NSW HEALTHY FLOODPLAINS

Environmental outcomes of implementing the Floodplain Harvesting Policy in the Macquarie Valley

Report

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Executive summary

Harvesting of water from floodplains reduces the volume, frequency and duration of floods and changes the timing of these events, impacting on the health of floodplains and downstream waterways. To manage unconstrained harvesting, the NSW Government has introduced the NSW Floodplain Harvesting Policy (the policy) to "manage floodplain water extractions more effectively in order to protect the environment and the reliability of water supply for downstream water users, ensure compliance with the requirements of the *Water Management Act 2000* and meet the objectives of the National Water Initiative" (NSW Office of Water 2013). The policy allows the licencing of floodplain harvesting within the long-term average annual extraction limit for eligible users and curtails future growth in use above that limit. Diversions within the Macquarie Valley remain within the legal limit so changes to hydrological and environmental outcomes are minor and primarily result from limiting ineligible works within the licencing framework.

Using modelled long-term (1895 to 2019) changes to the hydrology of the floodplain, this report provides an assessment of potential future outcomes for the environment achieved by implementing the policy in the Macquarie Valley within selected breakout zones[1]. Key hydrological metrics and environmental water requirements (EWRs) from a range of resources were used to test and identify these outcomes for assets (e.g. a location) and values (e.g. a species) including native fish, waterbirds, native vegetation, wetlands and flow-dependent frogs.

Key findings

Our findings are based on the analysis of two river system model scenarios for the Macquarie Valley floodplain that simulate current conditions with (regulated harvesting) and without (unconstrained harvesting) the policy implemented. The results reported herein are therefore only indicative of potential outcomes under implementation of the policy. Based on the findings presented in this report, implementation of the policy is predicted to result in:

- very little change to the environmental outcomes for key assets and values in this valley
- very little change in floodplain hydrology (that is volumes, durations and timing of floods)
- some improvements in hydrological and environmental outcomes at two of the 10 breakout zones with little to no change in the other eight zones.

A high-level summary of potential outcomes across the Macquarie Valley for waterbirds, native vegetation, native fish and water volumes is provided in map form in Figure 1.

The greater Macquarie Marshes supports the Macquarie Marshes Ramsar site which is one of the most important environmental assets in the Murray-Darling Basin. The Ramsar site is of international significance because of it's:

- unique wetlands, threatened species and threatened communities
- plant and animal biodiversity
- importance for breeding and refuge for waterbird populations and native fish communities.

Five breakout zones impact the Macquarie Marshes Ramsar site and the policy predicts some minor improvements in two of them and very little change in the other three. With the current proposed FPH policy settings and proposed monitoring and compliance mechanisms in place, no future FPH growth will occur in the Macquarie Valley and this will help to maintain the Ramsar site.

[1] As the water level rises from within the channel, the most common points through which inundation initially occurs are low areas where the stream can spill over onto its floodplain. These flow breakouts can extend across many properties, sometimes flowing along indistinct flow paths that can inundate large areas of the floodplain. Some breakout flow paths only get water flowing in very high flows, and others happen more frequently.

