focused project that may only be achievable in a reduced number of systems.

BWS outcome	LTWP objective	LTWP target	Priority system
Expand the range (or core range) of a nominated number of existing populations and/or establish a nominated number of additional populations for identified key species at priority locations	Increased prevalence and/or extent of occurrence (range) of key species driven by increased site prevalence and dispersal and establishment in additional locations	Key species detected annually in priority systems, with an increase in distribution (measured as prevalence) and abundance (measured as CPUE), with no more than one year (short-lived)/2 years (moderate-lived)/4 years (long-lived) without detection of immature size classes	Management zones where a weighted average modelled distribution of a nominated key species for the related catchment (Table B.1) is >50% probability of occurrence was used to identify priority systems and/or water management zones where range expansion targets will be included. In addition to this, historical records and expert opinion were used to identify potential catchments where establishment of additional population targets will be prioritised

5. Native vegetation objectives and targets

5.1 Background

The MDB supports a wide range of floodplain vegetation communities distributed as a mosaic within diverse landforms such as lakes, swamps and flats of the riverine landscape. Different types of inland floodplain wetland vegetation depend on specific ecological water regimes for their growth, survival and reproduction, driven by patterns of flooding and drying from river flows (Roberts and Marston 2011). Across the MDB there is a high diversity of non-woody wetland or understorey plant species (aquatic plants, forbs, grasslands, sedgelands and rushlands) that transition from dry to wet-adapted species when inundated. Tree diversity is low and dominated by iconic eucalypt forests and woodlands (river red gum, coolibah and black box). Amongst the high diversity of floodplain shrub species, lignum is the most ecologically significant shrub species occurring on the floodplains of most major rivers in the MDB (Roberts and Marston 2011). The floodplain vegetation across the MDB has declined in condition and extent as a result of altered flow and flooding regimes and increased land clearing on the floodplain (Keith et al. 2009; Kingsford 2015). Improving vegetation condition across the MDB is one of the main ecological objectives of the Basin Plan (MDBA 2012a) in response to the significant decline in vegetation condition observed during the Millennium Drought (MDBA 2012b).

There are 8 expected outcomes of environmental water delivery at the Basin scale for the structural water-dependent vegetation groups of forests and woodlands, shrublands and non-woody vegetation (Table B.3). These expected outcomes relate to maintaining extent and improving the condition of water-dependent vegetation on the parts of the MDB floodplain that can be actively managed[3] with environmental flows. Other parts of the floodplain will continue to support diverse vegetation communities; however, their extent and condition will be impacted by factors outside the influence of the Basin Plan (e.g. inundation from catchment-wide rainfall, climatic conditions, land-use decisions and fire) (MDBA 2014).

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[3] The floodplains and wetlands that can be inundated by flows from regulated rivers; also referred to as the 'managed floodplain' (MDBA 2014).

Table B.3 The BWS describes expected outcomes for 3 water-dependent vegetation structural groups from 2024 onwards (MDBA 2014)

BWS vegetation structural group	Expected outcomes
Forest and woodlands	• to maintain the current extent of forest and woodland vegetation including approximately: o 360,000[4] ha of river red gum o 409,000 ha of black box o 310,000 ha of coolibah • no decline in the condition of river red gum, black box and coolibah across the MDB • by 2024, improved condition of river red gum in the Lachlan, Murrumbidgee, Lower Darling, Murray, Goulburn–Broken and Wimmera–Avoca (see Appendix 5.1 for a regional breakdown) • by 2024, improved recruitment of trees within river red gum, black box and coolibah communities – achieving a greater range of tree ages in the long term. River red gum, black box and coolibah communities are presently comprised primarily of older trees, which places them at risk
Shrublands	• to maintain the current extent of extensive lignum shrubland areas within the MDB[5] • by 2024, improvement in the condition of lignum shrubland areas
Non-woody vegetation	• to maintain the current extent of non-woody vegetation • by 2024, increased periods of growth for communities that either: o closely fringe or occur within the main river corridors o form extensive stands within wetlands and low-lying floodplains including Moira grasslands in Barmah–Millewa Forest; common reed and cumbungi in the Great Cumbung Swamp and Macquarie Marshes; water couch on the floodplains of the Macquarie Marshes and Gwydir River; and marsh club-rush sedgelands in the Gwydir

The current basin-wide extent of forests and woodlands (river red gum, black box and coolibah) outlined in the BWS was developed from a model based on the analysis of several remotely sensed datasets: Landsat satellite derived datasets (median seasonal reflectance values of spectral bands and median seasonal indices calculated from an historical (2000–2010) Landsat composite product); ALOS PALSAR data; the Shuttle Radar Topography Mission (SRTM)-derived 1-second digital elevation model (DEM); and ground survey data sourced from 11,750 vegetation survey sites (Cunningham et al. 2013). At the time of writing the BWS there was no basin-wide or catchment-wide estimates of lignum extent. The BWS acknowledges that there is regional scale mapping of lignum available that can be used for quantifying areas at the asset scale by basin states (MDBA 2014a). The current condition of river red gum forests and woodlands, and black box woodlands in the southern Basin was mapped using the Stand and Condition Tool, a multi-year (2009, 2010 and 2012) model based on the relationship between condition variables surveyed on-ground at 174 reference sites within The

[4] Area derived from modelled distribution of vegetation community

[5] Lignum communities are most noteworthy in the following areas of NSW: lower Lachlan, lower Murrumbidgee, Lower Darling, lower Condamine-Balonne (including Narran Lakes), lower Gwydir, Macquarie Marshes, lower Border Rivers and the River Murray from the junction of Wakool River to downstream of Lock 3 (including Chowilla and Hattah Lakes).

Living Murray (TLM) icon sites, RapidEye™ and Landsat satellite-derived variables (Cunningham et al. 2013). The lack of on-ground surveys of condition variables in the northern Basin meant it was not possible to reliably map the current condition of river red gum, black box or coolibah in the northern catchments. There are plans to address this knowledge gap in the future (MDBA 2014).

5.2 Approach to developing vegetation objectives

The following approach was used to develop vegetation targets for each of the 9 LTWP WRPAs in NSW. Flood-dependent vegetation datasets were sourced, collated and attributed, and values were extracted from these datasets to help set specific targets.

5.2.1 Available datasets to identify water-dependent native vegetation communities

Across the NSW portion of the MDB, we collated all vegetation mapping available within each catchment and reviewed each dataset for suitability of inclusion in a catchment-wide water-dependent vegetation dataset. Datasets were reviewed based on their known accuracy, age, resolution and source. Information was sourced from vegetation mapping specialists within the NSW Department of Planning and Environment – Environment and Heritage Group (DPE–EHG) to assist in the identification and sorting of available datasets.

The following datasets were considered in each catchment where available:

- plant community type (PCT) mapping of floodplain wetland vegetation developed for the DPE–EHG environmental water management Monitoring Evaluation Research (MER) program (e.g. Bowen and Fontaine 2014; Bowen and Simpson 2010)
- vegetation extent by BWS vegetation type (MDBA) (Cunningham et al. 2013)
- floodplain mapping developed for the DPE–EHG Healthy Floodplains Project
- recent vegetation mapping of the NSW National Parks and Wildlife Service (NPWS) estate
- collated vegetation datasets provided by DPE–EHG, Biodiversity, Conservation and Science staff
- modelled PCT vegetation mapping of NSW (produced by DPE–EHG between 2014 and 2017)
- other good quality vegetation mapping sources (catchment by catchment basis).

No single vegetation dataset could be used to reliably capture an entire catchment because they either did not span the entire area, or the vegetation type was incorrectly assigned to a specific area. Each vegetation dataset therefore needed to be reviewed with environmental water managers and MER staff within DPE–EHG and the Commonwealth Environmental Water Office (CEWO) for accuracy. This process helped identify which datasets best represented the vegetation communities in different areas. Once the most appropriate datasets were identified for each area of the catchment, they were merged together (ensuring no overlapping of datasets occurred) to create a single 'best representation' vegetation dataset presenting vegetation communities across all the water-dependent environmental assets in each catchment. A geodatabase for each catchment was created to hold the data files in the geographic information system ArcGIS 10.1 (ESRI Australia 2010). The vegetation datasets used to develop each catchment-wide water-dependent vegetation dataset, and the order in which they were applied in each catchment are listed in Appendix 2.2.

Once relevant datasets were merged together and attribute tables aligned, we extracted and compiled a list of the vegetation communities and PCTs within each catchment. PCTs not considered to be water-dependent were discarded from the vegetation dataset[6]. PCTs were then allocated to BWS water-dependent vegetation types based on the dominant species of the community and the wetland status of the community.

Each PCT table was loaded into the relevant catchment geodatabase and a spatial join was undertaken between the merged vegetation community dataset and the PCT table based on vegetation community. Water-dependent PCT tables were compiled for each catchment and are contained in Appendix 5.1. Each water-dependent feature was attributed with the following data:

- BWS water-dependent vegetation types (either coolibah, black box, river red gum, lignum or not applicable (N/A))
- average recurrence interval (ARI): the water requirements of the PCT in years between flooding episodes (ranging from <1 year to >10 years)
- DPE–EHG hydro-ecological functional group[6]: a descriptor of the flooding characteristics of the PCT based on the flooding frequency, the position within the landscape and the floristic structure of the community. The following list contains the functional groups applied in this study:
    - flood-dependent forest
    - flood-dependent woodland
    - flood-dependent shrubland
    - non-woody wetland
    - floodplain
- OEH vegetation formation: same as the vegetation community Keith Formation (Keith 2004)
- OEH vegetation class: same as the vegetation community Keith Class (Keith 2004).

Analysis of confidence in datasets

An assessment of the estimated level of confidence in the mapped extent of water-dependent vegetation was undertaken to gain an understanding of the potential degree of error in the datasets, and to help inform setting objectives and targets for native vegetation.

To determine the relative confidence in datasets currently used for long-term water planning, a set of parameters were identified that could be obtained from file metadata and published reports. Largely this information was collected from the metadata statements available in the BioNet Vegetation Information System (BioNet VIS), published reports where available and other sources such as OEH network drives. These parameters were chosen as they could represent the potential confidence that could be assumed in a dataset in the process of long-term water planning. They are listed as follows:

- purpose and focus of map dataset
- type of imagery used, especially spatial resolution of the imagery
- methodology
- date compiled

[6] A description of how water-dependent vegetation species were identified and how they were grouped into hydro-ecological functional groups can be found in Chapter 10.3.2 and Appendix 5.1 and 10.3.

- availability on the BioNet VIS database
- relevant catchments overlapping the dataset.

The listed parameters were weighted to develop confidence scores in terms of importance to estimating the reliability of the dataset for water planning. Confidence scores were developed with the following approach:

- **Purpose of dataset**
  - Higher confidence scores were allocated to those datasets that were targeted towards water-dependent vegetation. With fewer PCTs to identify and specific targets, those datasets that are designed to map water-dependent vegetation are more likely to be fit for purpose for water planning.
- **Type of imagery**
  - Datasets that used a finer spatial resolution (such as ADS and aerial photos) were given a higher confidence score over those that primarily used lower spatial resolution imagery products (Landsat or SPOT). High resolution aerial photography allows the user to obtain a more detailed view of the landscape being mapped and allows other factors such as context and texture to be incorporated into the interpretation (Harvey and Hill 2001). In wetland and riverine landscapes steep ecological gradients occur and high spatial resolution imagery is often required to adequately capture these features.
- **Method**
  - Datasets that were collected using techniques such as air photo interpretation (API) based on extensive ground floristic surveys and field validation were given the higher confidence scores. Hunter and Hill (2001) determined that higher accuracies for vegetation mapping could be obtained with manual interpretation of high spatial resolution images than classified maps from satellite imagery. Preference was also given to datasets that used stereoscopic interpretation of high-resolution imagery. This 3D view of the landscape is particularly useful in separating wetland vegetation communities based on their relative heights.
  - The lowest confidence scores were for regional mapping products based on spatial modelling including the State Vegetation Type Map (SVTM) that is being created for the entire extent of NSW. This product is being developed through recognition and delineation of vegetation patterns using automated feature recognition largely using SPOT imagery. This product has come under some scrutiny for the levels of accuracy obtained during independent validation and it remains unclear how accurate the modelling and segmentation methods may be. This uncertainty has resulted in the low confidence scores for this product. It is inherently difficult for a product to map each PCT to a high level of accuracy in an area as large and diverse as NSW.
- **Date of data collection**
  - Preference was given to those datasets that have been created or the data collected in the past 10 years. A dataset is considered recent if created or updated in the past decade.
- **Availability on BioNet VIS database**
  - Ideally all datasets that are used are available on the BioNet VIS and have extensive metadata attached. This factor was also considered in the confidence scores.

Based on the information collected, each dataset was categorised to an appropriate confidence score, which provides a subsequent ranking of their potential usefulness for water planning. Where datasets were composed of a compilation of multiple layers the confidence scores were based on the relative confidence in the source layers rather than the actual compiled datasets.

Following the allocation of confidence scores based on the available metadata, a spatial analysis of the layers was required to determine which datasets should be used in certain locations. The dataset extents were clipped to the catchment boundary and were then combined using the update tool based on the confidence score developed for each dataset. The update tool was applied so that datasets with a higher confidence score overlayed those with lower scores. The following fields were included in the updated feature class:

- area
- confidence rating
- name of dataset
- BioNet VIS ID.

Barwon–Darling

At the catchment scale it can be estimated that 41.64% of the entire Barwon–Darling catchment could be placed in the moderate to high confidence category based on the designated scores. In the low category, there is 35.51% of the catchment based on the confidence scores (Table B.4).

Table B.4 Area of the water-dependent vegetation layer in the Barwon–Darling catchment that falls into certain confidence categories

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
Gwydir_veg_2008_2015_FINAL_25032017PUBLIC	0.45%	High	0.45%	Bowen S and Simpson SL (2017) *Extent and condition map of the vegetation communities of the Gwydir Wetlands and Floodplain 2008 and 2015*, NSW Office of Environmental and Heritage, Sydney.
DarlingFloodplain2014_E_4186	18.03%	Moderate–high	41.29%	Schultz N et al. (2014) *Survey and mapping of Darling floodplain vegetation between Tilpa and Brewarrina*, report prepared for OEH by Centre for Environmental Management, Federation University Australia, Ballarat.
Balonne_vegetation_20160301 Darling_vegetation_20160301	32.93%	Moderate–high	41.29%	Eco Logical Australia (2015) *Vegetation of the Barwon-Darling and Condamine-Balonne floodplain systems of New South Wales: Mapping and survey of plant community types*, prepared for the Murray-Darling Basin Authority.
brg_comp09_VIS_3801	7.54%	Moderate–high	41.29%	Eco Logical Australia (2009) *Upgrade of Vegetation Mapping in the Border Rivers-Gwydir Catchment*.
NamoiCMAcomposite_2013_E_4028	4.72%	Moderate–high	41.29%	Eco Logical Australia (2013) *Refinement of vegetation mapping in the Namoi Catchment: Extant and pre-European*, prepared for Namoi Catchment Management Authority, May 2013.
TooraleNP_2012_E_4027	3.42%	Moderate	0.3%	Gowans S, Milne R, Westbrooke M and Palmer G (2012) ‘Survey of vegetation and vegetation condition of Toorale, Version 1-1’, unpublished report to OEH, Centre for Environmental Management, University of Ballarat, Mt Helen.

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
ParooDarlingNP_Thiltakarra_E_968 ParooDarlingNP_MtMurch_E_3966 ParooDarlingNP_Wilga_E_3967	6.96%	Low–moderate	5.87%	Hunter JT and Fallavollita E (2003) *Vegetation and Floristics of Paroo-Darling National Park – Thilta karra Section*, report to NPWS. Westbrooke M and Gowans S (2006a) *The vegetation of the Coonavitra area, Paroo Darling National Park, western New South Wales*, Centre for Environmental Management, University of Ballarat. Westbrooke M and Gowans S (2006b) *The vegetation of the Mount Murchison and Wilga areas, Paroo Darling National Park, western New South Wales*, report to NPWS, Centre for Environmental Management, University of Ballarat. Westbrooke M et al. (2003) 'The vegetation of Peery Lake area, Paroo-Darling National Park western New South Wales', *Cunninghamia*, 8(1):111–128.
brewarrina_VISmap_1658	10.8%			Northern Floodplains Regional Planning Committee (2004) *Preclearing and Existing Vegetation Mapping of the Brewarrina Shire, Northern Floodplains, Far Western New South Wales*, Edition 2.
CentWestLachSVM_v1p4_PCT_E_4468 VegCentralWestLachlanPCT_v1_VIS4358_P SVTM_Western_PCTv0p1_5m VegBorderRiversGwydirNamoiV2_VIS4204_P	99.64%	Low	35.51%	State Vegetation Type Map: Central West / Lachlan Regional Native Vegetation PCT Map Version 2.0

Border Rivers

The water-dependent vegetation dataset in the Border Rivers catchment is entirely made up of the layer VegBorderRiversGwydirNamoiV2_VIS4204_P. This has resulted in the water vegetation dataset being classified in the low confidence category in its entirety (Table B.5). This is a result of having a significant part of the water-dependent vegetation dataset from a mapping project that is targeted at wetland vegetation and another that is based on a state-wide spatial modelling project.

Table B.5 Area of the water-dependent vegetation layer in the Border Rivers catchment that falls into certain confidence categories

File name	Area of catchment and dataset	Confidence category	Report or dataset name
BRG_Namoi_v2_0_E_4204	100%	Low	VegBorderRiversGwydirNamoiV2_VIS4204_P

Gwydir

The water-dependent vegetation dataset in the Gwydir catchment is split between a high (42.7%) and low (53.4) level of confidence with very little in between (Table B.6). This is a result of having a significant part of the water-dependent vegetation dataset from a mapping project that is targeted at wetland vegetation and another that is based on a state-wide spatial modelling project.

Table B.6 Area of the water-dependent vegetation layer in the Gwydir catchment that falls into certain confidence categories

File name	Area of dataset	Confidence category	Report or dataset name
GwydirWetlands_2008_E_3922	42.7%	High	Bowen S and Simpson SL (2010) *Changes in Extent and Condition of the Vegetation Communities of the Gwydir Wetlands and Floodplain 1996–2008: Final Report to the NSW Wetland Recovery Program*, NSW Department of Environment Climate Change and Water, Sydney.
Guyra_rbg_VISmap_240	2.86%	Moderate	N/A
WRA_API_VIS_1028			Beckers D and Binns D (2000) *Vegetation Survey and Mapping Stage 1 Report, Western Region*, project undertaken for the Resource and Conservation Assessment Council, NSW Western Regional Assessments, Project number WRA 13.
northern_crafti_VISmap_1082			NPWS (2001) *Completion of GIS Products for the Lower North East CRAFTI Structural and Floristic Layers, Lower North East RFA Region*, project undertaken for the Resource and Conservation Assessment Council NSW Regional Assessments.
ash_bin_inv_yal_ext_VIS_3794			Extant natural vegetation for Ashford, Bingara, Inverell and Yallaroi
ForestTypesFNSW_E_4026			Forestry Commission of NSW (1989) *Forest Types in NSW*, Research Note No.17.
boggabri_NVMP_VISmap_2134			Cannon G et al. (2002) *Native vegetation map report: Abridged version*, No. 3, Bellata, Gravesend, Horton and Boggabri 1:100 000 Map Sheets
horton_NVMP_VISmap_2136			Cannon G et al. (2002) *Native vegetation map report: Abridged version*, No. 3, Bellata, Gravesend, Horton and Boggabri 1:100 000 Map Sheets
cob_man_tam_ext_3796			Rolhauser A, Thonell J and Peacock R (2009) *Extant and potential natural vegetation of Tamworth, Manilla and Cobbadah 1:100,000 scale map sheets, NSW*, Appendix 1 – Local Vegetation Community profiles, Draft Version 1.1.
n/a			Eco Logical Australia (2009a) *A Vegetation Map for the Namoi Catchment Management Authority*, Eco Logical Australia.
Nandewar_ext_VIS_12	0.67%	Low–moderate	Nandewar WRA final vegetation layer – VIS_ID 12 & VIS ID 3881

File name	Area of dataset	Confidence category	Report or dataset name
NarrabriWheatbelt_E_4183			Sivertsen D and Metcalfe L (1995) 'Natural vegetation of the southern wheat-belt (Forbes & Cargelligo 1:250000 map sheets)', *Cunninghamia*, 4(1):103–128. Bedward M, Sivertsen DP, Metcalfe LM, Cox SJ and Simpson CS (2001) *Monitoring the rate of native woody vegetation change in the New South Wales wheatbelt*, Final Project Report to the Natural Heritage Trust / Environment Australia, NPWS, Sydney.
LandscapesNWslopesPlains_E_4169			Peasley B and Walsh A undated, *Mapping Vegetation Landscapes of the NSW North West Slopes & Plains*, NHT Project NW0339.97, Department of Land and Water Conservation and North West Catchment Management Committee.
dlwc_east_walg_VISmap_804			Peasley B and Walsh A (1999) *Mapping Vegetation Landscapes of the NSW North Western Slopes and Plains – A Project Overview*, NHT Project NW0339.97, report to the Natural heritage Trust and North West Catchment Management Committee, DLWC.
BRG_Namoi_v2_0_E_4204	53.4%	Low	N/A
Landuse_P.lyr			NSW Landuse 2007

Intersecting Streams

The water-dependent vegetation dataset in the Intersecting Streams catchment is split between a moderate–high (36.72%) and low (62%) level of confidence with very little in between (Table B.7). This is a result of having a significant part of the water-dependent vegetation dataset from a mapping project that is targeted at wetland vegetation and another that is based on a state-wide spatial modelling project.