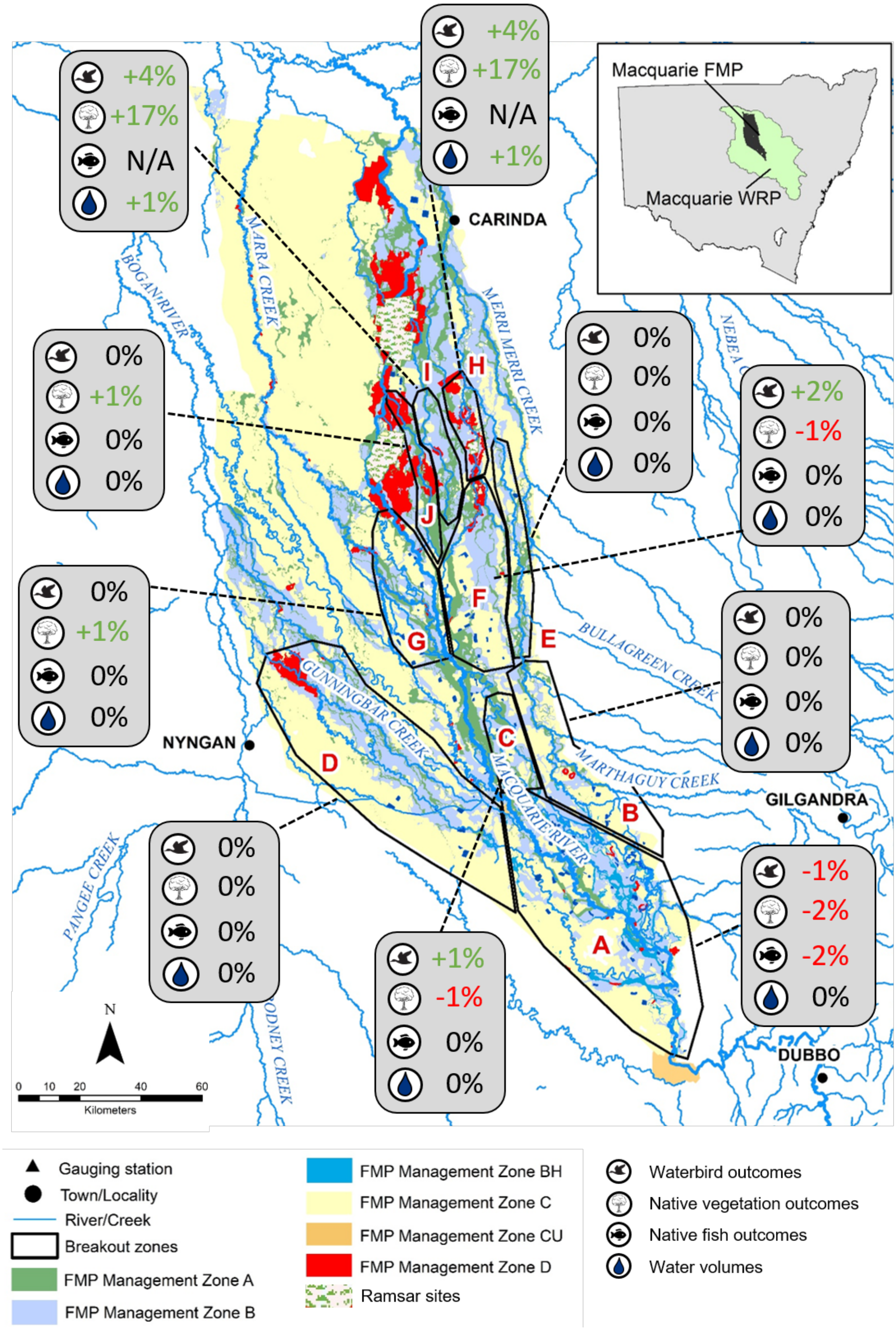

Figure 1 Mapped summary of predicted outcomes for waterbirds, native vegetation, native fish and water volumes for the 10 breakout zones on the Macquarie Valley floodplain. Percent change values show the predicted change from current (no policy) to current with policy implemented based on a 124 year simulation period. Values for waterbird, native vegetation and native fish outcomes are the average change in achieving key EWRs at each breakout zone. Water volume outcomes are the percentage change in mean annual volumes (see Table 5) during years with floods. FMP = Floodplain Management Plan. Breakout zones from most upstream to most downstream: A Trangie, B Marthaguy, C Birchells Plains, D Gunningbar, E Wyndabyne, F Gradgery, G Marebone, H Wilgara, I Glencoe, J Pillicarwarrina. The inset map shows the location of the Macquarie Valley within NSW and the extents of the Macquarie Flood Management Plan (FMP) and Water Resources Plan (WRP)

Hydrological outcomes

A range of ecologically relevant hydrological metrics were assessed, including flood magnitude (volume and flow rate), frequency of events, timing, and duration.

The majority of ecologically relevant hydrological metrics are predicted to have limited improvements once the policy is implemented, though this varies across breakout zones on the floodplain. Changes to hydrology are limited spatially with only two downstream breakout zones Wilgara and Glencoe predicted to benefit from implementation of the policy, which, in turn, leads to some improvements in environmental outcomes at these two breakout zones.