Table B.7 Area of the water-dependent vegetation layer in the Intersecting Streams catchment that falls into certain confidence categories

File name	Area of dataset	Confidence category	Report or dataset name
DarlingFloodplain2014_E_4186			Schultz N et al. (2014) *Survey and mapping of Darling floodplain vegetation between Tilpa and Brewarrina*, report prepared for OEH by Centre for Environmental Management, Federation University Australia, Ballarat.
Balonne_vegetation_201603001 Darling_vegetation_20160301			Eco Logical Australia (2015) *Vegetation of the Barwon-Darling and Condamine-Balonne floodplain systems of New South Wales: Mapping and survey of plant community types*, prepared for the Murray-Darling Basin Authority.
TooraleNP_2012_E_4027	36.72%	Moderate–high	Toorale NP
NarranLakeNR_2010_E_4016			Narran Lake Nature Reserve
MtGrenfell_add_2010_E_3979			Vegetation survey of Mount Grenfell Aboriginal Area
WarramboolSCA_2012_E_3985			Vegetation survey and mapping of Warrambool State Conservation Area

File name	Area of dataset	Confidence category	Report or dataset name
CulgoaNP_Additions_E_870	0.98%	Moderate	Vegetation survey of Diamunga, Pinegrove and Old Toulby additions to Culgoa National Park
MutawintjiNP_E_823			Mutawintji lands vegetation map
ledknapper_nr_VISmap_906			Vegetation and Floristics of the Ledknapper Nature Reserve
culgoa_np_VISmap_793			Vegetation and Floristics of Culgoa National Park
ParooDarlingNP_Thiltakarra_E_968 ParooDarlingNP_MtMurch_E_3966 ParooDarlingNP_Wilga_E_3967	0.33%	Low–moderate	Hunter JT and Fallavollita E (2003) *Vegetation and Floristics of Paroo-Darling National Park – Thilta karra Section*, report to NPWS.
N/A			Westbrooke M and Gowans S (2006a) *The vegetation of the Coonavitra area, Paroo Darling National Park, western New South Wales*, Centre for Environmental Management, University of Ballarat.
N/A			Westbrooke M and Gowans S (2006b) *The vegetation of the Mount Murchison and Wilga areas, Paroo Darling National Park, western New South Wales*, report to NPWS, Centre for Environmental Management, University of Ballarat.
brewarrina_VISmap_1658			Northern Floodplains Regional Planning Committee (2004) *Preclearing and Existing Vegetation Mapping of the Brewarrina Shire, Northern Floodplains, Far Western New South Wales*, Edition 2.
MurrayDarlingM305_Struct_E_917			Murray Darling Basin M305 Structural Vegetation Layer
GundabookaNP_2005_E_3969			Gundabooka National Park vegetation
northwest_pn_VISmap_825			The Natural Vegetation of North Western NSW
Cobar98_wheatbelt_VISmap_1603			Native Woody Vegetation Mapping of the NSW Wheat-belt
Walgett_VISmap_1662			Existing Vegetation Mapping of the Western Division section of Walgett Shire, Northern Floodplains Far Western NSW
CobarLGA_E_3332			Vegetation Mapping – Cobar Shire
Bourke_VISmap_1660			Preclearing and Existing Vegetation Mapping of the NE section of Bourke Shire
SVTM_Western_PCTv0p1_5m	62%	Low	Statewide Vegetation Map: Western
beadle_VISmap_838	N/A	N/A	Erosion and Vegetation Surveys Western Division Beadle
LedknapperNR_Gerara_2009_E_3978			Composition and extent of the present vegetation within the Gerara addition to Ledknapper Nature Reserve

Lachlan

The clear majority (85.84%) of the water-dependent vegetation layer is found in the low confidence category (Table B.8). Most of the remainder is in the moderate–high category (10.78%) with nothing classified as high confidence. One key issue is also that the overwhelming majority of the water-dependent vegetation for the Lachlan Catchment is in the west where confidence scores are the lowest.

Table B.8 Area of the water-dependent vegetation layer in the Lachlan catchment that falls into certain confidence categories

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
barton_nr_VISmap_837	0.001%	Moderate–high	10.78%	Lembit R and Skelton N (1998) *Vegetation Survey of Copperhania, Barton, Dapper & Boginderra Hills Nature Reserves*, report to NPWS, Bathurst.
CRA_Goulburn_Floristics_E_4139	7.5%			CRAFTI Southern Report – A project undertaken as part of the NSW Comprehensive Regional Assessments. November 1999
CWLachlanCMA_CentTab2010_E_4163	3.51%			DEC (2006a) *Reconstructed and extant distribution of native vegetation in the Central West Catchment*, NSW DEC, Dubbo. DEC (2006b) *Reconstructed and extant distribution of native vegetation in the Lachlan Catchment*, NSW DEC, Dubbo.
CopperhanniaNR_1998_E_3971	0.08%	Moderate	0.08%	Lembit R and Skelton N (1998) *Vegetation Survey of Copperhania, Barton, Dapper & Boginderra Hills Nature Reserves*, report to NPWS, Bathurst.
boorowa_extant_VISmap_1624	2.98%	Low–moderate	2.98%	NPWS (2002) *The Native Vegetation of Boorowa Shire*, NPWS, Hurstville.
EcosystemsVulnRev02_SC_E_4130	0.63%			EcoGIS (2002) *Validation of Rare and Vulnerable Extant Ecosystem Mapping in the NSW NPWS South Coast Region*, EcoGIS, May 2002.
FE_Revised2002_SEH_E_4136	0.48%			EcoGIS (2002) *Validation of Rare and Vulnerable Extant Ecosystem Mapping in the NSW NPWS South Coast Region*, EcoGIS, May 2002.
CentWestLachSVM_v1p4_PCT_E_4468	90.67%	Low	85.84%	State Vegetation Type Map: Central West / Lachlan Regional Native Vegetation PCT Map Version 1.0.
RM_VegCompileV6_20161118	28.46%	N/A	0.41%	Riverina Murray regional vegetation compilation

Macquarie–Castlereagh

Most the water-dependent vegetation datasets in the Macquarie catchment is considered to have low confidence (Table B.9). This result occurs where the SVTM is being used to determine the water-dependent vegetation. However, the Macquarie Marshes area, a key part of the Macquarie catchment, is considered to have high confidence datasets (12%).

Table B.9 Area of the water-dependent vegetation layer in the Macquarie–Castlereagh catchment that falls into certain confidence categories

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
MMVeg2013IntPU27042016	12.0%	High	12%	Bowen S, Simpson SL, Honeysett J, Hosking T and Shelly DS (2019) *Technical report: Vegetation extent and condition mapping of the Macquarie Marshes and floodplains 1991, 2008, 2013*, NSW Office of Environmental and Heritage, Sydney.
DarlingFloodplain2014_E_4186	0.94%	Moderate–High	1.16%	Schultz N et al. (2014) *Survey and mapping of Darling floodplain vegetation between Tilpa and Brewarrina*, report prepared for OEH by Centre for Environmental Management, Federation University Australia, Ballarat.
CWLachlanCMA_CentTab2010_E_4163	0.22%			DEC (2006a) *Reconstructed and extant distribution of native vegetation in the Central West Catchment*, NSW DEC, Dubbo. DEC (2006b) *Reconstructed and extant distribution of native vegetation in the Lachlan Catchment*, NSW DEC, Dubbo.
brewarrina_VISmap_1658	2.23%	Low–moderate	2.23%	Northern Floodplains Regional Planning Committee (2004) *Preclearing and Existing Vegetation Mapping of the Brewarrina Shire, Northern Floodplains, Far Western New South Wales*, Edition 2.
PCT_v1p0_Macquarie	84.6%	Low	84.6%	State of New South Wales and Office of Environment and Heritage (2016) NSW State Vegetation Type Map – Central NSW, Part A.

Murray Lower–Darling

The vast majority of the catchment (95.61%) is made up of the lower confidence scores (Table B.10). This is a result of the most reliable or only available dataset being the SVTM modelled product. There is a lower level of reliability for these products. As a result, there are very few areas in the catchment where the available vegetation datasets can be confidently relied upon for water planning. A small section of the catchment (0.33%) covered by the vegetation community and river red gum condition mapping received the highest confidence score. The source datasets that made up the Riverina Murray regional vegetation compilation contributed moderate–low confidence scores but only make up 3.46% of the catchment. These source datasets do not have complete extents or footprints and the gaps are filled by the Riverina SVTM dataset.

Table B.10 Area of the water-dependent vegetation layer in the Murray Lower–Darling catchment that falls into certain confidence categories

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
MurrayRiverPark_2010_E_3868 MurrayValMillewa_2010_E_3869 Barmah_2009_2010_E_3870	0.33%	High	0.33%	Bowen S, Powell M, Cox SJ and Simpson SL (2012b) *Vegetation community and river red gum canopy condition map of Murray River Park*, NSW Office of Environment and Heritage, Sydney. Bowen S, Simpson SL, Powell M and Steenbeeke G (2012) *The Vegetation Communities of the Millewa Forest, Murray Valley National and Regional Parks 2010*, NSW Office of Environment and Heritage, Sydney. Bowen S, Powell M and Simpson S (2012) *The Vegetation Communities of the Barmah National Park and Murray River Park 2009–10*, NSW Office of Environment and Heritage, Sydney
VegPlainsWandererRiverinaPlains_VIS826_PCT	0.92%	Moderate	0.87%	Roberts I and Roberts J (2001) 'Plains Wanderer (*Pedionmus torquatus*) habitat mapping, including woody vegetation and other landscape features Riverina Plains NSW', Earth Resources Analysis Pty Ltd, unpublished report to NPWS, Dubbo.
MurrayVegCombinedMMRGIP	0.84%	Low–moderate	2.59%	Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
AlburyVeg_VIS3926_PCT	0.07%			Bossard K and Mulvaney M (2008) 'Extant native vegetation type and condition for Albury City Council Area', unpublished digital dataset (VISID 3926), Department of Environment and Climate Change, Queanbeyan.
BerriganVegCombinedMM_PCT	0.15%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
ConargoVegMMRGIP	0.29%			'Current vegetation – 2002 – Compilation map', Map 2 in: WRRVC (2002) *Western Riverina Vegetation Management Plan*, Western Riverina Regional Vegetation Committee and Department of Land and Water Conservation, Sydney.
CorowaBiodiversity_PCT	0.16%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
DeniliquinLGABiodiversity_PCT20141024	0.01%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
JerilderieLGAVeg_Gapfill	0.01%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
WakoolESLBiodiversity_Comp20141028_RRGIP	0.93%			Update to Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
RiverinaSVM_v1_0_PCT_E_4371	18.2%	Low	95.65%	SVTM: Riverina Regional Native Vegetation Map Version v1.0
SVTM_Western_PCTv0p1_5m	81.25%			SVTM: Western Regional Native Vegetation PCT Map DRAFT v0.1
RM_VegCompileV6_20161118	6.66%	N/A	0	Riverina Murray regional vegetation compilation

Murrumbidgee

The Murrumbidgee catchment contains a variety of confidence scores from the source layers used in the major compilations. Significant portions in the east of the catchment contain an unknown level of confidence, which is a concern for water planning. However higher confidence scores are seen in the western part of the catchment where wetlands, floodplains and water-dependent vegetation are more prevalent. The most common confidence category was low (53.13%) and was derived largely from the Riverina Regional Native Vegetation Map Version v1.0 (Table B.11). However, it should be noted that much of this is from gap filling in areas where the Riverina Murray regional vegetation compilation excluded non-native or modified vegetation, or it was not mapped during source layer production. As a result, it is less likely that these areas will consist of water-dependent vegetation.

Table B.11 Area of the water-dependent vegetation layer in the Murrumbidgee catchment that falls into certain confidence categories

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
Lowbidgee_Veg_2008_2011_13_Draft	2.28%	High	2.30%	Bowen S and Simpson SL (2010) *Vegetation Map of Yanga National Park 2008*, NSW Department of Environment, Climate Change and Water, Sydney.
BogsFensSnowyMtns	0.02%			Hope G, Nanson R and Jones P (2012) *Peat-forming bogs and fens of the Snowy Mountains of NSW*, Technical Report, NSW Office of Environment and Heritage, Sydney.
VegADS40_CentralSouthernNSW_VIS3884	6.21%	Moderate–high	6.35%	Vegetation map by 3D digital image interpretation: Vegetation of central-southern NSW
MonaroGrasslands_GDA94	1.3%	Moderate	17.18%	Monaro Grassland Mapping, 2005

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
VegCWLachlanCMA_API_SWS_VIS4165_MMRGIP	0.0004%			DEC (2006a) *Reconstructed and extant distribution of native vegetation in the Central West Catchment*, NSW DEC, Dubbo. DEC (2006b) *Reconstructed and extant distribution of native vegetation in the Lachlan Catchment*, NSW DEC, Dubbo.
VegPlainsWandererRiverinaPlains_VIS826_PCT	15.36%			Roberts I and Roberts J (2001) 'Plains Wanderer (*Pedionmus torquatus*) habitat mapping, including woody vegetation and other landscape features Riverina Plains NSW', Earth Resources Analysis Pty Ltd, unpublished report to NPWS, Dubbo.
scivi_v14_e_2230_class_VIS_v10	0.52%			Tozer MG et al. (2010) Native vegetation of South eastern NSW: a revised classification and map for the coast and eastern tablelands, *Cunninghamia*, vol.11, no.3, pp.1–48.
boorowa_extant_VISmap_1624	0.001%	Low–moderate	5.66%	Extant Native Vegetation of Boorowa Shire and surrounds
balranald92_rbg_VISmap_3178	4.59%			Scott JA (1992) Balranald and Swan Hill 1:250,000 map sheets, *Cunninghamia*, vol.2, no.4, pp.597–652.
BerriganVegCombinedMM_PCT	0.02%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
RVMPML_ExistingVegetation_BlandLGA	0.36%			'Current vegetation – 2002 – Compilation map', Map 2 in: WRRVC 2002, *Western Riverina Vegetation Management Plan*, Western Riverina Regional Vegetation Committee and Department of Land and Water Conservation, Sydney.
Carrathool2015_MMRGP	0.14%			Update to Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
ConargoVegMMRGIP	1.44%			'Current vegetation – 2002 – Compilation map', Map 2 in: WRRVC 2002, *Western Riverina Vegetation Management Plan*, Western Riverina Regional Vegetation Committee and Department of Land and Water Conservation, Sydney.
Cootamundra_CombMM_Gapfill_201410.shp	0.001%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
CorowaBiodiversity_PCT	0.1%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
HayLGA_VegetationMMRGIP	3.02%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
JerilderieLGAVeg_Gapfill	0.01%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
Lockhart_110313VegAttrMMRGIP	0.01%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
Murrumbidgee_HCVGDA94_190911_GapMMRGIP	0.07%			'Current vegetation – 2002 – Compilation map', Map 2 in: WRRVC 2002, *Western Riverina Vegetation Management Plan*, Western Riverina Regional Vegetation Committee and Department of Land and Water Conservation, Sydney.
NarranderaESLBio260911_Gapfill	0.02%			Mulvaney M, Boak M, Priday S, Hudson K and Crane M (2005) *The Native Vegetation of Gundagai Shire*, NSW Department of Environment and Conservation, Queanbeyan.
UranaBiodiversity_GapFillExcl2014	0.03%			Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
WaggaVeg2004_VIS1559_MMRGIP	0.09%			Priday S and Mulvaney M (2005) *The Native Vegetation and Threatened Species of the City of Wagga Wagga*, Department of Environment and Conservation, Queanbeyan.
WakoolESLBiodiversity_Comp20141028_RRGIP	0.33%			Update to Allen W (2007) 'Combined vegetation layer for the Murrumbidgee Region – dataset description', unpublished report, Department of Environment and Climate Change, Queanbeyan.
Griffith_Council_Remnant_Vegetation	0.15%			GCC (2014) *Native Vegetation of Griffith LGA, digital dataset prepared by Griffith City Council*, Griffith.
Riverina_v1p0_Quickview	53.1%	Low	53.13%	OEH (2016) Riverina Regional Native Vegetation Map Version v1.0, metadata 20/04/16.
SVTM_Western_PCTv0p1_5m	0.03%			SVTM: Western Regional Native vegetation PCT map DRAFT v0.1
SELLS_veg_combined2014	7.04%	N/A	12.19%	South East Local Land Services (SELLS) biometric vegetation map, 2014
Rurl&RrlresPalerang	0.24%			

File name	Area of catchment	Confidence category	Area of dataset	Report or dataset name
murrumbidgeecma_2011_e_3879	4.95%			Barrett T (2011) *Work Module 2 – Terrestrial Biodiversity: Compilation of a Mosaic Vegetation Map and Modelling Investment Priority for the Murrumbidgee CMA*, Final Technical Report, November 2011. Eco Logical Australia (2011) *Composite Vegetation Map for the Murrumbidgee Catchment, NSW Keith Vegetation Class Allocation*, prepared for Department of Environment, Climate Change and Water.
RM_VegCompileV6_20161118	29.66%			Riverina Murray regional vegetation compilation
RiverinaSVM_v1p2_PCT_E_4469	N/A			Riverina Regional Native Vegetation Map, version v1.0

Namoi

Most of the water-dependent vegetation in the Namoi catchment (82.3%) is considered to have low confidence (Table B.12). This result occurs because much of the water-dependent vegetation dataset is derived from a product that uses regional-scale spatial modelling where there is uncertainty surrounding the accuracy of this dataset. A smaller portion of the catchment (15.0%) is considered to have low–moderate confidence. This is largely a result of the source datasets being derived from the Namoi CMA catchment dataset.

An accuracy assessment of both Namoi CMA catchment dataset (4028) and the SVTM map for the Namoi catchment by Hunter and Hawes (2013) found low classification accuracies for both. The results of this review by Hunter and Hawes (2013) indicated that both datasets obtained a roughly equivalent accuracy of 36–41% despite the differing methodologies used. Hunter and Hawes (2013) suggest that the similar results may be a result of a possible accuracy limit that can be obtained when mapping over larger landscapes without mass input of time and resources.

Table B.12 Area of the water-dependent vegetation layer in the Namoi catchment that falls into certain confidence categories

File name	Area of dataset	Confidence category	Report or dataset name
WarrumbunglesNP_2008_E_4017	0.04%	Moderate–high	Holme L (1990) 'Western Region Database Survey: Warrumbungle National Park and Pilliga Nature Reserve', unpublished report on work for NPWS Geographic Information System being undertaken on behalf of Western Region.
cob_man_tam_ext_3796	2.6%	Moderate	Peasley B and Walsh A (undated) *Mapping Vegetation Landscapes of the NSW North West Slopes & Plains*, NHT Project NW0339.97, Department of Land and Water Conservation and North West Catchment Management Committee.

File name	Area of dataset	Confidence category	Report or dataset name
ForestTypesFNSW_E_4026			Sivertsen D and Metcalfe L (1995) Natural vegetation of the southern wheat-belt (Forbes & Cargelligo 1:250000 map sheets), *Cunninghamia*, vol.4, no.1, pp.103–128. Bedward M, Sivertsen DP, Metcalfe LM, Cox SJ and Simpson CS (2001) *Monitoring the rate of native woody vegetation change in the New South Wales wheatbelt*, Final Project Report to the Natural Heritage Trust / Environment Australia, NPWS, Sydney.
northern_crafti_VISmap_1082			Rolhauser A, Thonell J and Peacock R (2009) *Extant and potential natural vegetation of Tamworth, Manilla and Cobbadah 1:100,000 scale map sheets, NSW*, Appendix 1 – Local Vegetation Community profiles, Draft Version 1.1.
WRA_API_VIS_1028			Forestry Commission of NSW (1989) *Forest Types in NSW*, Research Note No.17.
cobbora_NVMP_VISmap_2099			NPWS (2001) *Completion of GIS Products for the Lower North East CRAFTI Structural and Florisitic Layers, Lower North East RFA Region*, project undertaken for the Resource and Conservation Assessment Council NSW Regional Assessments.
coolah_NVMP_VISmap_2101			Beckers D and Binns D (2000) *Vegetation Survey and Mapping Stage 1 Report, Western Region*, project undertaken for the Resource and Conservation Assessment Council, NSW Western Regional Assessments, Project number WRA 13.
tam_spring_NVMP_VISmap_2104			Ismay K et al. (2004) *NSW Native vegetation report Cobbora, Coolah, Coonabarabran, Mendooran, Tambar Springs 1: 100 000 map sheets.*
curlewis_VISmap_803			Ismay K et al. (2004) *NSW Native vegetation report Cobbora, Coolah, Coonabarabran, Mendooran, Tambar Springs 1: 100 000 map sheets.*
horton_NVMP_VISmap_2136			Ismay K et al. (2004) *NSW Native vegetation report Cobbora, Coolah, Coonabarabran, Mendooran, Tambar Springs 1: 100 000 map sheets.*
boggabri_NVMP_VISmap_2134			Lezaich P (2003) Joint Vegetation Mapping Project, Brigalow Belt South Bioregion, NSW Western Regional Assessments, Project number WRA 24, project undertaken for the Resource and Conservation Assessment Council NSW Western Regional Assessments.