The predicted hydrological changes at Wilgara and Glencoe are improved frequency, duration, and timing of flows, with increases in number of events, total flow days, days with flow in summer, and reduced inter-event periods; minor increases in flow days in spring and autumn, and no change in winter months.

With the policy implemented and during flood years[2], a small increase of 3% or 4 gigalitres (GL) in mean annual volumes are predicted to return to the floodplain across all 10 breakout zones, with most of this increase (98%) in the downstream breakout zones of Wilgara and Glencoe (Figure 1). Relatively minor or no change (0% to 1% increase) are predicted for the remaining breakout zones (Figure 1).

Native fish

Water requirements of 14 native fish species in 4 guilds – flow-dependent specialists (such as Silver Perch), generalist species (such as Bony Herring), short–moderate-lived floodplain specialists (such as Olive Perchlet), and in-channel specialists (such as Murray Cod) – were used to predict outcomes for native fish under the policy.

Minimal change is predicted in relevant hydrological metrics, with none of the assessed fish guilds expected to benefit or be disadvantaged from implementation of the policy. In summary, no major change in outcomes for native fish is predicted in any of the breakout zones where fish are known or predicted to occur (Figure 1).

Waterbirds

More than 26 waterbird species comprising both colonial and non-colonial nesters are recorded or are predicted to occur in the Macquarie Valley breakout zones.

Colonial waterbirds are known to breed in habitats found within six (of the ten) breakout zones in this valley. Overall, implementing the policy is predicted to provide little to no benefit for colonial waterbirds. However, there are some small improvements, such as an increase of 30% in the number of days with flow during colonial waterbird nesting breeding periods (July-December) predicted in the Wilgara breakout zone.

Outcomes for non-colonial waterbirds are predicted to improve overall, mainly due to improved length of flow events during the ideal (+10%) and opportunistic (+3%) breeding seasons, specifically in Wilgara breakout zone. In this breakout zone, 142 more flow days during the ideal breeding period (spring-summer) are predicted over the 124-year model simulation period.

Besides improved outcomes in Wilgara breakout zone, no substantial improvement for either colonial or non-colonial waterbirds is predicted in any of the other breakout zones.

Native vegetation

Seven water-dependent vegetation species which occur on the floodplain were selected for this assessment as their water requirements are well documented. Modelling indicates that

[2] Zero flows dominate floodplain hydrology in the Northern Murray-Darling Basin as floods occur infrequently. A flood year is any year where the hydrological model has simulated flow on the floodplain at a specific breakout zone. Floodplain flows can be triggered by local rainfall runoff and/or overbank flows.

implementation of the policy will result in limited overall change in the achievement of these water requirements, although this varies across the breakout zones.

Again, better outcomes are predicted at Wilgara and Glencoe breakout zones. These zones have the greatest improvement in hydrological metrics and achievement of native vegetation EWRs. As such, the five assessed species that occur in these breakout zones – black box, coolabah, river red gum, river cooba and water couch – are predicted to have the greatest improvement (on average, 14% to 19% improvement in all water requirement metrics). The other two vegetation species assessed – lignum and cumbungi – were not recorded in Wilgara and Glencoe breakout zones based on the datasets used and are expected to receive little to no improvement with the policy implemented.

No change in outcomes is predicted for the other eight breakout zones. Improved outcomes would be expected in these breakout zones if they had more frequent and longer duration flooding flows in all seasons.

Wetlands

A variety of wetlands occur on the Macquarie Valley floodplain, including numerous significant anabranches, lagoons, wetlands, watercourses and billabongs. Of particular importance is the greater Macquarie Marshes, which includes Ramsar-listed areas of wetlands of international significance, and its water requirements (principally frequency and timing) were used to assess the impact of the policy.

Modelling suggests that implementation of the policy will provide no substantial increase in the mean annual volume and other hydrological metrics for three of the five breakout zones which are most likely to influence outcomes in the greater Macquarie Marshes. However, improvements in most of the other hydrological metrics are predicted for the two other zones – Wilgara and Glencoe – which incorporate areas of the Marshes (Figure 1). Changes in these two breakout zones include increased summer volumes (+4% and +6%), more flow events (+17% and +23%) and longer flood durations in summer, particularly January (+149% and +434%) which should benefit the Marshes.