File name	Area of dataset	Confidence category	Report or dataset name
BrigalowParkNR_2006_E_4024			Cannon G et al. (2002) *Native vegetation map report: Abridged version*, No. 3, Bellata, Gravesend, Horton and Boggabri 1:100 000 Map Sheets
PilligaNR_1990_E_969			Cannon G et al. (2002) *Native vegetation map report: Abridged version*, No. 3, Bellata, Gravesend, Horton and Boggabri 1:100 000 Map Sheets
PilligaNP_2010_E_3980 (1)			Hunter JT (2006) *Vegetation and floristics of Brigalow Park and Claremont Nature Reserves*, report to NPWS, Narrabri.
BRIGALOWBELTSTH_COMP_E_1649	15%	Low–moderate	Hunter JT (2010) 'Vegetation and Floristics of Cubbo, Etoo and Dewsons Lease sections of the Pilliga SCA, NP and Pilliga West SCA', unpublished report to NPWS, Narrabri.
Nandewar_ext_VIS_12			Eco Logical Australia (2013) *Refinement of vegetation mapping in the Namoi Catchment: Extant and pre-European*, prepared for Namoi Catchment Management Authority, May 2013.
LandscapesNWslopesPlains_E_4169			Lezaich P (2003) Joint Vegetation Mapping Project, Brigalow Belt South Bioregion, NSW Western Regional Assessments, Project number WRA 24, project undertaken for the Resource and Conservation Assessment Council NSW Western Regional Assessments.
NarrabriWheatbelt_E_4183			–
BRG_Namoi_v2_0_E_4204	82.3%	Low	–
Landuse_P.lyr	0.06%	None	–
ELA updates			Eco Logical Australia (2009a) *A Vegetation Map for the Namoi Catchment Management Authority*, Eco Logical Australia.

5.2.2 Quantifying the spatial area and condition of water-dependent vegetation communities

Native vegetation extent

An ArcGIS toolbox was developed for this project (Watering Objectives Tool) which enables users to extract a list of vegetation communities, including the spatial extent of each community within a user defined set of zones, such as sub-catchment boundaries, planning units[7], modelled flood extents or managed floodplain boundaries. The queried vegetation dataset is the merged and attributed water-dependent vegetation dataset that was developed for each catchment. The output from the toolbox is an Excel spreadsheet that contains output data in a tabulated format. This allows users to extract target areas of water-dependent vegetation within user specified boundaries and was utilised to help set native vegetation targets for the LTWP objectives (see Section 5.3.2 and LTWPs).

Native vegetation condition

Vegetation condition is the ‘state’ or ‘health’ of vegetation and a measure of the retention (or loss) of the ecological attributes that characterise the vegetation in its desired state (Sinclair et al. 2021). The scope, context and meaning of condition differs when applied to different levels of ecological organisation (individual plants, species, communities, ecosystems and landscapes) and spatial scales. Hence the evaluation of complex ecological change can be difficult to measure in dynamic and highly variable ecosystems such as riverine floodplain landscapes. For the purposes of long-term water planning, vegetation attributes are being used as indicators of condition for the defined hydro-ecological groups. In established representative sites key plant species and/or communities are determined. Vegetation response indicators such as, but not limited to, vegetation extent, vegetation cover, abundance, plant species diversity in terms of structure, composition and function, evidence of reproduction, invasive species, bare ground, and tree canopy condition metrics can be measured to determine a baseline from which to evaluate change.

Tree stand condition

Tree stand condition of river red gum forests and woodlands, and black box woodlands has been mapped in the southern Basin using the Stand Condition Tool (Cunningham et al. 2014a, b). In the northern Basin mapping of tree canopy condition is regionally based in the Macquarie Marshes (Bowen and Simpson 2014) and Gwydir wetlands (Bowen and Simpson 2017) although the methods for mapping differ from the southern Basin.

Tree stand condition variables have been surveyed on-ground at 175 reference sites within TLM Icon Sites since 2007 (Souter et al. 2010). This information could be used as a baseline from which to develop tree stand condition targets at the wetland scale

[7] The planning units broadly delineate areas of the catchment where environmental water can and cannot be delivered. Within each of the LTWP catchments, planning units were delineated based on existing environmental water delivery mechanisms within a catchment and best available information. For example, within the Macquarie Marshes area of the Macquarie–Castlereagh Catchment these planning units were based on previously identified water management regions (Thomas et al. 2011) and discussion with the catchment’s water managers.

5.3 Setting native vegetation objectives and targets

5.3.1 Expected outcomes

The LTWPs present SMART (specific, measurable, achievable, realistic, time-bound) objectives and targets for vegetation group extent and condition over 5, 10 and 20-year timeframes. Where possible the LTWP vegetation objectives and targets were aligned with the BWS objectives and expected outcomes. When developing targets for vegetation, the water requirements of each vegetation group were considered, as well their position in the landscape (channels, wetlands and floodplains), local constraints for water delivery, and how different environmental water delivery options can influence their flooding. The BWS expected outcomes for vegetation are, at a minimum, to maintain extent and improve condition of water-dependent vegetation on the actively managed part of the floodplain by 2024. Achieving these outcomes depends on reinstating the required lateral and longitudinal connectivity. The focus of the NSW LTWP vegetation objectives and targets are to maintain extent and viability of non-woody vegetation communities, to maintain extent and improve condition of forests, woodlands and floodplain shrublands.

5.3.2 LTWP objectives and targets

Objective 1: Maintain the extent and viability of non-woody vegetation communities occurring within or closely fringing channels

Ecological objective	Quantified targets			Evaluation (measure of success)
	5 years	10 years	20 years	
Maintain the extent and viability of non-woody vegetation communities occurring within or closely fringing river channels	Increase the cover and viability[8] of non-woody, inundation-dependent vegetation within or closely fringing river channels following inundation events			Mapped extent of fringing river channel non-woody vegetation communities is maintained in the 2019–2024 period, where baseline extent had been established. By 2024, established baseline data and representative monitoring sites for fringing river channel non-woody vegetation communities for all catchments. Extent, cover and viability of non-woody vegetation within or closely fringing river channels increased in the 2024–2029 period. Review and/or re-evaluation of targets for the 2029–2039 period.

[8] Successful growth, flower and seed set.

Details of catchment specific targets and evaluation methods for Objective 1

- Murray: in at least 50% representative sites (10 years) and in at least 75% representative sites (20 years)
- Murrumbidgee: evaluated at specific sites only
- Condition and viability are measured over a 5-year rolling period to account for variation between naturally dry and wet times
- Establishment of representative sites and baseline data are still required in some catchments
- To improve viability (growth and reproduction) of key species, populations and/or communities, may need to provide at least 2 occurrences of clustered, successive flows (over 2–3 years) within the 20-year period
- Murrumbidgee, Murray: no loss of non-woody vegetation in the first 5 years
- Intersecting Streams target in the Paroo, Warrego, Moonie and Yanda Creek, no loss of non-woody vegetation over the life of the plan
- Due to the high diversity of non-woody wetland or understorey plant species (aquatic plants, forbs, grasslands, sedgelands and rushlands) and landforms within the Murray–Lower Darling WRP area, non-woody vegetation was differentiated between: (1) non-woody vegetation communities within semi-permanent, intermittent, temporal, and ephemeral wetland and floodplain areas, and (2) ephemeral understorey vegetation within forest, woodland and open floodplain areas.

Objective 2: Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains

Ecological objective	Quantified targets			Evaluation (measure of success)
	5 years	10 years	20 years	
Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains	Over a 5-year rolling period, **non-woody floodplain vegetation**[9] to flower and set seed seasonally at least 2 years in 5 following inundation events Maintain the extent of non-woody, inundation-dependent vegetation to the **most recent mapped extent** in priority environmental assets[10]			Mapped extent of wetland and floodplain non-woody vegetation communities is maintained in the 2019–2024 period, where baseline extent had been established. By 2024, established baseline data and representative monitoring sites for wetland and floodplain non-woody vegetation communities for all catchments. Extent, cover and viability of wetland and floodplain non-woody vegetation communities increased in the 2024–2029 periods. Review or re-evaluation of targets for the 2029–2039 period.

[9] Specific non-woody floodplain vegetation types to be identified for each catchment

[10] Priority environmental assets are defined by the Basin Plan as assets that can be managed with environmental water.

Details of catchment specific targets and evaluation methods for Objective 2

- Extent of non-woody vegetation should be measured over a 5-year rolling period to account for variation between naturally dry and wet times
- Murray: in at least 40% of representative sites (within a 10-year period on the actively managed floodplain, under current constraints) and in at least 60% of representative sites (within a 20-year period on the actively managed floodplain, under constraints relaxed)
- Murray targets differentiate between: (1) non-woody vegetation communities within semi-permanent, intermittent, temporal and ephemeral wetland and floodplain areas, and (2) ephemeral understorey vegetation within forest, woodland and open floodplain areas
- In the Lachlan catchment, the total area of non-woody vegetation communities occurring in wetlands and on floodplains is expected to increase by 10% within actively managed flow paths. This assumes there are no constraints to environmental water delivery to these locations
- Establishment of representative sites and baseline data are still required in some catchments.

Objective 3: Maintain the extent and improve the condition of river red gum communities closely fringing river channels

Ecological objective	Quantified targets			Evaluation (measure of success)
	5 years	10 years	20 years	
Maintain the extent and improve the condition of river red gum communities closely fringing[11] river channels	Maintain the mapped extent of river red gum woodland communities closely fringing river channels			Mapped extent maintained compared to the 2016 baseline extent
	Over a 5-year rolling period: • Maintain the extent and proportion of river red gum that are in moderate or good condition • No further decline in the condition of river red gum that are in poor or degraded condition	Over a 5-year rolling period: • Increase the proportion of river red gum that are in moderate or good condition • Improve the condition score of river red gum that are in poor, degraded or severely degraded condition by at least one condition score		By 2024 to have established baseline data and representative monitoring sites for river red gum communities closely fringing river channels for all catchments. Proportion of river red gum closely fringing river channels in moderate to good condition is maintained in the 2019–2024 period. Condition of river red gum closely fringing river channels is improved in the 2024–2029 period. Review or re-evaluation of targets for the 2029–2039 period.

Details of catchment specific targets and evaluation methods for Objective 3

- In the Border Rivers (Paroo, Warrego, Moonie and Yanda Creek), Macquarie–Castlereagh, and Murrumbidgee catchments, no improvement of condition is targeted.

[11] Closely fringing refers to river red gum that occur up to a distance of 50 m from the centre line of the river channel.

Objective 4: Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains

Ecological objective		Quantified targets: 5 years	Quantified targets: 10 years	Quantified targets: 20 years	Evaluation (measure of success)
Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains	River red gum forest	Maintain the mapped extent of river red gum forest communities			Mapped extent maintained compared to the 2016 baseline extent.
		Over a 5-year rolling period: • Maintain the proportion of river red gum forests in moderate or good condition • No further decline in the condition of river red gum forests in poor or degraded condition	Over a 5-year rolling period: • Increase the proportion of river red gum forests in moderate or good condition within actively managed flow paths and maintain the proportion outside of these		By 2024 to have established baseline data and representative monitoring sites for river red gum forests for all catchments. Proportion of red gum forests in moderate to good condition is maintained and the condition of poor or degraded woodlands is stabilised in the 2019–2024 period. Condition of river red gum forests is improved in the 2024–2029 period. Review or re-evaluation of targets for the 2029–2039 period.
	River red gum woodland	Maintain the mapped extent of river red gum woodland communities			Mapped extent maintained compared to the 2016 baseline extent.
		Over a 5-year rolling period: • Maintain the extent and proportion of woodlands in moderate or good condition • No further decline in the condition of woodlands in poor or degraded condition • Increase the abundance of woodland seedlings and saplings in degraded river red gum woodlands on the actively managed floodplain	Over a 5-year rolling period: • Increase the proportion of woodlands in moderate or good condition • Improve the condition score of woodlands in poor, degraded or severely degraded condition by at least one condition score • Support successful recruitment of trees in the long term by increasing the abundance of young adult trees (10–30 cm DBH) compared to the previous 10-year period		By 2024 to have established baseline data and representative monitoring sites for river red gum woodlands for all catchments. Proportion of river red gum woodlands in moderate to good condition is maintained, the condition of poor or degraded woodlands is stabilised and abundance of seedlings/saplings increased in the 2019–2024 period. Condition of river red gum woodlands is improved, and abundance of young adult trees (10–30 cm DBH) increased in the 2024–2029 period. Review or re-evaluation of targets for the 2029–2039 period.

<table>
<thead>
<tr><th rowspan="2" colspan="2">Ecological objective</th><th colspan="3">Quantified targets</th><th rowspan="2">Evaluation
(measure of success)</th></tr>
<tr><th>5 years</th><th>10 years</th><th>20 years</th></tr>
</thead>
<tbody>
<tr><td rowspan="2"></td><td rowspan="2">Black box woodland</td><td colspan="3">Maintain the mapped extent of black box woodland communities</td><td>Mapped extent maintained compared to the 2016 baseline extent.</td></tr>
<tr><td>Over a 5-year rolling period:
• Maintain the extent and proportion of woodlands in moderate or good condition
• No further decline in the condition of woodlands in poor or degraded condition
• Increase the abundance of woodland seedlings and saplings in degraded river black box woodlands on the actively managed floodplain</td><td colspan="2">Over a 5-year rolling period:
• Increase the proportion of woodlands in moderate or good condition
• Improve the condition score of woodlands in poor, degraded or severely degraded condition by at least one condition score
• Support successful recruitment of trees in the long term by increasing the abundance of young adult trees (10–30 cm DBH) compared to the previous 10-year period</td><td>By 2024, have established baseline data and representative monitoring sites for black box woodlands for all catchments.
Proportion of black box woodlands in moderate to good condition is maintained, condition of poor or degraded woodlands is stabilised and abundance of seedlings/saplings increased in the 2019–2024 period.
Condition of black box woodlands improved, and abundance of young adult trees (10–30 cm DBH) increased in the 2024–2029 period.
Review and or re-evaluate targets for the 2029–2039 period.</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">Coolibah woodlands</td><td colspan="3">Maintain the mapped extent of coolibah woodland communities</td><td>Mapped extent maintained compared to the 2016 baseline extent.</td></tr>
<tr><td>Over a 5-year rolling period:
• Maintain the extent and proportion of woodlands in moderate or good condition
• No further decline in the condition of woodlands in poor or degraded condition
• Increase the abundance of woodland seedlings and saplings in degraded coolibah woodlands on the actively managed floodplain</td><td colspan="2">Over a 5-year rolling period:
• Increase the proportion of woodlands in moderate or good condition
• Improve the condition score of woodlands in poor, degraded or severely degraded condition by at least one condition score
• Support successful recruitment of trees in the long term by increasing the abundance of young adult trees (10–30 cm DBH)</td><td>By 2024, have established baseline data and representative monitoring sites for coolibah woodlands for all catchments.
Proportion of coolibah woodlands in moderate to good condition is maintained, condition of poor or degraded woodlands is stabilised and abundance of seedlings/saplings increased in the 2019–2024 period.
Condition of coolibah woodlands is improved and abundance of young adult trees (10–30 cm DBH) increased in the 2024–2029 period.</td></tr>
</tbody>
</table>

Ecological objective		Quantified targets			Evaluation (measure of success)
		5 years	10 years	20 years	
			compared to the previous 10-year period		Review or re-evaluation of targets for the 2029–2039 period.
	Lignum shrublands	Maintain the mapped extent of lignum shrubland communities within actively managed wetlands and floodplains	Increase the total area of lignum shrublands by 10% occurring within actively managed wetlands and floodplains		Mapped extent maintained compared to the 2016 baseline extent. Total area of lignum shrublands improved in 10% of actively managed wetlands and floodplains improved by the 2024–2029 period.
		Over a 5-year rolling period: • Maintain the extent and proportion of shrublands in moderate or good condition • No further decline in the condition of shrublands in poor or degraded condition	Over a 5-year rolling period: • Increase the proportion of shrublands in moderate or good condition • Improve the condition score of shrublands in poor, degraded or severely degraded condition by at least one condition score		By 2024, have established baseline data and representative monitoring sites for lignum shrublands for all catchments. Proportion of lignum shrublands in moderate to good condition is maintained, condition of poor or degraded shrublands is stabilised in the 2019–2024 period. Proportion of lignum shrublands in moderate to good condition has increased and condition of poor, degraded or severely degraded shrublands has improved by the 2024–2029 period. Review or re-evaluation of targets for the 2029–2039 period.
	Coolibah wetland woodland[12]	Maintain the mapped extent of coolibah wetland woodland communities within actively managed wetlands and floodplains	Increase the total area of coolibah wetland woodland by 10% occurring within actively managed wetlands and floodplains		Mapped extent maintained compared to the 2016 baseline extent. Total area of coolibah wetland woodlands improved in 10% of actively managed wetlands and floodplains improved by the 2024–2029 period.

[12] Coolibah wetland woodland objectives and targets are only applied in the Gwydir catchment.

Ecological objective	Quantified targets			Evaluation (measure of success)
	5 years	10 years	20 years	
	Over a 5-year rolling period: • Maintain the extent and proportion of woodlands in moderate or good condition • No further decline in the condition of woodlands in poor or degraded condition • Increase the abundance of woodland seedlings and saplings in degraded coolibah wetland woodlands on the actively managed floodplain	Over a 5-year rolling period: • Increase the proportion of woodlands in moderate or good condition • Improve the condition score of woodlands in poor, degraded or severely degraded condition by at least one condition score • Support successful recruitment of trees in the long term by increasing the abundance of young adult trees (10–30 cm DBH) compared to the previous 10-year period		Proportion of coolibah wetland woodlands in moderate to good condition is maintained, condition of poor or degraded woodlands is stabilised and abundance of seedlings/saplings increased in the 2019–2024 period. Condition of coolibah wetland woodlands is improved and abundance of young adult trees (10–30 cm DBH) increased in the 2024–2029 period. Review or re-evaluation of targets for the 2029–2039 period.

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6. Waterbird objectives and targets

6.1 Background

Waterbirds are a key indicator of the health of the MDB's water-dependent ecosystems. They are a group of highly mobile species and can respond to flows over large spatial scales (Amat and Green 2010; Kingsford and Norman 2002). Improvements in waterbird populations across the MDB is one of the main ecological objectives of the Basin Plan (*Commonwealth Water Act 2007)*. This ecological objective is based on evidence of long-term declines in waterbird populations in the MDB (Bino et al. 2014; Kingsford et al. 2017) and the strong relationships between waterbird populations and river flows (Arthur et al. 2012; Bino et al. 2014; Kingsford and Auld 2005; Kingsford and Johnson 1998; Scott 1997). With more water available for the environment through the Basin Plan, increases in frequency, duration and extent of inundation of wetland areas are expected to provide more habitat for waterbirds and other water-dependent species (MDBA 2014).

There are 5 expected outcomes of environmental water delivery (at a Basin scale) for waterbirds (Table B.13, Figure B.2). These expected outcomes relate to maintaining the number and type of waterbird species, increasing waterbird abundance and increasing opportunities for waterbird breeding (MDBA 2014).

Table B.13 The BWS describes 5 expected outcomes for waterbirds from 2024 onwards (MDBA 2014)

BWS objective	Expected outcomes
Maintain the number and type of waterbird species	The number and type of waterbird species (including shorebirds) present in the MDB will not fall below current observations
Increase abundance	A significant improvement in waterbird populations, in the order of 20–25%, over the baseline scenario[13], with increases in all waterbird functional groups
Improve breeding	Breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase (frequency and size of events) by up to 50% compared to the baseline scenario[13]
	Breeding abundance (nests and broods) for all other functional groups to increase by 30–40% compared to the baseline scenario[13], especially in locations where the Basin Plan can improve overbank flows[14]
Maintain migratory shorebird populations[15]	By 2019, at a minimum, to maintain populations of the following 4 key species: curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper, at levels recorded between 2000 and 2014

[13] The Baseline modelled scenario represents the MDB with consumptive use and sharing rules and arrangements as at June 2009.

[14] These catchments are described in Figure B.7.

[15] Note that the migratory shorebird expected outcome is specific to South Australia, because of the importance of the Coorong, Lakes Albert and Alexandrina, for these species. This objective and target were not considered in NSW long-term water planning.

Medium-term improvements in waterbird breeding between 2020 and 2030 are expected to result in increases in total waterbird abundance in the MDB by 2030–2035 (Figure B.2). This is because it is recognised it will take some time for waterbird populations to respond to improved flow regimes (MDBA 2014, 2017), as recruitment of young birds into the adult population is needed for total numbers of waterbirds to increase. For example, the long-term Annual Waterbird Survey of Eastern Australia (AWSEA) program has detected increases in waterbird breeding in years where large natural flood events were recorded but increases in total waterbird abundance were not seen until the following year after these events (Bino et al. 2014; Porter et al. 2017).