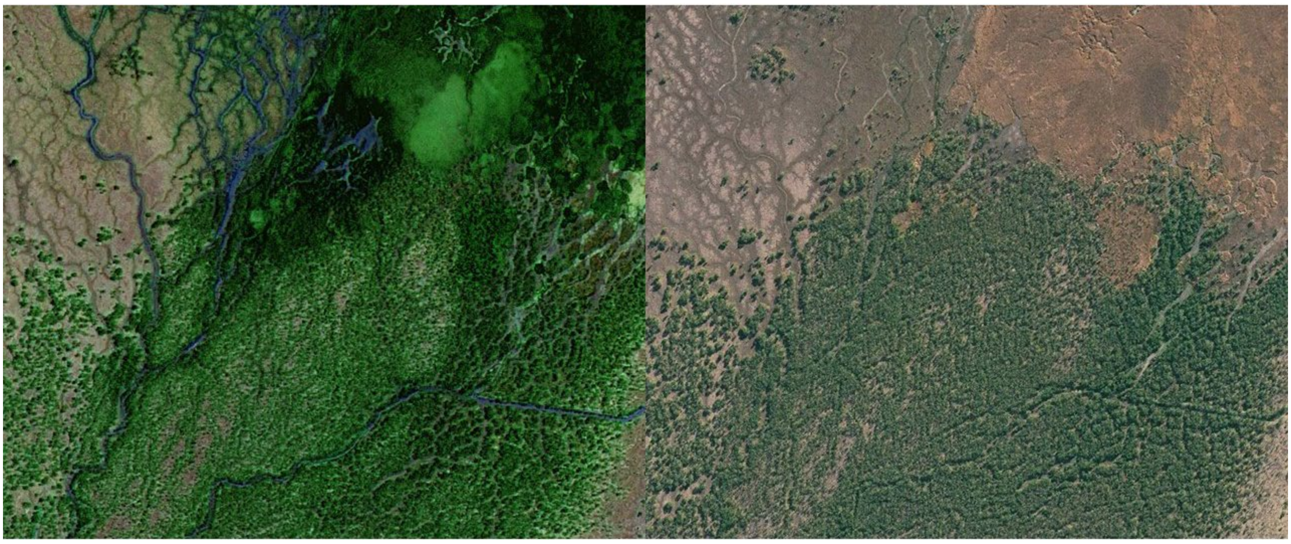

Figure 2 Satellite image of Little Bora Channel and Macquarie River entering the Macquarie Marshes Nature Reserve during a flow event in 2014 (left) versus a severe drought year in 2019 (right). This is a Ramsar nationally significant wetland which provides critical refugia for water-dependent ecosystems. [Image sourced from EES APOLLO Image WebServer]

Environmental outcomes for the greater Macquarie Marshes as a whole are difficult to predict as the achievement of EWRs in some breakout zones are expected to improve, while other zones remain unchanged. Again, improvements in the Wilgara and Glencoe breakout zones will contribute to achieving the environmental water requirements (frequency and timing) of the Marshes more frequently once the policy is implemented. EWR outcomes in the other three breakout zones which have a high likelihood of affecting the greater Macquarie Marshes are predicted to remain unchanged. Given the environmental significance of this nationally and internationally recognised wetland, improvements in all five breakout zones which incorporate the Marshes would be desirable.

Flow-dependent frogs

The Macquarie Valley floodplain supports important refugia and habitat for frog species including anabranches, lagoons, wetlands, watercourses and billabongs. Up to 20 flow-dependent frog species are predicted to occur or have been recorded in the breakout zones. Of these, 8 have been assessed due to their strong association with flow.