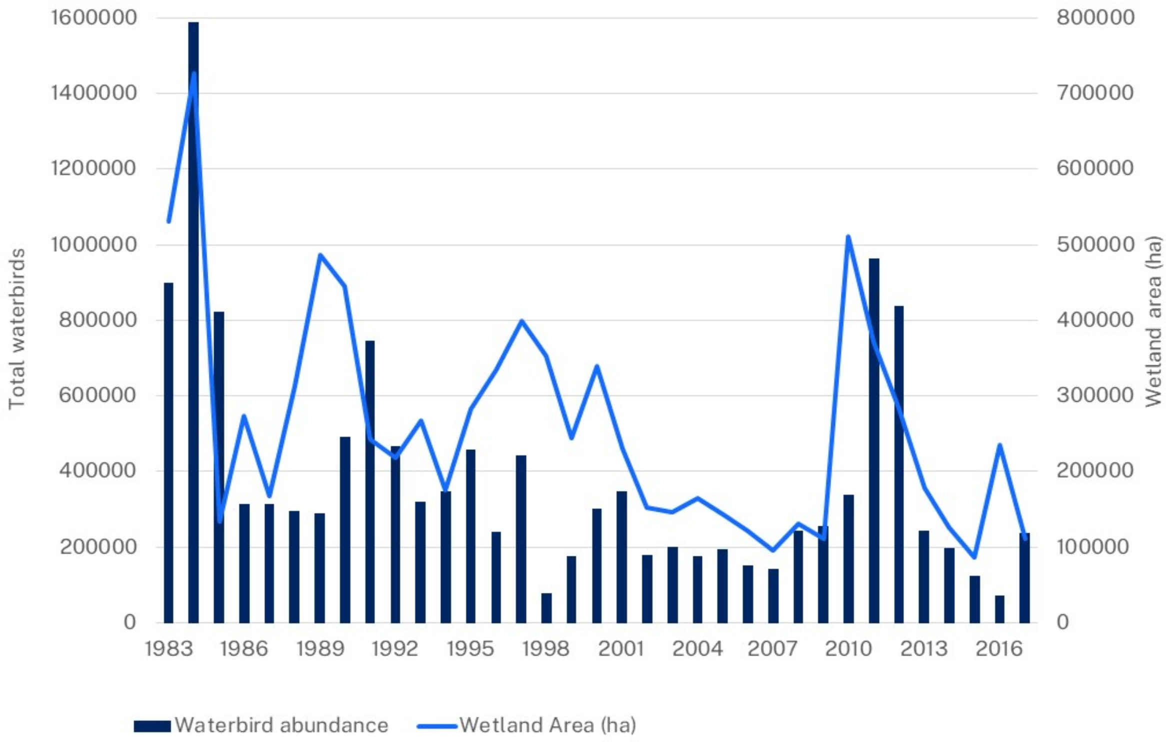

Figure B.1 **Long-term aerial surveys of Eastern Australia show that waterbird abundance fluctuates with available wetland habitat (hectares) in the survey transects (from Porter et al. 2017)**

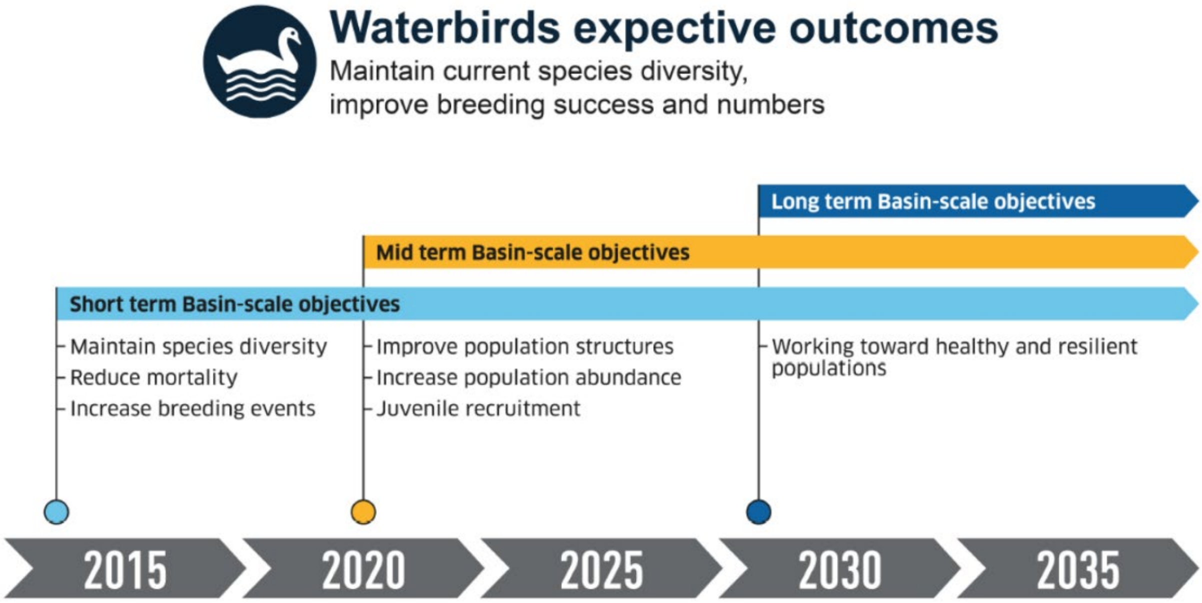

Figure B.2 Short and mid-term outcomes needed to meet long-term Basin-scale objectives for improvements in waterbird populations (reproduced from MDBA 2017)

The BWS identifies 33 environmental assets in the MDB as important sites for achieving sustainable populations of waterbirds across the MDB (MDBA 2014). Of these 33 assets, 19 are in the NSW portion of the MDB and cover 7 separate WRPAs (Appendix 6.1, Figure B.3). These wetland sites were identified through analysis of aerial survey datasets available for the 1983–2012 period (Bino et al. 2014). It was recognised that outcomes for waterbird species at these important sites will only be achieved through use of all types of water including natural events, environmental water and consumptive water (MDBA 2014). The sites identified in Figure B.3 include wetland complexes where environmental water can be delivered; for example, the Gwydir Wetlands, Lowbidgee Floodplain and Macquarie Marshes. Other waterbird assets are part of unregulated catchments where flows cannot be managed directly but still provide important habitat for waterbirds; for example, the Paroo Lakes and Cuttaburra Channels in north-western NSW (Figure B.3, Appendix 6.1).

Broad watering strategies were identified in the BWS for achieving positive outcomes for waterbirds including:

- provision of a diversity of wetland habitats in good condition to support lifecycles and a range of waterbird species
- protection of drought refuges (for feeding and roosting during dry periods)
- supporting successful waterbird breeding through the provision of breeding habitats and food resources (MDBA 2014).

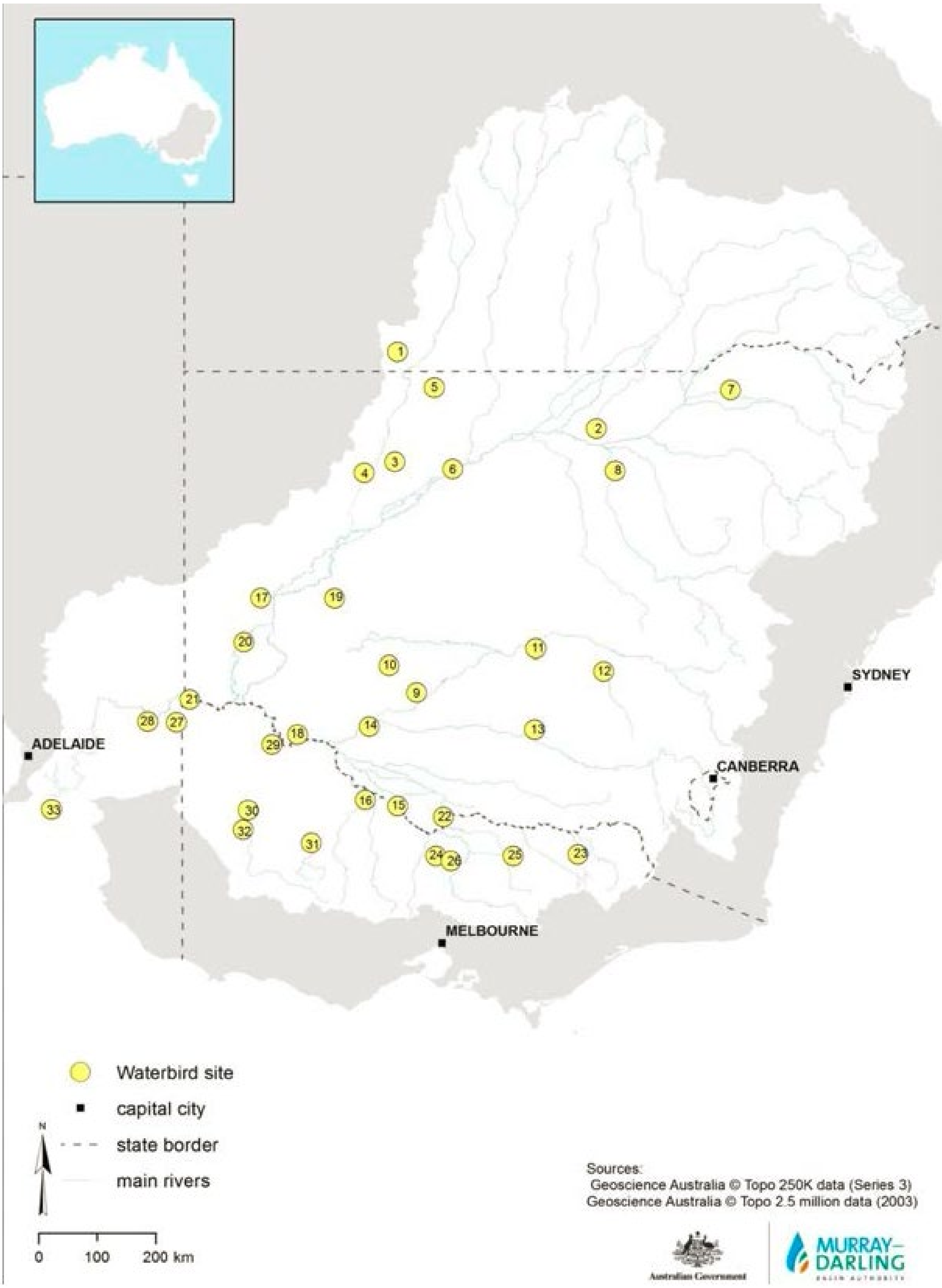

Figure B.3 There are 33 important wetlands identified as important sites for waterbirds across the MDB[16] (reproduced from MDBA 2014)

6.2 Approach to developing waterbird objectives and targets

We collated waterbird data for the NSW portion of the MDB to inform 3 steps in the development of NSW Long Term Water Plans (LTWPs) including:

- identification of water-dependent assets in each WRPA
- development of water requirements for waterbird groups in the NSW MDB
- development of draft objectives and targets for waterbirds for each WRPA.

6.2.1 Available datasets

Waterbird species records were collated from state (BioNet – Atlas of NSW Wildlife) and Commonwealth (Australian Living Atlas) government databases, University of New South Wales (UNSW) aerial survey datasets, DPE–EHG ground surveys, and UNSW and DPE–EHG colonial waterbird breeding records (see Appendix 6.4). In addition to information on species richness, UNSW and DPE–EHG data provided systematic counts of waterbird taxa (and therefore each functional group), the number of breeding species, and numbers of nests and broods for each surveyed wetland.

Many of the NSW WRPAs have long-term records of waterbirds through the AWSEA program now coordinated by UNSW. The AWSEA monitors waterbird populations and wetlands across Eastern Australia each spring (Kingsford and Porter 2009). Seven of the 10 AWSEA survey transects cover wetlands in the MDB, covering 13.5% of the combined MDB land surface (Bino et al. 2015). Aerial surveys have the advantage of being rapid and repeatable over large systems (Kingsford 1999). In NSW, major wetlands surveyed include the Lowbidgee Floodplain (Murrumbidgee WRPA), the top third of the Macquarie Marshes (Macquarie–Castlereagh WRPA), River Murray and Euston Lakes, Menindee Lakes (NSW Murray–Lower Darling WRPA), Talywalka Lakes, Upper Darling River (Barwon–Darling), and Paroo River Overflow Lakes and Cuttaburra Lakes (Intersecting Streams).

Additional systematic aerial survey data for important waterbird sites outside of the AWSEA survey bands in the NSW MDB (see Figure B.5), were available from 2007 onwards through various programs including the Specified Environmental Asset (SEA) aerial survey program (see Appendix 6.4 for details). The MDBA has funded the SEA program since 2014 (it was formerly the MDBA's hydrologic indicator sites (HIS) and Targeted Wetland survey programs established in 2010) where all 33 MDB waterbird assets are surveyed each spring (Kingsford et al. 2013; Kingsford et al. 2017) alongside the existing AWSEA program (Figure B.4 and Figure B.5).

DPE–EHG and partner agencies coordinate ground surveys each spring in important waterbird sites in the NSW MDB, many of which receive environmental water to support waterbird habitat. On-ground surveys complement the aerial survey programs by providing more detailed taxonomic information for waterbird groups that cannot easily be differentiated to species level during aerial counts; for example, migratory shorebirds, small grebes and small egrets. Counts from the DPE–EHG ground survey

[16] Waterbird sites in NSW include: (2) Narran Lakes, (3) Cuttaburra Channels, (4) Paroo River Overflow Lakes, (5) Yantabulla Swamp, (6) Upper Darling River, (7) Gwydir Wetlands, (8) Macquarie Marshes, (9) Booligal Wetlands, (10) Great Cumbung Swamp, (11) Lake Brewster, (12) Lake Cowal, (13) Fivebough Swamp, (14) Lowbidgee Wetlands, (15) Gunbower-Koondrook-Perricoota, (17) Menindee Lakes, (18) River Murray and Euston Lakes, (19) Talywalka Lakes, (20) Darling Anabranch and (22) Barmah–Millewa.

program for the 2008–2016 period included the Gwydir Wetlands (from 2007), Lowbidgee Floodplain (from 2008), Barmah–Millewa Forest (from 2008 through TLM program monitoring), Macquarie Marshes, Fivebough Swamp and Narran Lakes (since 2012), Lake Brewster, Lake Cowal, Great Cumbung Swamp, Booligal Wetlands (2016 only) (Spencer et al. 2014; Spencer et al. 2016; Spencer et al. 2018) (see Appendix 6.4). DPE–EHG including NPWS (and predecessor organisations) have also carried out ground surveys of known colonial waterbird breeding sites, during and outside of the spring survey period (Brandis 2010; Spencer 2010, 2017).

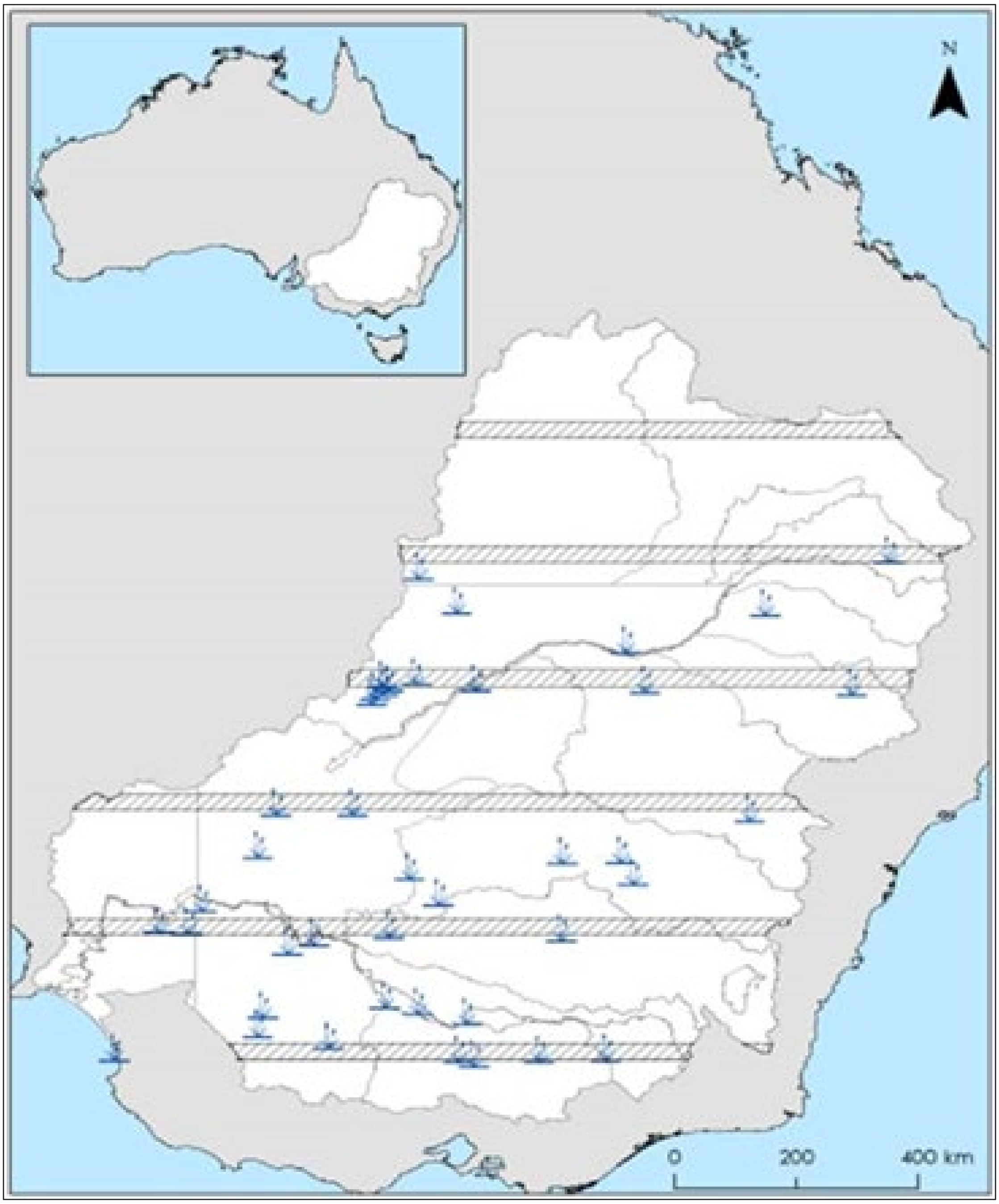

Figure B.4 UNSW aerial survey datasets (AWSEA and SEA programs) were used for setting objectives and targets in NSW LTWPs (see Appendix 6.4)

Three of the 6 AWSEA 30 km wide survey transects cross MDB wetlands in NSW. Additional waterbird assets have been surveyed annually by UNSW since 2010 as part of MDBA funded programs and include waterbird assets outside the AWSEA transects (reproduced from Bino et al. 2015).

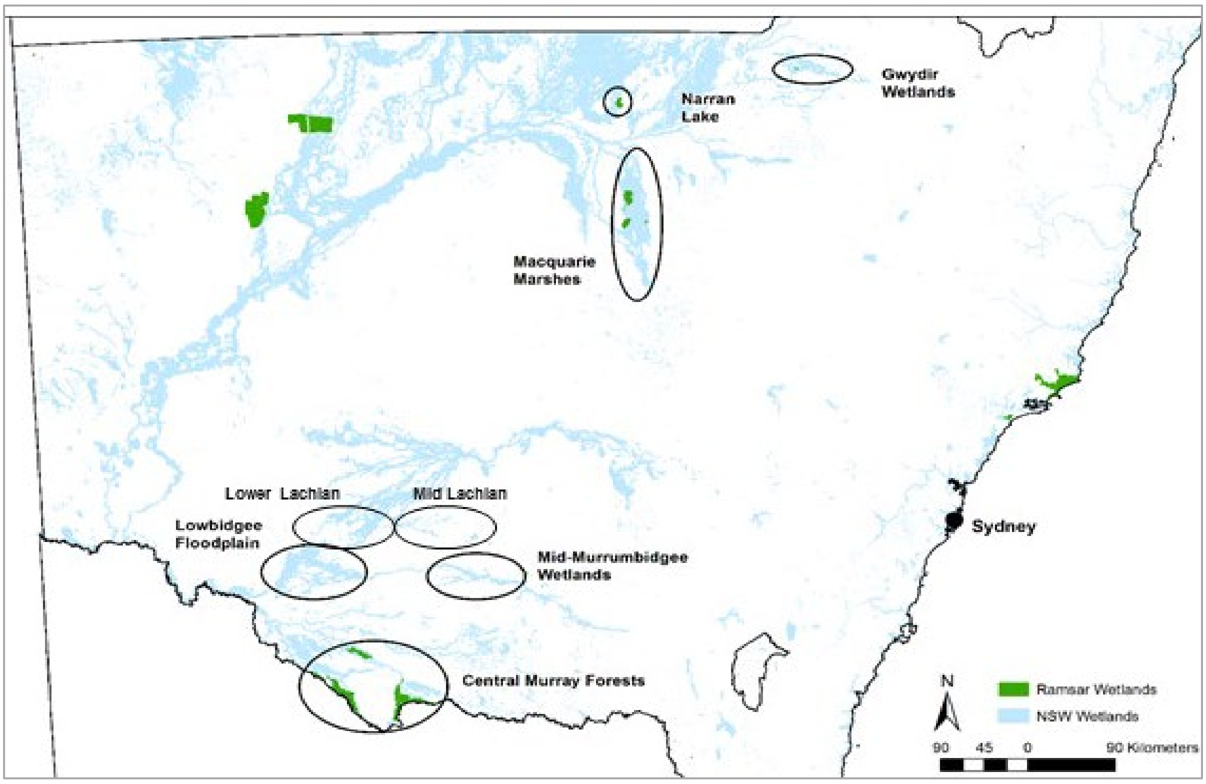

Figure B.5 **DPE–EHG annual ground surveys were used for setting objectives and targets in NSW LTWPs (see Appendix 6.4)**

DPE–EHG annual ground surveys from 2008–2016 were timed to coincide with the AWSEA and SEA aerial surveys each spring.

Location of waterbird assets

The 33 waterbird assets identified in the BWS were identified by Bino et al. (2014) as those wetland systems that contributed more than 80% of the abundance for 57 waterbird taxa and each of the 5 waterbird functional groups. They also identified sites important for shorebirds in the NSW MDB, including the Macquarie Marshes, Narran Lakes, Paroo Lakes, Cuttaburra Channels, Lowbidgee Floodplain and Fivebough Swamp, and sites that provide habitat for waterbirds during dry periods (see Appendix 6.1).

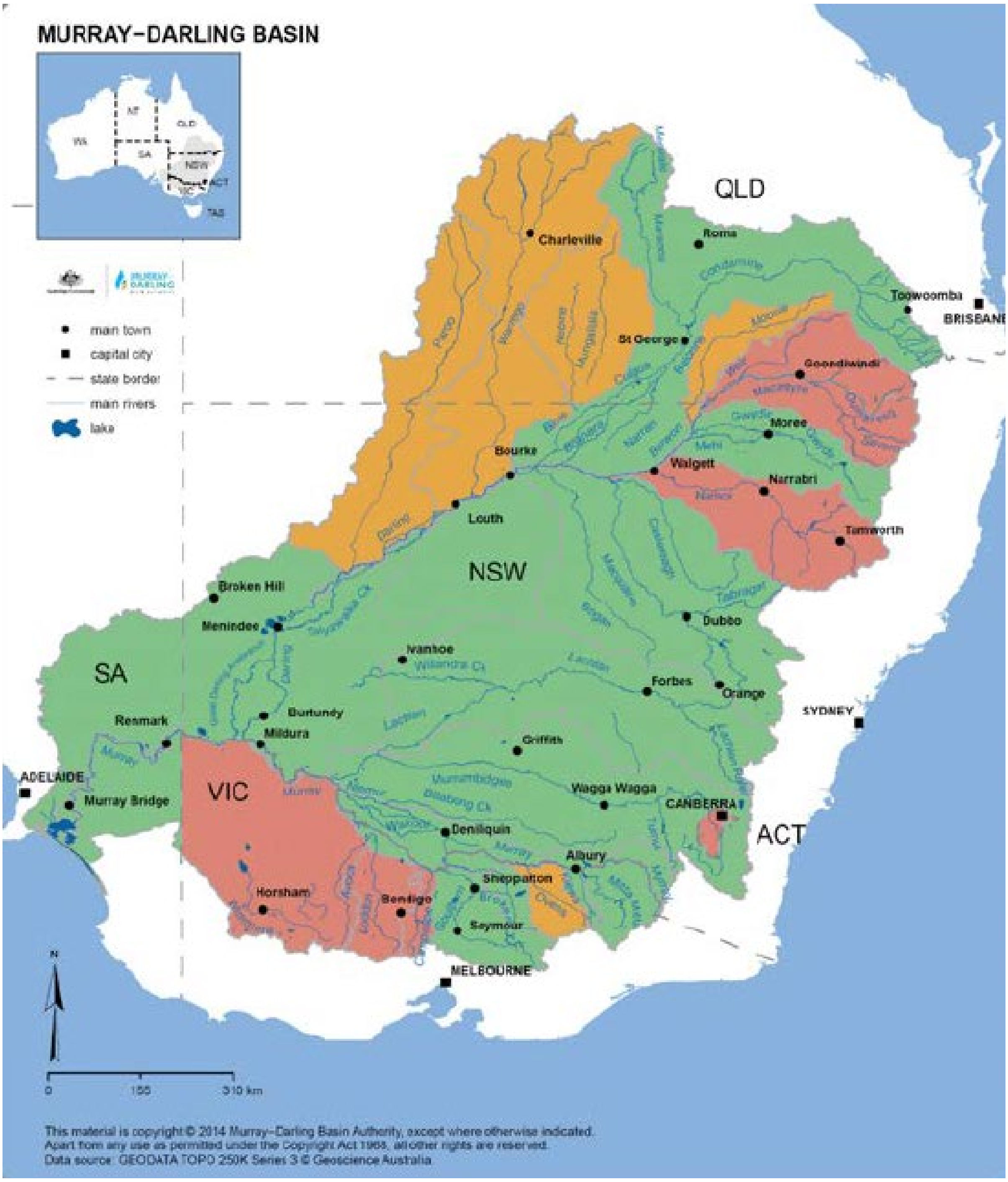

Figure B.6 **Flow component improvements expected under the Basin Plan (reproduced from MDBA 2014)**

WRPAs shaded: orange (minimal water resource development, therefore, no improvements sought – rather, maintenance of all current flow components); green (improvements in connectivity are possible under the Basin Plan for base flows, low in-channel freshes and bank full/low floodplain overbank flows); red (improvements sought in base flows and low in-channel flows only, as bank full and low floodplain overbank flows are either relatively intact or there is limited floodplain).

The NSW LTWPs waterbird objectives and targets focus on BWS waterbird assets in NSW and are based on information provided by Bino et al. (2014) and Bino et al. (2015), and available waterbird records collated for each WPRA (see Appendix 6.2). The waterbird assets are in 'lowland regions' in the floodplains of major rivers in each WRPA. These sites are identified as important for achieving sustainable populations of waterbirds in the MDB. For example, the Gwydir Wetlands (Gwydir WRPA), Macquarie Marshes (Macquarie–Castlereagh WRPA) and Lowbidgee Floodplain (Murrumbidgee WRPA) were identified as sites important for maintaining the number of waterbird species, increasing waterbird abundance across the MDB and providing opportunities for colonial waterbird breeding (MDBA 2014) (see Appendix 6.1). Note that while a small number of sites that support waterbird habitat are not identified as a waterbird asset and do not have any LTWP objectives and targets, these sites are usually not a focus of water delivery. It may be that in future revisions of the LTWPs and changes to water delivery (including relaxed constraints) it will be possible to set quantified waterbird targets for additional wetland areas.

The spatial boundaries of each of the LTWP waterbird areas (or BWS waterbird assets) were determined through consultation with water managers, and by using existing WRPA water source boundaries and LTWP planning units. For example, the Gwydir Wetlands was defined as the area west of Moree to include the main watercourses, Gingham, Lower Gwydir and Mehi–Mallowa in the Gwydir WRPA (spatial boundaries of each waterbird area are defined in Appendix 6.1 and Figure B.7).

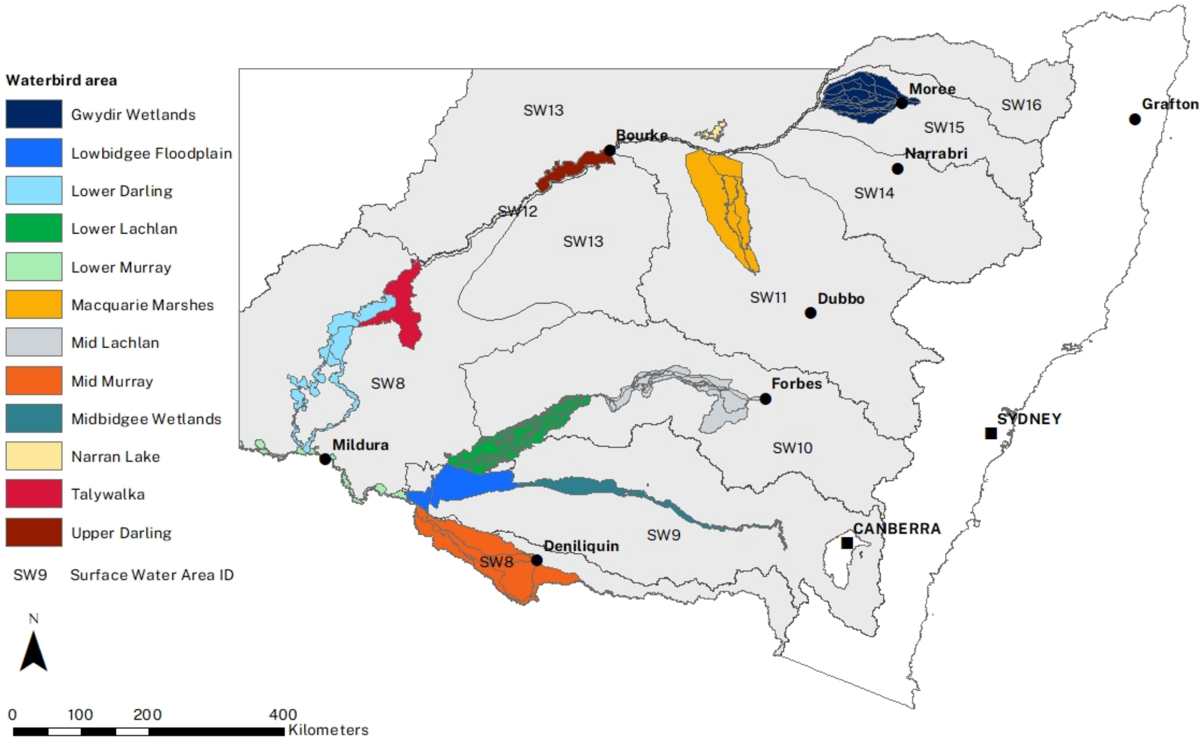

Figure B.7 **Locations of major wetland systems identified as waterbird areas in the NSW WRPAs used for the development of LTWP waterbird objectives and targets**

See Appendix 6.1 for a further description of waterbird planning area boundaries.

6.2.2 Establishing a spatial boundary

The spatial boundaries were first established for each waterbird area in the WRPAs. As waterbirds are highly mobile and dependent on the inundation of floodplain habitats, the spatial boundary of each waterbird area was reasonably large to represent an appropriate area in which to consider waterbird responses to flows. We combined planning units, where appropriate, to include river channels and connecting floodplain areas to define a single waterbird area. For example, the combined 'Gwydir Wetlands' asset included the Lower Gwydir, Gingham Watercourse and the Mehi–Mallowa system, and the 'Macquarie Marshes' waterbird area included the East, North and South Marsh water management areas. This approached ensured the LTWP areas aligned with the BWS waterbird assets. One exception to this approach was the Fivebough–Tuckerbil Swamp in the Murrumbidgee Catchment (a BWS waterbird asset identified for its importance for shorebird species), which only covers 689 hectares and the spatial extent was determined by the Ramsar boundary (see Appendix 6.1 for a description of boundaries for all waterbird areas).

Many of the LTWP waterbird areas (Figure B.7) also include wetlands that have supported colonial waterbird breeding in the last decade and sites that historically (pre-2006) supported active colonies (Spencer 2017). The historical colony sites were included to recognise that improved habitat condition in these sites could contribute to greater breeding opportunities for colonial waterbird species.

Other exceptions to this method include the Namoi and Border Rivers catchments, which do not have any waterbird assets identified in the BWS; however, these catchments are known to support a diverse array of waterbirds, including threatened species and listed migratory birds. Although there are no specific waterbird areas defined in these catchments, the total extent of water-dependent assets was identified as important to support waterbird species across the MDB, and the outcomes sought in the BWS and LTWPs.

6.3 Selecting an appropriate baseline

The availability of waterbird survey data varies considerably across the NSW WRPAs but there has been consistent aerial survey coverage for the BWS waterbird assets since 2010 with ground surveys initiated in many of these sites from 2012 onwards (see Appendix 6.4). For example, in the Macquarie–Castlereagh WRPA, waterbird numbers in the northern Macquarie Marshes have been surveyed annually as part of long-term aerial surveys of Eastern Australia (AWSEA) since 1983, with aerial and ground surveys of the entire Macquarie Marshes commencing in 2008 and 2012, respectively. Comparatively, very few data are available for the Gwydir WRPA, with systematic aerial and ground surveys for the Gwydir Wetlands only being available from 2008 onwards. The Lowbidgee Floodplain has comprehensive aerial survey data available from 1983 onwards through the AWSEA program with ground surveys initiated by DPE–EHG in 2008. A summary of survey programs for each waterbird area is provided in Appendix 6.4.

Annual spring aerial and ground (where available) survey data from 2012–2016 represented 5 water years (from 2012–2017) post implementation of the Basin Plan. This survey period was used as the baseline for measuring the status of waterbird populations in each of the LTWP waterbird areas. This baseline 5-year period represents years for many waterbird areas where water recovery had already taken place and environmental water has been actively delivered to support waterbird habitat. These 5 water years also covered a range of climatic conditions including a water year of average conditions (in 2012–13), drier conditions for 3 water years (2013–14, 2014–15 water years to the middle of the 2015–16 water year) and a year of above average rainfall and large inflows recorded in many parts of the MDB (in the 2016–17 water year). The Gwydir Wetlands and Narran Lakes and other wetlands in far NW NSW were exceptions to this pattern with above average rainfall and large inflows recorded at the start of the 5-year period (in 2012–13), followed by drier conditions for the remaining 4 years (2013–2017).

As the Basin Plan came into effect in November 2012, we also used all records for the period 1992–2012 (commencing in July 1992 and ending in June 2012 to cover 20 water years) for each WRPA (see Appendix 6.4). The BWS states that achieving the waterbird expected outcomes will result in waterbird population numbers similar to those in the early 1990s, which is necessary to ensure the resilience of waterbird populations across the MDB (MDBA 2014). This early 1990s period represents conditions before major resource development in many catchments. We used the long-term species records, including the aerial survey records, to determine the frequency of occurrence of all waterbird species over 5, 10 and 20-year intervals. In this analysis we excluded unconfirmed records for 7 waterbird species, 2 introduced species, and 6 vagrant species (see Appendix 6.3), which are not typically found in Australia. This allowed us to set an additional target for measuring the total number of waterbird species and number of waterbird groups in each waterbird area in addition to the species richness target based on annual survey data (see below).

6.4 Setting waterbird objectives and targets

6.4.1 Expected outcomes

The LTWPs set out SMART objectives and targets for waterbird species richness, abundance and breeding over 5, 10 and 20-year timeframes. The NSW LTWP waterbird objectives and targets were aligned where possible with the BWS objectives and expected outcomes (Table A.1 in Part A). When developing targets for waterbirds, the water requirements of each waterbird group were considered, and local constraints for water delivery and how environmental water delivery can influence waterbird habitat. The BWS expected outcomes for waterbirds are specified for beyond 2019, with the target of a 20–25% increase in waterbird abundance from 2024. It is assumed this increase will be a result of increased habitat and breeding opportunities for waterbird species with increased water recovery (MDBA 2014). The NSW LTWP waterbird objectives and targets aim to maintain the type and number of waterbird species, increase total abundance, increase opportunities for non-colonial and colonial waterbird breeding, and improve the condition and extent of waterbird habitats.

6.4.2 LTWP objectives and targets

Objective 1: Maintain the number and type of waterbird species

Ecological objective	Quantified targets	2024 evaluation (measure of success)
Maintain the number and type of waterbird species	Maintain a 5-year rolling average of **x or more** waterbird species across the 5 functional groups[17] in the waterbird area[18] (as determined by annual surveys[19])	Species richness in waterbird area[18] maintained in the 2012–2024 period
	Identify at least **x** waterbird species in the waterbird area[18] in a 10-year period[4]	
	At least x waterbird species[20] observed in the waterbird area[18] in the next 20 years	Evaluated for the 2012–2039 period

Species composition can be an important indicator of the health of waterbird populations as the extent of occurrence can be an indicator of species persistence. In a recent evaluation of the Basin Plan the MDBA determined that waterbird species richness, using the annual aerial survey data (AWSEA), had been maintained in the 2012–2017 period compared to the 1983–2011 period (MDBA 2017). From 1983 onwards more than 50 taxa have been identified during the AWSEA program. Due to the nature of the surveys, several species need to be grouped, including small egrets (little egret, cattle egret, intermediate egret), small grebes (hoary-headed grebe, Australasian grebe) and migratory shorebird species (as either small or large migratory shorebirds), as they cannot be identified easily from the air. The annual DPE–EHG ground surveys have provided additional information on occurrence of some of these species.

Due to the nature of their occurrence, incidental records of less common species, including those that are threatened and/or cryptic, recorded outside the annual spring survey programs by the public and other survey programs can also be extremely valuable. In moderate to very wet years waterbird species uncommon in the MDB have also been observed during ground surveys of the waterbird areas. This includes species such as comb-crested jacana and pied heron, which are more common in the Northern Territory, and also migratory shorebird species that can spend their non-breeding season in inland wetlands during Australian summer months (Lane 1987). When all available species records were considered the number of threatened and migratory species detected had a large influence on the total number of waterbird species recorded in each waterbird area during the 1992–2012 period. Species records in public databases (NSW BioNet (2017) and ALA (2017)) provided another line of evidence to describe species richness trends, in addition to total species observed in the annual aerial and ground survey programs. We have built in this data source as a second target in the LTWP waterbird species richness target described above.

[17] The 5 functional groups are ducks, herbivores, piscivores, large waders and shorebirds as these groups can be identified by the aerial survey program.

[18] Waterbird areas (see Figure B.7) are defined for each WRPA based on the location of BWS waterbird assets (see Appendix 6.1).

[19] Annual spring survey data collected through UNSW annual aerial surveys and ground surveys (where available) for the 2012–2016 period.

[20] Total number of all waterbird species (not including vagrant species) in each waterbird area over a 20-year period was determined by compiling all available long-term records from 1992–2012.

Objective 2: Increase total waterbird abundance across all functional groups

Ecological objective	Quantified targets	2024 evaluation (measure of success)
Increase total waterbird abundance across all functional groups	Maintain total waterbird abundance, across all functional groups[21], in the waterbird area[22] as determined through annual spring surveys[23]	No decline in total waterbird abundance (across all functional groups) in the waterbird area[22] in the 2019–2024 period
	Total waterbird abundance increased in the waterbird area[22] by 20–25%[24] with increases in all functional groups in the next 10-year period	Evaluated in 2029 for the 2019–2029 period with further targets set for the 2029–2039 period

Analysis of the long-term aerial survey dataset shows there have been significant declines in total waterbird abundance across all functional groups in the MDB (Kingsford et al. 2017). Bino et al. (2015) estimated a 74% decline in mean abundance of all waterbirds recorded between the first decade of the AWSEA program (1983–1992) and the last decade of the survey (2003–2012). Partial recovery in waterbird abundance was observed in the 2010–2012 period, which coincided with large flooding, compared to 1983–1992 levels (Figure B.8), with the key drivers in this response being total river flows and wetland area lagged by one year (Bino et al. 2014).

Analysis of the MDB aerial survey datasets (2010–2012 period) also highlighted how NSW WRPAs Intersecting Streams, Lachlan, Murrumbidgee and Macquarie–Castlereagh all contributed to total waterbird abundance across the MDB and that some sites can support extremely large numbers of ducks and large waders in moderate to very wet conditions (Bino et al. 2015). For example, in spring 2010 more than 80,000 waterbirds were recorded in Yantabulla Swamp (Intersecting Streams WRPA), more than 90,000 waterbirds in the Lowbidgee Floodplain (Murrumbidgee WRPA) and more than 120,000 waterbirds in the Booligal Wetlands (Lachlan WRPA) (Bino et al. 2015). The Namoi and Border Rivers WRPAs support lower numbers of waterbirds overall, and therefore no waterbird assets were identified in these catchments, but the AWSEA aerial survey dataset did indicate that the Namoi WRPA can support high numbers of piscivores during dry and very dry conditions across the MDB (Bino et al. 2015).

Modelling of waterbird abundance under different water development scenarios showed that waterbird responses were strongly linked to annual total flows and Bino et al. (2014) predicted that with decreased water diversions total waterbird abundance across the MDB would increase by 20–27%. These increases across all functional groups were expected to occur in parts of the MDB where water recovery is greatest, with smaller increases in waterbird populations expected in parts of the MDB where reductions in water diversions are lower (Bino et al. 2014) (see Figure B.6).

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[21] The 5 functional groups are ducks, herbivores, piscivores, large waders and shorebirds as these groups can be identified by the aerial survey program.

[22] Waterbird areas (Figure B.7) are defined for each WRPA based on the location of BWS waterbird assets and NSW LTWP watering priorities (Appendix 6.2).

[23] Annual spring survey data collected through UNSW annual aerial surveys and ground surveys (where available) for the 2012–2016 period.

[24] In line with the expected outcome in the BWS (MDBA 2014) of a significant improvement in waterbird populations in the order of 20–25% across the MDB, with increases in all waterbird functional groups. We expect to also observe local increases in waterbird abundance at the waterbird area scale within the next 10 years.