Across all breakout zones, the average predicted change in breeding (0%) and inter-event frequencies (-2%) for maintaining flow-dependent frogs was small. The timing of flows for spring to summer breeders (7%, additional 49 flows October to March) and flexible breeders (3%, additional 95 flow days July to April) are predicted to improve, although not substantially. While these increases are small averaged across all breakout zones there are specific areas predicted to have greater change. The Wilgara and Glencoe breakout zones are both expected to have the greatest percentage change in the number of flow days in summer, timing for spring to summer breeders, and reductions in inter-event period. This should help maintain flow-dependent frog habitats in the Wilgara and Glencoe breakout zones. However other breakout zones are predicted to have little or no beneficial change. Longer durations and more frequent flows in spring in these areas would provide better outcomes for frogs.

Improving assessment of environmental outcomes

The results presented in this report are based on the best available simulation modelling, using locally specific information where available, else inferred from the literature or from similar environments in NSW. However, building understanding of the likely effects of floodplain harvesting on floodplain condition requires further investment, including to:

- improve the underlying river system models. Return flows are not yet included in the river system models. Along with major floodplain flows, these need to be measured and represented in the models. This will allow cumulative downstream impacts and end-of-system impacts to be estimated. At present, little to no environmental benefit is detectable in some downstream floodplain breakout zones. It is unclear whether this is due to the inability of the models to incorporate return flows and thus cumulative downstream impacts, or if this is a real outcome predicted after implementation of the policy.
- incorporate modelling of additional flow thresholds into the floodplain inundation models to quantify changes to flood inundation extent (lateral and longitudinal) and duration across a wider range of flows. Hybrid hydrological/hydraulic models may enable changes to flood inundation duration and extent to be modelled based on modelled changes to hydrology. This would enable a more robust assessments of EWRs (frequency, maximum inter-event period, duration and timing) and policy changes.
- implement long-term environmental monitoring, evaluation and reporting (MER) programs for floodplain environmental assets and values to complement existing long-term MER programs run by other agencies such as the NSW Department of Planning, Industry and Environment – Environment, Energy and Science. This is critical to be able to measure real-world outcomes of the policy.
- Incorporating climate change predictions into the hydraulic and hydrological models

Incorporating these recommendations into the implementation of the policy would reduce uncertainties in the current modelling and improve confidence in predicted outcomes.

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1 Introduction

1.1 Background

In 2013, the NSW Government introduced the NSW Floodplain Harvesting policy (the policy). The purpose of the policy is to:

> 'manage floodplain water extractions more effectively in order to protect the environment and the reliability of water supply for downstream water users, ensure compliance with the requirements of the *Water Management Act 2000* and meet the objectives of the National Water Initiative' *(*NSW Office of Water 2013*).*

The policy aligns with the objectives of the National Water Initiative, an intergovernmental commitment made by the Council of Australian Governments in 2004 to increase the efficiency of Australia's water use. The policy aims to manage unconstrained floodplain harvesting by bringing it into a licensing framework. The NSW Government is currently implementing the policy in the designated floodplains of five inland northern NSW valleys – Border Rivers, Gwydir, Macquarie, Namoi and Barwon-Darling.

Improved environmental outcomes for floodplains is one of the key outcomes sought through implementation of the policy. Unconstrained harvesting of water from floodplains reduces the amount of water available to meet wetland and floodplain needs and to ensure downstream river health. Floodplain harvesting can also affect connectivity between a river and its local floodplain wetlands by reducing flow volume and redirecting flood flows (DPIE Water 2019).

1.2 Report purpose

This report considers the predicted environmental outcomes (i.e. ecological responses) to changed floodplain harvesting volumes in the Macquarie Valley after implementing the policy. It includes identification of floodplain water-dependent environmental assets (such as wetlands) and values (such as native fish), modelled hydrological changes and predicted outcomes for floodplain ecosystems with and without implementation of the policy. This assessment has a targeted focus on areas of the floodplain where floodplain harvesting occurs.

1.3 Assessment approach

The choice of assessment approach and selection of assessment metrics was dictated by the availability of data and access to a river system model that was capable of simulating the flow of water overbank and onto floodplains over a long-term period and under different management practices (as would occur under implementation of the policy). The three components of the approach are shown in Figure 3. Identification of values (such as native fish species) and assets (such as wetlands) is described in Section 0. The hydrological assessment (of ecologically relevant flow statistics) is described in Section 4. Relating the results of the hydrological assessment with the water requirements of key environmental values and assets is described in Section 0.