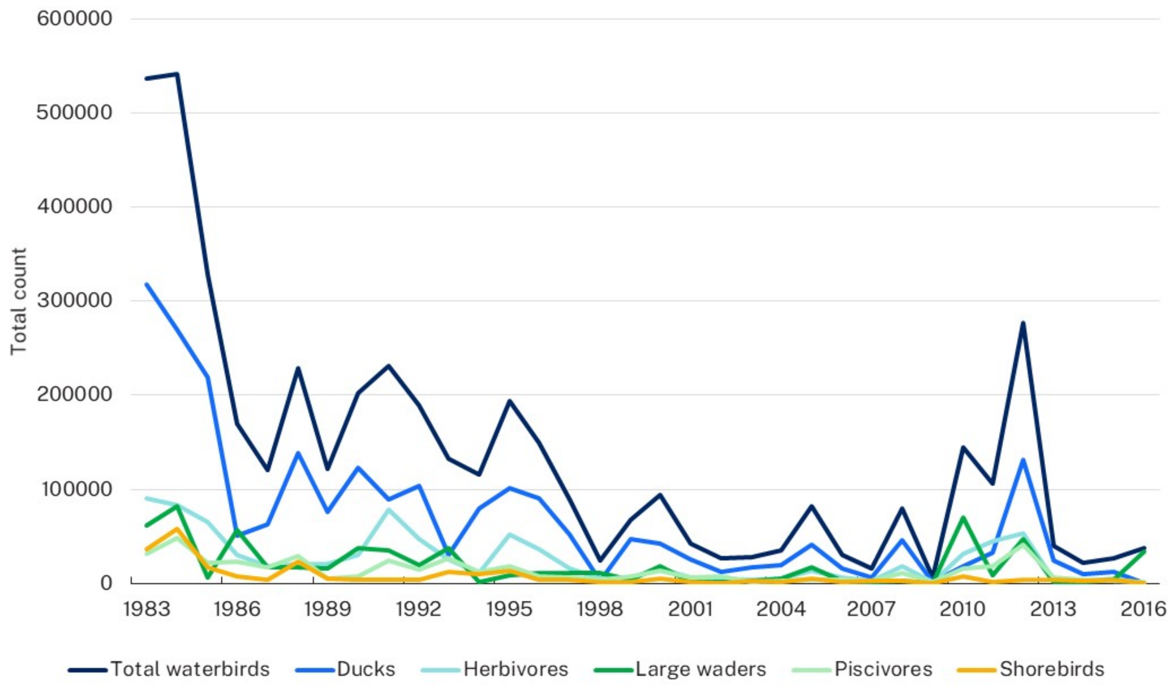

Figure B.8 **Total waterbird abundance (and total of each BWS functional group, ducks, herbivores, large waders, piscivores, shorebirds) recorded in the NSW MDB during long-term aerial surveys (1983–2016) (Porter et al. 2016)**

The NSW LTWP waterbird objectives' intent for the next 5 years is to record no further decline in total waterbird abundance in the waterbird areas and a maintenance of waterbird abundance recorded over the 2012–2016 period. This baseline period includes some recovery in waterbird abundance after the 2010–2012 flood events (Figure B.8) and the delivery of environment water to many of the waterbird areas in NSW including the Gwydir Wetlands, Macquarie Marshes, Lower Lachlan, Mid Murray and Lowbidgee Floodplain.

The MDBA expected outcomes for waterbirds are based on medium-term improvements in waterbird breeding between 2020 and 2030 resulting in increased waterbird abundance in the MDB by 2030–2035 (see Figure B.2).This is because it is recognised it will take some time for waterbird populations to respond to improved flow regimes (MDBA 2014, 2017), as recruitment of young birds into the adult population is needed for total numbers of waterbirds to increase. Following 10 years of coordinating flows for waterbirds we would expect waterbird numbers to increase across the waterbird areas in response to increased habitat availability.

Objective 3: Increase opportunities for non-colonial waterbird breeding

Ecological objective	Quantified targets	2024 evaluation (measure of success)
Increase opportunities for non-colonial waterbird breeding	Maintain number of non-colonial breeding species and total abundance of non-colonial waterbirds in the waterbird area[25] as determined by annual surveys[26]	No decline in number of breeding non-colonial species and total abundance of non-colonial waterbirds in the waterbird area[25] in the 2019–2024 period
	Increase in total non-colonial waterbird abundance in the waterbird area[25] by 20–25%[27] in the next 10 years	Evaluated in 2029 for the 2019–2029 period with a further target set for the 2029–2039 period

Modelling of waterbird abundance under different water development scenarios showed that with decreased water diversions waterbird breeding abundance across the MDB would increase (by 28–40% depending on the level of water recovery) (Figure 6) (Bino et al. 2014). The abundance of non-colonial waterbirds (i.e. waterfowl, grebes, water hens, shorebirds) is linked to breeding outcomes for this group of species in the previous water year. For example, where there are records of waterbird breeding in non-colonial (and also colonial) waterbird species there tends to be a large increase in waterbird total abundance in the following spring (Bino et al. 2014). As the aerial and ground surveys tend to underestimate total number of broods for non-colonial waterbird species due to the cryptic nature of many species' breeding behaviour, we developed an additional target based on the number of observed breeding species from both aerial and ground surveys.

Objective 4: Increase opportunities for colonial waterbird breeding

Ecological objective	Quantified targets	2024 evaluation (measure of success)
Increase opportunities for colonial waterbird breeding	Support waterbird colonies[28] in waterbird area[29] by maintaining the water depth and duration of flooding (as required) to support breeding through to completion (from egg laying through to fledging including post-fledgling care) and maintain duration of flooding in key foraging habitats to enhance breeding success and the survival of young	Successful[30] waterbird breeding in colonies active during the 2019–2024 period Water levels in waterbird colonies and associated foraging habitats active in the 2019–2024 period maintained for duration of breeding

[25] Waterbird areas (Figure B.7) are defined for each WRPA based on the location of BWS waterbird assets and NSW LTWP watering priorities (see Appendix 6.2).

[26] Annual spring survey data collected through UNSW annual aerial surveys and ground surveys (where available) for the 2012–2016 period.

[27] In line with the expected outcome in the BWS (MDBA 2014) of a significant improvement in waterbird populations in the order of 20–25% across the MDB, with increases in all waterbird functional groups. We expect local increases in waterbird abundance to also be observed at the waterbird area scale within the next 10 years.

[28] A colony is a site supporting nesting colonial waterbird species identified in Appendix 6.3.

[29] Waterbird areas (Figure B.7) are defined for each WRPA based on the location of BWS waterbird assets and NSW LTWP watering priorities (see Appendix 6.2).

[30] Successful breeding relates to completion of nests where fledglings and juvenile birds are observed at the end of each breeding event.

Ecological objective	Quantified targets	2024 evaluation (measure of success)
	Where possible[31], initiate and support small-scale colonial waterbird breeding in line with natural cues in the waterbird area in 2 out of 5 years	Small-scale colonial waterbird breeding recorded in the waterbird area and successfully[27] completed in 2 years of the 2019–2024 period

Increasing the frequency and duration of inundation events will increase opportunities for colonial waterbird breeding and influence the recovery of waterbird populations in the MDB. Environmental water can be used to augment natural large flow events to maintain the duration and extent of inundation in active colony sites. Environmental water was delivered in 5 NSW WRPAs during 2006–2016 to extend the duration of flooding in breeding and foraging habitats to maximise breeding success during large flood events. Widespread overbank flooding occurred during the high flow years of 2010–11 and 2011–12, supporting more colony sites, more breeding species, a greater number of large breeding events (>1,000 nests) and a larger number of nests overall compared to other years. The intervening low–moderate flow years in the 2006–2016 period supported some small-scale breeding (<500 nests) but this was largely restricted to the southern catchments (Murrumbidgee and NSW Murray) where environmental water was used to initiate and support colonial waterbird breeding (Spencer 2017).

Bino et al. (2014) used long-term records of colonial waterbird breeding in Australia collated by Brandis (2010) to identify important breeding sites in the MDB. This analysis focused on 9 colonial waterbird species only, for which there were long-term records of breeding. Important sites in NSW are listed in Appendix 6.1 and include the Narran Lakes, Lowbidgee Floodplain, Macquarie Marshes, Barmah–Millewa Forest, Booligal Wetlands and Gwydir Wetlands. The Lowbidgee Floodplain, Macquarie Marshes, Narran Lakes and Paroo Overflow Lakes supported the greatest (more than 6 species) number of breeding species (Bino et al. 2014). There were significant relationships with total flow volume across the MDB and the number of colonial waterbird breeding events (Bino et al. 2014). The expected increase of 50% colonial waterbird breeding events specified in the BWS (MDBA 2014) was based on a modelled scenario, where flows conducive to breeding (flow thresholds exceeded for more than 3 months) were identified in water recovery scenarios as an improvement compared to the baseline scenario, with any change representing increases in opportunity for breeding (Bino et al. 2014).

Determining appropriate quantified targets to measure colonial waterbird breeding in relevant waterbird areas was influenced by the location of each colony site and the level of management interventions possible for managing colonial waterbird breeding in each WRPA. Major colonial waterbird breeding is triggered in the waterbird areas by natural large-scale flooding and high rainfall in the upper catchment of each WRPA. Colonial waterbird breeding responses can include the number of breeding events, number of active colony sites, total number of breeding colonial waterbird species, estimated total number of nests (e.g. see Figure B.9), and success of breeding (measured on-ground in terms of evidence of completion of nesting) and additional data on water levels and extent and duration to measure the effectiveness of watering actions aimed to maintain breeding events.

[31] In line with the expected outcome in the BWS (MDBA 2014) of an increase in breeding events by 2024 (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds. Initiation of small-scale colonial waterbird breeding (for small egrets, herons, spoonbills and cormorant colonies rather than large egret, heron and ibis breeding events) is largely limited to the mid Murrumbidgee wetlands, mid Murray and Lowbidgee Floodplain, where management interventions are possible to create conditions where these species will breed in small numbers (generally <500 nests in total).

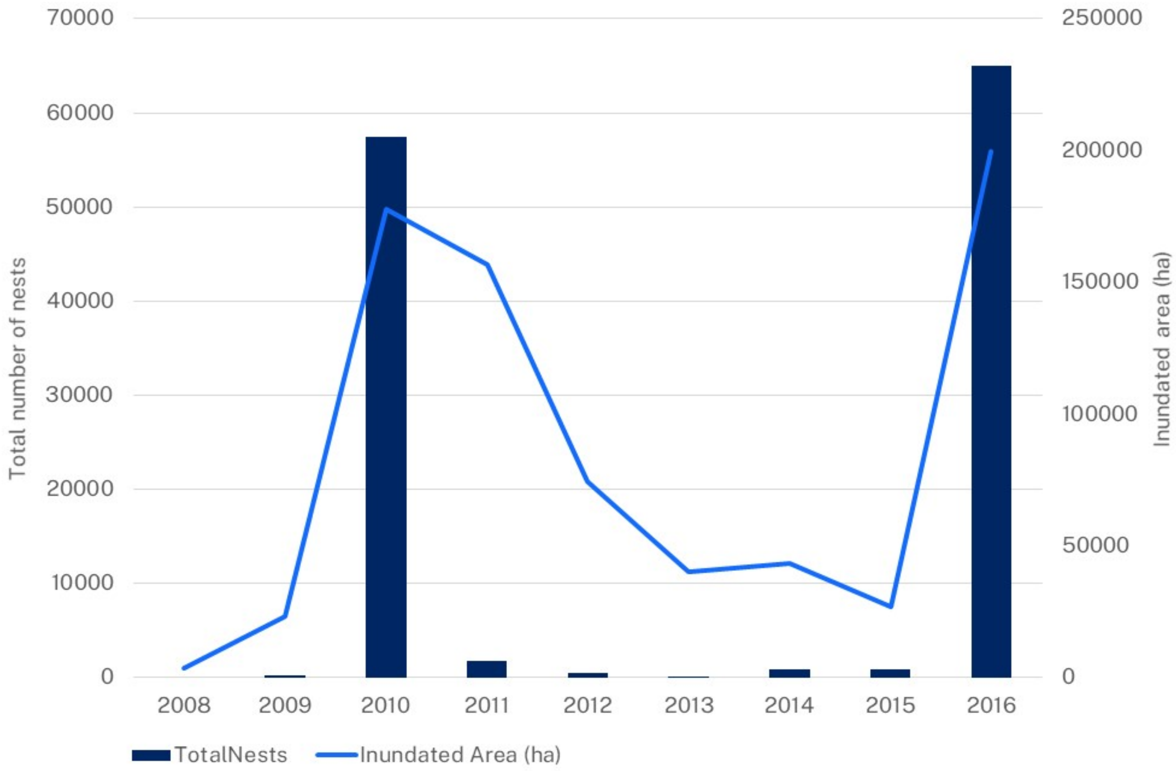

Figure B.9 Total number of nests of colonial waterbird species (e.g. egrets, herons, ibis, spoonbills and cormorants) recorded in the lower Murrumbidgee wetlands from 2008–2016

Total cumulative inundated area (in hectares) recorded during water years associated with breeding records was determined through analysis of Landsat satellite imagery (Thomas and Heath 2017).

Objective 5: Improve extent and condition of waterbird habitats

Ecological objective	Quantified targets	2024 evaluation (measure of success)
Maintain extent and improve condition of waterbird habitats	Maintain extent and improve condition of nesting vegetation, including river red gum, common reed, lignum, cumbungi, river cooba, in known breeding locations in the waterbird area	Water requirements (duration and frequency of inundation) of key vegetation communities at colony sites
	Maintain or increase extent and improve condition of waterbird foraging habitats and potential colonial waterbird breeding locations in the waterbird area	To be evaluated under LTWP targets set for native vegetation in the waterbird area

Colonial waterbird species are dependent on relatively few sites across the major wetlands of the MDB (Brandis 2010; Spencer 2017). The dominant vegetation types of active colony sites in the 2006–2016 period were river red gum (67% of sites), lignum (15%), river cooba (7%) and common reedbeds (5%) (Spencer 2017). Waterbird habitat condition is not listed in the BWS but can be assessed through the LTWP vegetation targets set for key foraging (non-woody vegetation) and breeding habitats (river red gum, lignum, river cooba and common reedbeds). The condition of known colony sites can also be assessed in terms of whether flows delivered over 5, 10 and 20-year timeframes have met the water requirements (duration and frequency of inundation) of nesting vegetation. This approach can be done through remotely sensed data collection of inundation patterns, which would be particularly valuable to assess the effectiveness of flows targeted to restore historical breeding sites.

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7. Priority ecosystem functions objectives and targets

7.1 Background

Hydrodynamic diversity is critical to supporting ecosystem functions as it:

- provides a myriad of habitat types
- supports geomorphic processes such as sediment transport and deposition
- allows the dispersal of biota across the Basin
- provides food resources by transferring energy and nutrients between environments
- supports productivity pathways
- allows interactions between groundwater and surface water, and
- supports soil health (MDBA 2014).

Through the construction of water regulating infrastructure and increasing water extraction, hydrodynamic diversity has been significantly disturbed across the MDB (MDBA 2014). Changes in the natural flow regime have impacted on the health, abundance and range of many water-dependent species. The use of water for the environment aims to restore ecologically significant parts of the flow regime to a more natural pattern.

Habitat recovery and restoration is a complex issue and requires supporting physical, biological and chemical processes to ensure ecosystem functioning and the maintenance of resulting ecosystem services (Geist and Hawkins 2016). There are 11 expected outcomes of environmental water delivery at the Basin scale to support priority ecosystem functions (PEFs), including longitudinal and lateral connectivity and end-of-basin flows (Table B.14) (MDBA 2014). These expected outcomes relate to maintaining and increasing the magnitude and frequency of in channel flows and flows that connect rivers with floodplains, wetlands and anabranches. The outcomes also look to support end-of-basin flows and improved water quality that will support a variety of quality aquatic habitats.

Table B.14 The BWS describes expected Basin-wide outcomes related to longitudinal and lateral connectivity, and end-of-basin flows by 2024 (MDBA 2014)

BWS objective	Expected outcomes
Improve longitudinal connectivity	Keep baseflows at least 60% of the natural level[32]. A 10% overall increase in flows in the Barwon–Darling: from increased tributary contributions from the Condamine–Balonne, Border Rivers, Gwydir, Namoi and Macquarie–Castlereagh catchments collectively. A 30% overall increase in flows in the River Murray: from increased tributary contributions from the Murrumbidgee, Goulburn, Campaspe, Loddon and Lower Darling catchments collectively. A 30–40% increase in flows to the Murray mouth.
Improve lateral connectivity	A 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows in the Murray, Murrumbidgee, Goulburn–Broken and Condamine–Balonne catchments. A 10–20% increase in freshes and bankfull events in the Border Rivers, Gwydir, Namoi, Macquarie–Castlereagh, Barwon–Darling, Lachlan, Campaspe, Loddon and Wimmera catchments. Current levels of connectivity maintained in the Paroo, Moonie, Nebine, Ovens and Warrego catchments.
Improve end-of-basin flows	The barrage flows are greater than 2,000 GL/year on a 3-year rolling average basis for 95% of the time, with a 2-year minimum of 600 GL at any time. The water levels in the Lower Lakes are maintained above: • sea level (0 m AHD) and • 0.4 m AHD, for 95% of the time, as far as practicable, to allow for barrage releases. Salinity in the Coorong and Lower Lakes remains below critical thresholds for key flora and fauna including: • salinity in Lake Alexandrina is lower than 1,000 EC 95% of the time and less than 1,500 EC all the time • salinity in the Coorong's south lagoon is less than 100 grams per litre 95% of the time. The Murray mouth is open 90% of the time to an average annual depth of 1 m.

7.2 Approach to developing PEF objectives and targets

We collated ecosystem function information for the NSW portion of the MDB to inform 3 steps to inform development of LTWP objectives and targets, including:

- identification and description of the broad range of ecosystem functions that are supported by healthy inland aquatic environments
- determining where in a catchment the PEFs might occur in the NSW MDB, and what types of flows support them
- development of objectives and targets based on the most practical indicators for each WRPA.

[32] Some less-developed rivers have baseflows greater than 60% of natural. Where this is the case, the aim is to protect that current level of flow. In other catchments, baseflows are currently well below the target of 60% of natural flows, especially during dry times. Cease-to-flow events should not exceed natural, where possible.

7.2.1 Describing PEFs

As described in Chapter 8, Part 5 of the Basin Plan, a PEF is 'an ecosystem function that requires environmental watering to sustain it'. Section 8.50 provides some requirements for identifying PEFs based on criteria specified in Schedule 9.

The Basin Plan and the BWS were used as a framework to begin to identify PEFs. Significant bodies of work exist that describe aquatic ecosystem functions and the processes that support them. This information, in addition to expert scientific input, helped to identify additional ecosystem functions that can be supported by flow management and the greater volumes of water for the environment available under the Basin Plan (Table B.15). The PEFs considered in the NSW LTWPs include: creation and maintenance of habitats (including groundwater-dependent ecosystems (GDEs)), provision of refugia, nutrient cycling and fluxes, food webs and trophic dynamics, and longitudinal and lateral connectivity between riverine and floodplain habitats to facilitate energy transfer and the movement and dispersal of biota (within and between catchments).

Section 8.50 Method for identifying ecosystem functions that require environmental watering and their environmental watering requirements

1. An ecosystem function that requires environmental watering to sustain it, and its environmental watering requirements, must be identified having regard to the information on the environmental assets and ecosystem functions database, using the following method:

a. identify any ecosystem function that meets one or more of the assessment indicators for any of the 4 criteria specified in the table in Schedule 9

b. identify the ecosystem functions that can be managed with environmental water (priority ecosystem function)

c. For priority ecosystem functions, identify ecological objectives that are consistent with the criteria used to identify those ecosystem functions

d. Identify ecological targets to achieve those objectives

e. In accordance with section 8.51, determine the environmental watering requirements needed to meet the targets in order to achieve the objectives

2. This method may be applied in a flexible manner, having regard to the particular circumstances.

Table B.15 Criteria for identifying an ecosystem function, as described in Schedule 9 of the Basin Plan, and the corresponding LTWP functions

Criterion	Assessment indicators	Relevant LTWP functions
The ecosystem function supports the creation and maintenance of vital habitats and populations	Provides a refugium for native water-dependent biota during dry periods and drought Provides pathways for the dispersal, migration and movement of native water-dependent biota	Refuge for water-dependent biota during dry periods Diversity of wetted areas for feeding, breeding and nursery sites Hydrodynamic diversity Regulation of water quality

Criterion	Assessment indicators	Relevant LTWP functions
	Provides a diversity of important feeding, breeding and nursery sites for native water-dependent biota Provides a diversity of aquatic environments including pools, riffle and run environments Provides a vital habitat that is essential for preventing the decline of native water-dependent biota	Surface–groundwater interactions
The ecosystem function supports the transportation and dilution of nutrients, organic matter and sediment	Provides pathways for the dispersal and movement of organic and inorganic sediment Supports the dilution of carbon and nutrients from the floodplain to the river systems	Erosion and deposition of sediment Transfer of energy and nutrients between environments Nutrient cycling Aquatic primary productivity Aquatic secondary productivity
The ecosystem function provides connections along a watercourse (longitudinal connections)	Supports dispersal and recolonisation of native water-dependent communities Supports migration to fulfil requirements of life-history stages Supports instream primary production	Dispersal and movement of aquatic biota Aquatic primary productivity Aquatic secondary productivity
The ecosystem function provides connections across floodplains, adjacent wetlands and billabongs (lateral connectivity)	Provides lateral connections for foraging, migration and recolonisation of native water-dependent species and communities Provides lateral connections for off-stream primary production	Dispersal and movement of aquatic biota Transfer of energy and nutrients between environments Terrestrial primary productivity
N/A	N/A	Soil salinity Soil nutrient bioavailability Soil biota Soil carbon accretion

Once the broad range of relevant PEFs were identified, they were grouped into broad categories and the specific ecosystem processes that support each function were described (Table B.16). These were drafted based on published research and refined during a series of workshops with scientific experts from universities and state and federal government departments (Alluvium 2010).

The BWS PEF outcomes are mainly related to flows, so it was possible to match them with the LTWP PEFs and ecosystem processes they supported. This was an important step to ensure the BWS outcomes would be supported by the PEFs identified in the LTWPs, and later helped to inform setting the LTWP objectives and targets.

Table B.16 PEFs and the specific processes identifed for the LTWPs grouped into categories, and linked to the specific BWS themes and expected outcomes

Function category	Function	Specific processes	BWS theme	BWS expected outcome
Habitat	Refuge for water-dependent biota during dry periods	Regulation of water quality and depth Sediment transport (e.g. to maintain pool depth)	Longitudinal connectivity Lateral connectivity	• keep base flows at least 60% of the natural level • 10% overall increase in flows in the Barwon–Darling[33] • 30% overall increase in flows in the River Murray[34]: • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows[35] • 10–20% increase of freshes and bankfull events[36] • current levels of connectivity maintained[37]
	Diversity of wetted areas for feeding, breeding and nursery sites	Inundation of instream, wetland and floodplain habitat Creation of inundation–drying phases and disturbances through drying Support natural geomorphic processes (i.e. sediment transport processes that maintain geomorphic features in the main channel, lateral channels and riparian zone; recruitment of snags into channels)	Longitudinal connectivity Lateral connectivity	• keep base flows at least 60% of the natural level • 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events • current levels of connectivity maintained

[33] From increased tributary contributions from the Condamine–Balonne, Border Rivers, Gwydir, Namoi and Macquarie–Castlereagh catchments collectively

[34] From increased tributary contributions from the Murrumbidgee, Goulburn, Campaspe, Loddon and Lower Darling catchments collectively

[35] Relevant in the Murray and Murrumbidgee catchments

[36] Relevant in the Border Rivers, Gwydir, Namoi, Macquarie–Castlereagh, Barwon–Darling and Lachlan catchments

[37] Relevant in the Paroo, Moonie, Nebine, Ovens and Warrego catchments

Function category	Function	Specific processes	BWS theme	BWS expected outcome
	Hydrodynamic diversity	Appropriate magnitude of flows and connectivity with habitat features that create turbulence, slackwater, fast velocities, etc. Flow variability Sediment transport processes that maintain geomorphic features in channels Recruitment of snags into channels	Longitudinal connectivity Lateral connectivity	• keep base flows at least 60% of the natural level • 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events
	Regulation of water quality	Filtering and sequestering of nutrients Dilution of nutrients, sediment and dissolved organic carbon (DOC) Transport and replenishment of dissolved oxygen Temperature regulation Mixing processes as a water parcel moves downstream Salinity regulation	Longitudinal connectivity Lateral connectivity End-of-basin flows	• keep base flows at least 60% of the natural level • 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–40% increase in flows to the Murray mouth • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events • current levels of connectivity maintained • salinity in the Coorong and Lower Lakes remains below critical thresholds for key flora and fauna
Geomorphic processes	Erosion and deposition of sediment	Erosion and deposition processes in-channel (bed, banks, bars, benches) Avulsion Transport of sediment to floodplain Maintenance of waterways and effluent streams	Longitudinal connectivity Lateral connectivity	• 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–40% increase in flows to the Murray mouth • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events • current levels of connectivity maintained

Function category	Function	Specific processes	BWS theme	BWS expected outcome
Dispersal / movement of biota	Dispersal and movement of aquatic biota	Longitudinal and lateral connectivity, including between catchments	Longitudinal connectivity Lateral connectivity	• keep base flows at least 60% of the natural level • 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–40% increase in flows to the Murray mouth • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events • current levels of connectivity maintained
Food resources	Transfer of energy and nutrients between environments: • floodplain – channels • wetlands – channels • in-channel features – lateral channels	Appropriate flows and connectivity (lateral and longitudinal) Flow variability Sediment transport processes that maintain geomorphic features in river channels, wetlands and on the floodplain Recruitment of snags into channels	Longitudinal connectivity Lateral connectivity	• keep base flows at least 60% of the natural level • 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–40% increase in flows to the Murray mouth • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events
	Aquatic primary productivity	Algal production Phytoplankton production Macrophyte growth Biofilm growth	Longitudinal connectivity Lateral connectivity	• keep base flows at least 60% of the natural level • 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–40% increase in flows to the Murray mouth • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events

Function category	Function	Specific processes	BWS theme	BWS expected outcome
	Terrestrial primary productivity	Growth and recruitment of amphibious and inundation-tolerant vegetation (macrophytes and understorey vegetation)	Lateral connectivity	• 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events
	Aquatic secondary productivity	Zooplankton production Support macroinvertebrates Breeding, growth and recruitment of decapods (shrimp/crayfish) Support fish larvae[38]	Longitudinal connectivity Lateral connectivity	• 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events
	Nutrient cycling	Flows and connectivity (within and between catchments) Sediment supply and transport, especially from unregulated tributaries Transport and retention of nutrients in channels Wetting–drying of channel features Decomposition or organic matter	Longitudinal connectivity Lateral connectivity	• 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–40% increase in flows to the Murray mouth • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events
Groundwater interactions	Surface–groundwater interactions	Groundwater recharge and discharge Dilution of saline groundwater Export salt from the MDB	Lateral connectivity	• 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events
Soil health	Soil carbon accretion	Accretion of carbon on floodplain	Lateral connectivity	• 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events
	Soil biota	Soil microbial structure, biomass and activity in floodplain soils	Lateral connectivity	• 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows

[38] Look for a boom in larvae being produced, e.g. 90 days after inundation

Function category	Function	Specific processes	BWS theme	BWS expected outcome
	Soil nutrient bioavailability[39]	Accretion of soil nitrogen and phosphorus on floodplains	Lateral connectivity	• 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows
	Soil salinity	Soil salinity processes Groundwater recharge and discharge	Longitudinal connectivity Lateral connectivity	• keep base flows at least 60% of the natural level • 10% overall increase in flows in the Barwon–Darling • 30% overall increase in flows in the River Murray • 30–60% increase in the frequency of freshes, bankfull and lowland floodplain flows • 10–20% increase of freshes and bankfull events

[39] Also covered in Nutrient cycling function in the Food resources category

7.2.2 Available datasets

Multiple sources of information were used to identify PEFs, and these varied between catchments depending on what specific information was available for each location. Sources of information included:

- hydrological data (modelled and observed daily flow rates)
- published research
- current monitoring programs, such as the CEWO Long Term Intervention Monitoring (LTIM) project led by the University of Canberra
- targeted engagement with aquatic ecosystem function experts
- water quality guidelines, such as ANZECC water quality guidelines and the WRP water quality management plans
- water managers' experience from delivering water for the environment, especially around lateral and longitudinal connectivity
- LTWP objectives and targets for other species and their specific life-history requirements.

7.2.3 Establishing spatial boundaries

Establishing the spatial boundaries for a PEF involved 3 main steps:

- describing the different types of environments that occur in the MDB
- identifying the environment type where the PEF is most likely to occur
- attributing PEFs to specific planning units in a catchment.

Many of the specific functions identified initially could be grouped because they occurred in similar types of environment and were supported by similar flow regimes. This later helped to focus the number of objectives and targets in the LTWP.

Table B.17 PEFs and their key contributing processes and where they are likely to occur in the catchment

Priority ecosystem function	Key contributing processes	Where is it likely to occur?
Refuge for water-dependent biota during dry periods or drought	• Regulation of water quality and depth • Sediment transport (e.g. to maintain pool depth) • Surface–groundwater interactions	Everywhere • River channels (especially pools) • Wetlands • Lakes (perennial)
Diversity of quality wetted habitat for feeding, breeding and nursery sites	• Inundation of instream, wetland and floodplain habitat • Longitudinal and lateral connectivity: o at range of spatial scales (in channel features – inter-catchment) o between different aquatic and terrestrial assets o on floodplains: inundation of a diversity of wetland types and forest–woodland–non-woody vegetation types	• Wetlands • Floodplains • River channels • Lateral channels • Weir pools

Priority ecosystem function	Key contributing processes	Where is it likely to occur?
	• Appropriate magnitude of flows and connectivity with habitat features that create turbulence, slackwater, fast velocities, etc. • Creation of wetting–drying phases and disturbance through drying • sediment transport processes that maintain geomorphic features in the main channel, lateral channels and riparian zone • recruitment of snags into channels (supporting riparian veg. recruitment for future supply of snags)	
Erosion and deposition of sediment Energy and nutrient cycling Soil carbon accretion	• Erosion and deposition processes • Avulsion • Transport of sediment to floodplain • Maintenance of waterways / effluent streams • Flows and connectivity (within and between catchments) • Sediment supply and transport, especially from unregulated tributaries (many nutrients are transported adsorbed onto fine sediment particles) • Transport and retention of nutrients in channels • Wetting–drying of channel features • Decomposition of organic matter • Accretion of carbon on floodplain (e.g. through macrophyte growth)	• All channels • Lateral channels • Wetlands • Floodplains
Dispersal and movement of aquatic biota	• Longitudinal and lateral connectivity, including between catchments	• Channels • Floodplains • Wetlands • Between catchments
Aquatic and terrestrial primary productivity	• Algal production • Phytoplankton production • Macrophyte growth • Biofilm growth • Growth and recruitment of amphibious and inundation-tolerant vegetation (macrophytes and understorey veg.)	• Floodplains • Channels: bed, bars, benches, banks (esp. lateral margins of wetted area) • Wetlands • Weir pools • Ephemeral/lateral channels • Riparian zone • Wetland margins
Surface–groundwater interactions	• Groundwater recharge and discharge • Dilution of saline groundwater • Export of salt from MDB	• Riparian areas • Floodplains

7.3 Setting PEF objectives and targets

7.3.1 Expected outcomes

The BWS specifies outcomes for flows and connectivity expected by 2024 as a result of increased water availability for the environment and more coordinated Basin-scale water management (MDBA 2014). The LTWP builds on these broad outcomes and describes the specific ecosystem functions that should be supported from implementing the Basin Plan and the LTWP. The 8 PEF objectives that the LTWP aims to support relate to:

- protecting a diversity of refugia
- creating quality habitats
- providing movement and dispersal opportunities to water-dependent species
- supporting instream and floodplain productivity
- supporting nutrient, carbon and sediment transport
- supporting groundwater-dependent biota
- increasing the contribution of flows into downstream catchments.

7.3.2 LTWP objectives and targets

The process of setting objectives and targets to support the identified PEFs in the NSW MDB began with the long list of PEFs identified through research and workshops. PEFs were grouped together if they:

- were likely to occur in similar environments (e.g. channels or wetlands) (Table B.17)
- were supported by similar BWS outcomes or hydrological indicators (Appendix 10.7, Table B.16)
- were supported by similar flow categories (Appendix 10.7).

This grouped set of PEFs was used to describe the outcomes that are required to support healthy functioning ecosystems, and that are expected as a result of improved water management and the additional water for the environment available under the Basin Plan. An additional connectivity specific objective was included to capture specific end-of-system flow requirements as specified in the BWS.

Monitoring is not currently comprehensive within or across all catchments for many of the PEFs, making it difficult to track progress towards the LTWP objectives. A pragmatic approach was taken and many of the LTWP PEF targets were developed based on what could be practically monitored. The targets include water quality parameters such as dissolved oxygen and salinity concentrations and surrogate hydrological indicators expressed as various environmental water requirement (EWR) parameters (flow magnitude, timing, duration, frequency, inter-event period) and other related indicators that can be used to infer support of PEF objectives.

Specific objectives and targets were not set for soil health as there is currently minimal monitoring of soil health in the context of environmental watering, so there is no baseline to work from. Additionally, monitoring and evaluation workplans across the NSW MDB do not include plans for future monitoring of any indicators of soil health. SMART targets could therefore not be developed. It was discussed and agreed with the expert panel at the workshops that flows for other PEFs would support soil health and therefore specific objectives and targets for soil health were not essential.

7.4 References

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Table B.18 LTWP PEF objectives, description of the key contributing processes, and potential indicators to monitor progress towards objectives

Ecological objective		Description and key contributing processes	Potential indicators[40]
Provide and protect a diversity of refugia across the landscape		Water depth and quality in pools (in-channel), core wetlands and lakes Condition of vegetation in core wetlands and riparian zones	Recommended EWR metrics (especially very low flows, baseflows, wetland inundating flows and cease-to-flows) Adequate water depth is maintained in key refuge pools during dry times Maintain permanent inundation of acid sulphate soils Maintain dissolved oxygen >4 mg/L at key gauges or in key refuge pools Salinity targets at key sites (e.g. end of system)
Create quality instream, floodplain and wetland habitat		Regulation of dissolved oxygen, salinity and water temperature Flow variability and hydrodynamic diversity Provision of diverse wetted areas Appropriate wetting and drying cycles Geomorphic (erosion / deposition) processes that create and maintain diverse physical habitats Appropriate rates of fall to avoid excessive bank erosion Control of woody-vegetation encroachment into river channels and wetlands	Rates of rise and fall (do not exceed the 5th and 95th percentiles respectively of natural rates) Natural wetting and drying regimes Recommended EWR metrics (especially cease-to-flows, freshes, and overbank and/or wetland inundating flows) Recommended flow velocities (especially in weir pools and in-channel flows)
Provide movement and dispersal opportunities for	(a) within catchments	Dispersal of eggs, larvae, propagules and seeds downstream and into off-channel habitats Migration to fulfill life-history requirements	Annual detection of species and life stages representative of the whole fish community across the catchment

[40] List of all potential indicators to measure progress towards achieving the LTWP objectives. Specific targets may vary between catchments and planning units depending on the specific requirements of the environment and current available information. Specific PEF targets for each catchment can be found in Appendix 7.1.

Ecological objective		Description and key contributing processes	Potential indicators[40]
water-dependent biota to complete lifecycles and disperse into new habitats	(b) between catchments	Foraging of aquatic species Recolonisation following disturbance	Recommended EWR metrics for flows that provide longitudinal and lateral connectivity (especially baseflows, freshes, bankfull, overbank and wetland inundating flows) Dispersal opportunities for key moderate to long-lived riverine and flow-pulse specialist native fish species
Support instream and floodplain productivity		Aquatic primary productivity (algae, macrophytes, biofilms, phytoplankton) Terrestrial primary productivity (vegetation) Aquatic secondary productivity (zooplankton, macroinvertebrates, fish larvae, adult fish) Decomposition of organic matter	Native fish condition metrics Abundance and distribution of decapod crustaceans Supply of autochthonous and allochthonous carbon and nutrients Native vegetation condition metrics Native fish population structure
Support nutrient, carbon and sediment transport along channels and between channels and floodplains/ wetlands		Sediment delivery to downstream reaches and to/from anabranches, floodplains and wetlands Entrainment of carbon and nutrients from dry in-channel surfaces (e.g. benches and banks), floodplains and wetlands to support production by aquatic species Dilution of carbon and nutrients that have returned to rivers	Nutrient and carbon (DOC) pulses detected at multiple locations along channels Extent and condition of floodplain vegetation Recommended EWR metrics (especially large freshes, bankfull, overbank and wetland inundating flows) Organic matter storage capacity of wetland and floodplain soils (i.e. soil nitrogen, phosphorus and carbon levels)
Support groundwater conditions to sustain groundwater-dependent biota		Groundwater recharge and discharge Dilution of saline groundwater Salt export from the MDB	Mapped extent of groundwater-dependent vegetation communities Groundwater levels
Increase the contribution of flows into downstream catchments[41]		Provision of end of system flows (NSW lower Murray and Lower Darling River) to support ecological objectives in downstream catchments (South Australian River Murray)	Recommended EWR metrics (especially for in-channel connecting flows to the South Australian River Murray and small overbank flows)

[41] Relevant downstream catchment specified in each LTWP, where applicable

8. Frogs and other species objectives and targets

8.1 Background

The NSW LTWPs identify the water needs of other water-dependent species (other species), in addition to vegetation, fish and waterbirds that occur through the NSW MDB. Although these additional fauna groups were not recognised in the BWS (MDBA 2014) many frogs, turtles, snakes, water rats, bats, platypus and woodland bird species benefit from the inundation of wetland habitat by natural and managed flows. For this reason, 5 of the 9 NSW LTWPs have objectives and targets for other species to inform monitoring activities and to better understand their responses over time to water management.

Frog species are included in the LTWPs as they are an indicator of wetland health and respond to water management (Gibbons et al. 2006; Ocock et al. 2014). Flow-dependent frogs, in particular, are considered important due to their strong relationship with overbank flows for habitat and breeding and their reliance on aquatic refuge habitat during periods of drought. Several studies in the NSW MDB have documented the importance of floodplain wetland habitat for flow-dependent frog species and their responses to environmental watering. Species include the spotted marsh frog *Limnodynastes tasmaniensis*, barking marsh frog *Limnodynastes fletcheri* and eastern sign-bearing frog *Crinia parinsignifera* (McGinness et al. 2014; Ocock et al. 2014; Walcott et al. 2020; Wassens and Maher 2011). The nationally vulnerable southern bell frog *Litoria raniformis* (Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)) has also been successfully supported with water for the environment, with evidence of breeding recorded in response to watering in the southern MDB (Wassens et al. 2019; Waudby et al. 2020).

Other water-dependent fauna species, such as freshwater turtles, have similar habitat requirements to frogs. The eastern long-necked turtle *Chelodina longicollis,* broad-shelled turtle *Chelodina expansa* and Macquarie river turtle *Emydura macquarii macquarii* are the 3 most commonly detected species in the NSW MDB (Chessman 2012). There is limited knowledge on freshwater turtle responses to floodplain inundation; however, the broad-shelled turtle and Macquarie river turtle distributions have been found to be restricted to frequently inundated wetlands, while eastern long-necked turtles utilised a broader range of aquatic habitats (Ocock et al. 2018). Maintaining core and refuge habitat for all 3 species is crucial for their survival.

Platypus are an important top predator in freshwater environments in Australia, and an excellent indicator of the productivity of aquatic systems (Hawke et al. 2019; Serena and Williams 2010). They are reliant on adequate surface water flows to support foraging and provide protection from predators, while riparian vegetation provides protection and promotes favourable habitat conditions for their invertebrate prey (Serena and Williams 2010). Platypus feed in slow moving riffle habitats on benthic invertebrates, including aquatic insect larvae, crustaceans, molluscs, worms, as well as fish eggs and potentially, small frogs (Connolly et al. 2016). While they can still be found in about 80% of the west-flowing river systems in NSW, evidence suggests their populations have declined in many parts of their range (Bino et al. 2018; Serena and Williams 2010). Several studies have reported fragmentation of platypus distribution within individual river systems attributed to loss of riparian vegetation, stream bank erosion, and channel sedimentation, flow regulation, drought, climate change, water quality, and exotic species (Grant and Temple-Smith 2003; Serena and Williams 2010).

Some woodland bird species are highly dependent on floodplain woodland communities and many of these species have been declining across inland NSW in recent decades (McGinness et al. 2010). Woodland bird community composition has been linked to floodplain tree canopy health. For example, Blackwood et al. (2010) found that woodland bird community composition varied between river red gum sites in good and poor condition in the Macquarie Marshes, with good sites typically having a denser canopy and thicker understorey. There is also some evidence that flood events can have long-term benefits for woodland bird species (Blackwood et al. 2010; Parkinson et al. 2002), as the peak emergence of invertebrate prey following flooding can coincide with peak numbers of woodland birds. In some instances, this increase in food abundance can influence bird numbers up to 3 years later in sites that have been flooded (Parkinson et al. 2002).

8.2 Approach to developing objectives and targets

8.2.1 Available datasets

Frog species records were collated from NSW-wide datasets (BioNet – Atlas of NSW Wildlife) and existing monitoring programs within the NSW MDB (NSW BioNet 2016). These data provided presence/absence information for frog species at an individual site scale across the NSW MDB. Records from 1980 to 2016 from the NSW BioNet – Atlas of NSW Wildlife were used to establish a list of frog species for which environmental water requirements (EWRs) were developed. Data from monitoring programs in the last decade was available in 5 of the 9 NSW WRPAs and used to inform objectives and targets for relevant LTWPs. This included the Gwydir, Macquarie–Castlereagh, Lachlan, Murrumbidgee and NSW Murray–Lower Darling WRPAs.

The NSW Department of Planning and Environment – Environment and Heritage Group (DPE–EHG) have run an annual spring frog monitoring program in the Gwydir Wetlands since 2015 (including lower Gwydir, Gingham, Mallowa Creek and Mehi watercourses) and the Macquarie Marshes since 2014 (Walcott et al. 2020). The department's surveys in the Macquarie Marshes follow on from a PhD study by Ocock (2013) from 2009–2011.

Monitoring in the lower Lachlan (Figure B.10) was conducted from 2012–2016 by Charles Sturt University (CSU) through funding from the NSW Office of Environment and Heritage (OEH) and later through the CEWO LTIM project. Although these were separate monitoring programs the method was consistent with Amos (2017) across all surveyed sites in the lower Lachlan from the Great Cumbung Swamp to the Booligal Wetlands (Amos 2017; Amos et al. 2013; Amos et al. 2014; Dyer et al. 2016).

The Murrumbidgee WRPA has an ongoing frog monitoring program led by CSU through the CEWO LTIM program (2014–2019) and current Flow MER program (2019–2022). The LTIM/ Flow MER surveys focus on 4 wetland sites in the mid Murrumbidgee wetlands and 8 wetland sites in the Lowbidgee Floodplain (Wassens et al. 2014a). This monitoring followed on from frog surveys undertaken between 2007 and 2014 as part of joint CSU and NSW monitoring funded through the NSW Rivers Environmental Restoration Program (RERP) (Spencer and Wassens 2010), NSW Catchment Action Plan (CAP) Testing Wetland Resilience project (Spencer et al. 2011) and other targeted surveys (Wassens 2007; Wassens et al. 2008; Wassens and Amos 2011; Wassens and Spencer 2012), and CEWO funded short-term monitoring projects (Wassens et al. 2012; Wassens et al. 2013; Wassens et al. 2014b).