The values were selected to ensure that the range of flow requirements needed for assessing environmental responses to changes in flow were captured. The intent was to cover the spectrum of environmental flow dependencies. The approach compares the influence of flow only, all other influences being equal.

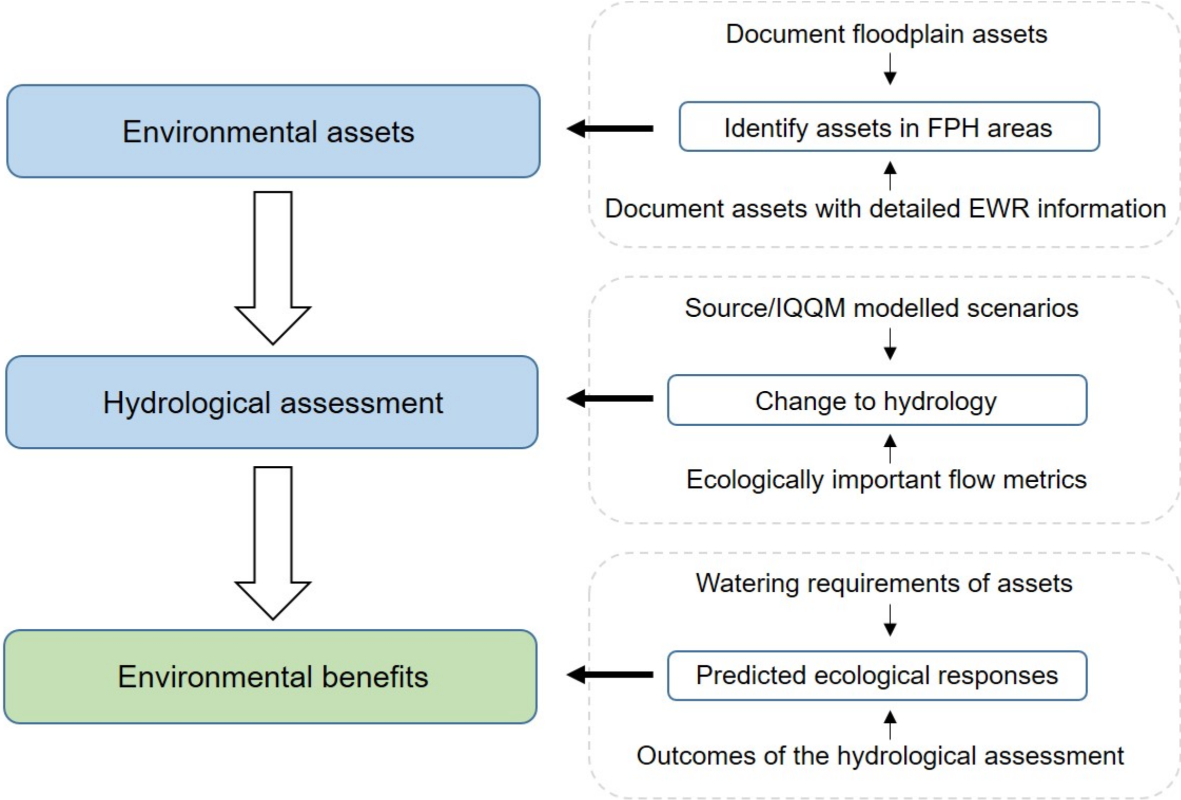

Figure 3 Summary of the approach adopted to identify the environmental outcomes of implementing the NSW Floodplain Harvesting policy (FPH = floodplain harvesting; Source/IQQM are river system/hydrological models)

1.4 Companion reports

This report is one of a suite of 3 reports that are prepared for each of the 5 NSW northern Murray-Darling Basin Valleys. This report describes an assessment of the predicted environmental outcomes from implementing the policy.

This assessment relies on having access to a detailed hydrological river system model of the Macquarie Valley, which represents the physical movements of water onto, through and exiting the valley with the regulations, policies and practices in place to equitably manage that water for all water users. Those models have been extended or rebuilt for each valley. The build of the Macquarie Valley model is described in *Building the river system model for the Macquarie Valley regulated river system* (DPIE Water 2021a).