In the Lower Darling, frog monitoring data collected by the Murray–Darling Freshwater Research Centre in sites along the Darling Anabranch were available for the 2010–2014 period (Bogenhuber et al. 2013; Bogenhuber et al. 2014). NSW OEH frog monitoring data was also available for the mid and lower Murray wetland regions (Figure B.10) from 2012 to 2017 (Wilson and Healy, unpublished data 2017).

In 2016 OEH started the *Saving our Species* (SoS) program, focusing on threatened species conservation across NSW. Strategic conservation programs for Sloane's froglet *Crinia sloanei* and the southern bell frog were funded by the SoS program in 2017, building on the work that had been done for these species over the past 10–15 years by threatened species officers and environmental water managers. Both frog species occur in the NSW MDB and are nationally threatened (EPBC Act). Monitoring data collected through the SoS program and others were used to establish objectives and targets for these species against which to measure the success of recovery efforts, including delivery of environmental water, in the NSW Murray and Murrumbidgee WRPAs (Wassens et al. 2019; Waudby 2019; Waudby et al. 2020).

Records for other water-dependent species, including platypus records, were collated solely from NSW-wide datasets (NSW BioNet 2016). This data provided presence/absence information at an individual site scale across the NSW MDB. No monitoring programs currently exist for these species in the 9 NSW WRPAs to measure their abundance.

8.2.2 Establishing a spatial boundary

The spatial boundaries used to develop the objectives and targets for frog species were focused on wetland regions that support flow-dependent frog species (see species list in Table B.19). Flow-dependent frog species are entirely reliant on aquatic habitat. They also have limited ability to move large distances and are dependent upon hydrological connectivity to do so. Spatial boundaries for flow-dependent frog species were most appropriate at a wetland region scale, consisting of the core wetland areas and wider connected floodplain. Some LTWP planning units were combined to create a single wetland and floodplain frog area (Figure B.10). For example, the 'Macquarie Marshes' frog area included the East, North and South Marsh planning units. These boundaries are consistent with the established waterbird spatial boundaries (see Section 6), as they rely on similar wetland habitat to persist. Note there was variable monitoring coverage across the spatial boundaries.

Spatial boundaries for developing platypus and a general target for all other water-dependent species were based on known distributions from state-wide datasets (BioNet – Atlas of NSW Wildlife) and are described at the planning unit scale. The spatial extent of platypus is currently described for the Lachlan and Gwydir catchments only, where LTWP objectives and targets have been set for platypus.

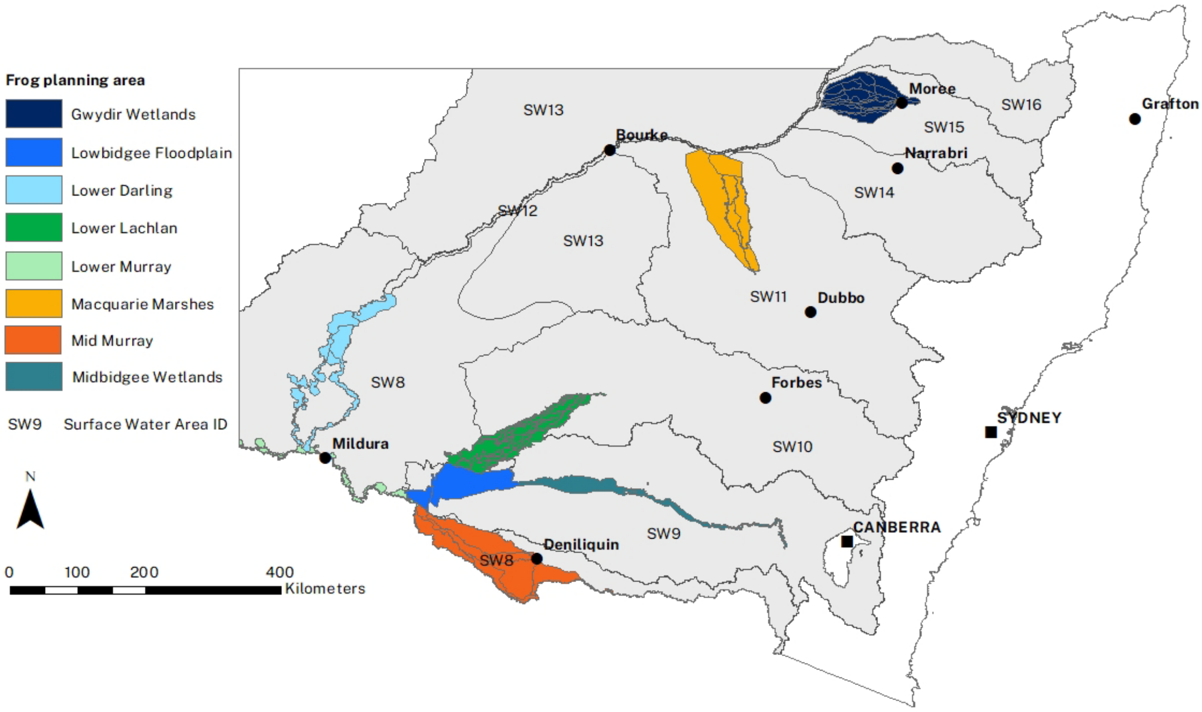

Figure B.10 Locations of major wetlands that support flow-dependent frog species in the NSW WPRAs

These planning units were used for the development of LTWP objectives and targets for flow-dependent frog species.

8.3 Selecting an appropriate baseline

Available monitoring data was used to determine a baseline for setting objectives and targets for flow-dependent frog species (Appendix 8.2). The availability of data varied spatially across the NSW WRPAs, particularly for documenting breeding success, and had varying temporal coverage. Preference was given to datasets derived from systematic surveys undertaken within wetland spatial boundaries and that were conducted over several years to capture a range of flow periods (e.g. large flood years and environmental water events).

Insufficient frog monitoring data were available for the Intersecting Streams, Barwon–Darling, Namoi and NSW Border Rivers WRPAs. As such, frog objectives were not developed for these catchments. A data gap also exists for frog breeding and recruitment (other species Objective 2) in the mid and lower Murray and the mid Lachlan region, so frog breeding targets were not set in these areas.

The baseline for threatened frog species objectives (other species Objectives 3a and b) were established for southern bell frog communities in the Murrumbidgee and Murray–Lower Darling only and Sloane's froglet in the Murray–Lower Darling. Data available from the department's SoS program and also for the Murrumbidgee LTIM program was used (Wassens et al. 2019; Waudby et al. 2020). In the Murray–Lower Darling the southern bell frog targets align with SoS southern bell frog program targets of maintaining southern bell frogs at 80% of sites with improvement to 90% occupancy at surveyed sites (Waudby 2019). Future data collected by these programs will be used to assess achievement of these targets and objectives.

Limited or no monitoring data was available for many water-dependent species identified in the overall species richness objective and target (other species Objectives 4). These objectives are therefore set at a broad WRPA scale. Platypus targets are, however. set at the planning unit scale as individual home ranges are typically small (anywhere from 0.5–15 m of linear habitat) (Bino et al. 2019; Hawke et al. 2018; Serena and Williams 2010).

8.4 Setting objectives and targets

8.4.1 Expected outcomes

The LTWP sets SMART targets for other species in NSW across a 5, 10 and 20-year timeframe. The focus of the other species objectives and targets in the LTWP is to maintain frog species richness and species distribution across NSW WRPAs and increase opportunities to breed for the defined flow-dependent frogs. Water delivery constraints, environmental water delivery and the ability to support other species' habitat with water was also considered in the setting of targets and objectives. The objectives and targets also support the maintenance and increase in the distribution of the threatened southern bell frog and Sloane's froglet. For WRPA specific targets and objectives please see Appendix 8.3.

8.4.2 LTWP objectives and targets

Objective 1 Maintain species richness and distribution of flow-dependent frog species

Ecological objective[42]		Targets		
		2024	2029	2039
OS1	Maintain species richness and distribution of flow-dependent frog communities	Detect all **x flow-dependent frog** species known from the **LTWP area** based on comprehensive surveys over the **xxxx–xxxx** period		

These LTWP objectives and targets only apply to areas where flow-dependent species occur, i.e. the floodplain habitat and low-relief streams located in the mid and lowland areas of relevant WRPAs. The measurement of this target is based on comparison with baseline data from comprehensive surveys in the 2012–2017 period (Appendix 8.2).

[42] See Table B.19 for total number of species and insert name of LTWP area and baseline period for the area.

Table B.19 Flow-dependent frog species recorded in the MDB in baseline periods for each relevant WRPA

Common name	LTWP wetland area[43]						
	Macquarie Marshes	Gwydir Wetlands	Murrum-bidgee[44]	Lower Lachlan	Lower Darling	Mid Murray	Lower Murray
Barking marsh frog	X	X	X	X	X	X	X
Broad-palmed frog	X	X					
Brown tree frog							
Common eastern froglet						X	X
Eastern banjo frog						X	X
Eastern dwarf sedge frog							
Eastern sign-bearing froglet	X	X	X	X	X	X	X
Giant banjo frog			X	X	X	X	X
Northern banjo frog							
Peron's tree frog	X	X	X	X	X	X	X
Salmon striped frog	X	X					
Sloane's froglet						X	
Southern bell frog			X			X	X
Spotted marsh frog	X	X	X	X	X	X	X
Striped marsh frog							
Tyler's tree frog							
Verreaux's frog							
Victorian frog							

[43] Baseline data sources listed in Appendix 8.2. Baseline data used to set objectives and targets for flow-dependent frog species in the LTWPs.

[44] Records the same for both the mid and lower Murrumbidgee.

Objective 2 Maintain successful breeding opportunities for flow-dependent frog species

Ecological objective[45]		Targets		
		2024	2029	2039
OS2	Maintain or increase successful breeding opportunities for flow-dependent frog species	Maintain proportion of wetlands sites where breeding activity of flow-dependent frog species is detected in the **LTWP area** compared to the **xxxx–xxxx** period	Maintain or increase proportion of wetlands sites where breeding activity of flow-dependent frog species is detected in the **LTWP area** compared to the **xxxx–xxxx** period	

Maintaining the opportunity for frog species to breed is crucial for the persistence of populations in the long term. Flow-dependent frog species are aquatic breeders and rely on habitat inundation, largely of floodplain wetlands, to successfully breed and for young to recruit into the adult breeding population. The proportion of sites where breeding and/or recruitment is detected during a flow event is indicative of a positive response to watering.

The aim of the NSW LTWPs (where frog objectives are defined) is to maintain breeding opportunities for flow-dependent frog species within the LTWP area for the next 5 years and if possible, increase them from 10 years onwards. Achieving this relies on both maximising the proportion of sites inundated within a water-year (for a minimum of 3 months for certain species) and maintaining the frequency of inundation across years. Increasing the area of inundation from overbank or wetland inundating flows is expected to increase breeding opportunities and recruitment for flow-dependent species.

For the second objective, successful breeding is measured by completion of different stages of the breeding lifecycle, i.e. egg laying, presence of tadpoles, completion of metamorphosis (i.e. 'metamorphs'). When monitoring the targets, male frog calling activity, tadpoles detected and/or recently metamorphosed juvenile frogs provide evidence of breeding activity, and the presence of recently metamorphosed juvenile frogs is evidence of potential recruitment of new individuals into the adult breeding population.

Frog breeding targets were set for the Gwydir Wetlands, Macquarie Marshes, lower Lachlan, lower Murrumbidgee and mid Murrumbidgee wetland regions for the 2019–2024 period based on existing monitoring data collected pre-2019. This was not possible for the mid Murray, lower Murray or mid Lachlan where baseline data on the distribution of frog breeding was not available. It is recommended that monitoring programs are established to collect baseline data on breeding activity of flow-dependent frog species in these wetland regions in the 2019–2024 period to set appropriate 10 and 20-year targets (see Appendix 8.3).

[45] See Appendix 8.2 for baseline data for each LTWP area. This objective was only used for wetland areas where appropriate baseline data was available.

Objective 3 Maintain and increase number of wetland sites occupied by the threatened frog species

Ecological objective[46]		Targets		
		2024	2029	2039
OS3a	Maintain and increase number of wetland sites occupied by the threatened southern bell frog	Detect southern bell frog at 80% of known **wetland sites in the LTWP area** in 5 out of 5 years	Detect the southern bell frog at 90% of known wetland sites in the LTWP area in 5 out of 5 years	
		Detect potential recruitment of southern bell frog **at a minimum of xx wetland sites in the LTWP area** in 5 out of 5 years	Detect potential recruitment of southern bell frog **at a minimum of xx wetland sites in the LTWP area** in 5 out of 5 years	
OS3b	Maintain and increase number of wetland sites occupied by the threatened Sloane's froglet	Detect Sloane's froglet at **all** known **xx** wetland sites in the upper and mid Murray in the 2019–2024 period	Increase number of Sloane's froglet wetlands sites by **xx%** compared to the 5-year target	

The LTWPs' objectives aim to maintain and increase the site occupancy for 2 threatened frog species, the southern bell frog and Sloane's froglet (NSW *Biodiversity Conservation Act 2016* (BC Act), EPBC Act).

The southern bell frog objective and targets, OS3a, apply specifically to the NSW Murray–Lower Darling and the Murrumbidgee WRPAs. If the distribution expands into, or new populations are detected in other WRPAs, such as the Lachlan WRPA, these could be included in future revisions of the LTWPs. The Murray–Lower Darling LTWP targets align with the already established targets of the department's SoS program that operates in the Murrumbidgee and mid Murray. The targets are to detect southern bell frogs at 80% of the survey sites with detection of this species exceeding this target in the last year of SoS monitoring (detected at 90% of sites).

The Sloane's froglet objective and targets, OS3b, apply specifically to the NSW Murray–Lower Darling WRPAs. They align with SoS targets already established for the upper Murray and mid Murray. Targets for the Sloane's froglet could be included in future LTWPs, provided water delivery constraints are relaxed and better information is available on the species for setting objectives and targets. Further work is needed to determine how much influence water management has on the distribution of this species and what additional conservation actions are needed.

[46] See Appendix 8.2 for baseline data for each LTWP area. This objective was only used for wetland areas with appropriate baseline data was available. These objectives should only be used for MLD plan (upper and mid Murray)

Objective 4 Maintain water-dependent species richness

Ecological objective		Targets		
		2024	2029	2039
OS4	Maintain water-dependent species richness	Over the long term (20 years) no reduction in the number and range of water-dependent species that are found throughout the catchment Maintain the current range of platypus across the catchment[47,48] Evidence of platypus burrows and successful breeding detected[47,48]		

Objective 4 (OS4) aims to ensure that the unique diversity of water-dependent species is maintained across each catchment in the NSW MDB. Currently, OS4 is included in the Gwydir, Lachlan and NSW Murray–Lower Darling LTWPs. Targets are specific to each catchment depending on the socially or culturally significant species present. Future revisions of NSW LTWPs should consider including OS4 in all LTWPs as well as the inclusion of any other relevant water-dependent species.

Targets pertaining to platypus apply specifically to the upper Gwydir and upper Lachlan catchments. Current distribution of platypus in these catchments was determined from state-wide datasets (BioNet – Atlas of NSW Wildlife).

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[47] Monitored at the planning unit scale.

[48] Only present in the Gwydir and Lachlan catchments in relevant planning units.

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Shortened forms

AER	Aquatic Ecosystems Research
ALA	Australian Living Atlas
AWSEA	Annual Waterbird Survey of Eastern Australia
BC Act	NSW *Biodiversity Conservation Act 2016*
BWS	Basin-wide environmental watering strategy
CAP	NSW Catchment Action Plan program
CEWO	Commonwealth Environmental Water Office
CPUE	catch per unit effort
CSU	Charles Sturt University
the department	NSW Department of Planning and Environment
DPE	NSW Department of Planning and Environment
DPE–EHG	NSW Department of Planning and Environment – Environment and Heritage Group
DPE–Water	NSW Department of Planning and Environment – Water
DPI	NSW Department of Primary Industries
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EWR	environmental water requirement
FCS	fish community status
FCSandTSD	Fish Community Status and Threatened Species Distribution
GAM	generalised additive modelling
HIS	hydrologic indicator sites
LTIM	CEWO Long Term Intervention Monitoring project
LTWP	NSW Long Term Water Plan
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
MER	Monitoring Evaluation Research program
NPWS	NSW National Parks and Wildlife Service
OEH	NSW Office of Environment and Heritage (former)
PCT	plant community type
PEF	priority ecosystem function
RERP	NSW Rivers Environmental Restoration Program
SEA program	Specified Environmental Asset (SEA) aerial survey program
SMART (target)	specific, measurable, achievable, realistic, time-bound
SoS	NSW *Saving our Species* program
TLM	The Living Murray program
UNSW	University of New South Wales, Sydney
WRP	water resource plan
WRPA	water resource plan area

Glossary

Broods	Broods are young of adult waterbirds in a nest or dependent offspring observed with adult parents.
Colonial-nesting waterbird (colonial waterbird)	Colonial-nesting waterbird species can nest in very large numbers in single or multi-species colonies. This group usually obtain most of their food from aquatic sources, such as fish, invertebrates and amphibians. In the MDB colonial-nesting species include members of 6 waterbird families: Ardeidae (egrets and herons), Threskiornithidae (ibises and spoonbills), Phalacrocoracidae (cormorants), Anhingidae (darter) and Pelecanidae (pelican).
Condition (vegetation)	Indicators used in defining vegetation condition in the LTWPs include vegetation extent, vegetation cover, abundance, plant species diversity in terms of structure, composition and function, evidence of reproduction, invasive species, bare ground, and tree canopy condition metrics.
Ecological objective	Objective for the protection and/or restoration of an ecological asset or function.
Ecological target	Level of measured performance that must be met to achieve the defined objective. The targets in this Long Term Water Plan are SMART (specific, measurable, achievable, realistic, time-bound).
Environmental water	Water for the environment. It serves a multitude of benefits not only to the environment, but to communities, industry and society. It includes water directly managed by the NSW and Australian governments (held environmental water) or protected from extraction from waterways (planned environmental water) for meeting the requirements of water-dependent ecosystems.
Environmental water requirement	The flow event/s required to support the completion of key known elements of a lifecycle of an organism or group of organisms (taxonomic or spatial), consistent with the objective/target, measured at the most appropriate gauge. They are described by their magnitude, duration, timing, frequency and maximum dry period. EWRs can be met by various flows in a system including natural inflows, held environmental water, planned environmental water, essential supplies, conveyance water and consumptive orders.
Fledgling	A young bird that has left its nest but is still dependent on adults for food, sometimes for an extended period known as the 'post-fledging period'.
Flow-dependent frogs	Wetland frog species that have a strong relationship with overbank flows that create breeding habitat, and also rely on aquatic refuge habitat during periods of drought.
Flow regime	The pattern of flow events in a stream over time.
Held environmental water	Water available under a water access licence or right, a water delivery right, or an irrigation right for the purposes of achieving environmental outcomes including water that is specified in a water access right to be for environmental use. In NSW, typically managed by either the Commonwealth Environmental Water Holder or the department.
Hydro-ecological functional group	A set of species, or collection of organisms, that respond to flow conditions in a similar way.
Juvenile bird	Juvenile birds can feed independently from adults but are not part of the adult breeding population.

Juvenile frog	Young fully developed frog. Often determined from size by measuring the individual from snout to vent length.
Metamorph	Juvenile frog that still has a tail stump from late stage development.
Metamorphosis	Development of a frog from tadpole to adult.
Non-colonial waterbird	Non-colonial waterbird species include waterfowl (ducks, geese and swans), grebes, crakes, rails and waterhens, and resident shorebirds (small waders). These species generally do not congregate in large numbers to breed but they are still dependent on wetlands for nesting and feeding habitat to raise their young.
Other species	Other species in this document refers to water-dependent frogs, turtles, snakes, water rats, bats, platypus and woodland bird species that benefit from the inundation of riverine and wetland habitat by natural and managed flows.
Planned environmental water	Water that is committed by the Basin Plan, a water resource plan, a water sharing plan, or a plan made under state water management law to achieve environmental outcomes.
Population structure	The range of age and size classes within a species' population. A population with a range of age and size, with a good number of sexually mature individuals, demonstrates regular recruitment and is healthy.
Priority ecosystem function	The water-dependent resources and services that sustain human, plant and animal communities and are provided by the processes and interactions occurring within and between ecosystems.
Recruitment	The addition of new individuals, resulting in an increase in a population, due to successful breeding of species, and growth and survival of their offspring into the adult population. Also, the part of a plant or animal's lifecycle from germination/ birth/ spawning through stages of immature development and growth, and then entry into the breeding population, so they can contribute to the next generation.
Shorebird (or small wader)	Shorebirds, also known as small waders, are a group of waterbirds from the suborder Charadrii, including plovers and sandpipers, that often feed along the water edge or in shallow inundated habitat of estuaries, lakes and swamps.
Vagrant	Species that occasionally occur in Australia, but records are well outside their normal distribution.
Vegetation community	A type of native vegetation community that is described through a combination of its floristics, life forms and ecological characteristics. Vegetation communities are derived from large-scale forest and plant community mapping and are the basic units described and mapped in the NSW LTWP vegetation maps.
Waterbird	A bird species that lives (breeds and forages) in or around wetland habitats. Excludes bird species that are predominantly associated with marine habitats or spend most of their lives in terrestrial habitats. Does not include other water-dependent bird species that use wetlands for part of their lifecycle, e.g. some raptors, reed-inhabiting passerines and kingfishers.
Water-dependent	An ecosystem or species that depends for its natural functioning and survival on periodic or sustained inundation, waterlogging, or significant inputs of water (such as wetlands, floodplains, streams, lakes).