Modelling scenarios have been developed which use the river system model, with two alternate parameter settings that describe the current condition and the condition with the policy implemented. How these have been built and used to assign floodplain harvesting entitlements is described in *Floodplain harvesting entitlements for the Macquarie Valley regulated river system – Model scenarios* (DPIE Water 2021b).

The three reports together serve to describe how the modelling meets the objectives of the policy.

2 Floodplain harvesting in the Macquarie Valley

The Macquarie Valley floodplain is within the Macquarie River catchment. The floodplain begins at Narromine, with Marthaguy Creek in the east extending to the Bogan River at the western extent. Downstream of Narromine, the Macquarie River channel capacity progressively decreases as it enters broad and flat plains. Here a complex system of anabranches and effluent creeks occur, which connect the Macquarie, Bogan, Castlereagh and Barwon-Darling river systems. Downstream of Warren, the Macquarie River flows through 120 km of a meandering network of effluent channels and anabranches featuring the Macquarie Marshes (DOI Water 2018). The Macquarie Marshes are a Ramsar listed wetland that is the largest flood-dependent ecological asset in the valley (Commonwealth Environmental Water Office 2013). When inundated, the Marshes serve as a refuge and breeding area for a variety of waterbirds and other fauna (Kingsford and Thomas 1995, Kingsford and Auld 2005a). However, the ecological functions and habitats of the Marshes have been under stress for some time due to the combined effects of river regulations and drought (DOI Water 2018).

Burrendong Dam, upstream of Wellington, is the largest flow regulating structure in the Macquarie Valley. From Burrendong Dam downstream to the Macquarie Marshes, the Macquarie River is a regulated watercourse (DOI Water 2018). After the dam's construction in 1967, a major increase in flood work development began, shifting the land use from low-intensity grazing to high-intensity irrigation. This was accompanied by development channels and levee banks, to deliver water and protect crops, across large areas of the floodplain. Other earthworks, such as weirs, flood works, town levees, major roads and railways and vegetation clearing have also appeared. Consequently, the natural flood storage volume of the floodplain has been reduced, causing historically high flood levels (SKM 2008). These floodplain works have also caused a substantial change in the effluent[3] creek system, altering the commence to flow levels, channel capacities, and the distribution, seasonality, variability and frequency of high and low flows (DOI Water 2018).

A key part of the Healthy Floodplains Project involves the development of valley specific floodplain management plans for the designated floodplain valleys in the Border Rivers, Gwydir, Namoi, Macquarie and Barwon-Darling catchments. These floodplain management plans establish management zones and set rules for new flood works and amendments to existing flood works that are designed to protect the passage of floodwater, whilst minimising the risk to life and property.The (draft) Floodplain Management Plan for the Macquarie Valley Floodplain was published for public exhibition on July 2018 and is currently being prepared for commencement.

The other key component of the Healthy Floodplains Project is the licensing of floodplain harvesting and the management of these licences through water sharing plans. The framework for implementing this licensing and management regime is provided by the NSW Floodplain Harvesting policy. In effect, the policy describes the process for licensing and managing floodplain harvesting within the long term average annual extraction limits (LTAAEL) already established in water sharing plans, ensuring no future growth on a valley-wide basis. For clarity, the LTAAEL established in water sharing plans is analogous with the Baseline Diversion Limit (BDL) referenced in the Basin Plan 2012. The portion of floodplain harvesting diversions are currently around 39 GL which is approximately 6 GL over the Water Sharing Plan Scenario and 2 GL over the Plan Limit Compliance Scenario. The implementation of the policy will bring the average annual diversions (all diversion components) back in line with the CAP scenario or the Water Sharing Plan Limit[4], which in this case is the smaller long term average total diversion and considered the Plan Limit Compliance Scenario (Table 1).

The process for reducing floodplain harvesting diversions and determining new share components differs for the regulated and unregulated water sources. Where volumes need to be reduced to not exceed the LTAAEL, impacts are distributed as equitably as possible across all licensed individuals. The policy ensures that

> "share components for individual floodplain harvesting access licences in regulated river water sources will be determined in two steps:

[3] Effluents, also called effluent creeks or effluent systems, are rivers or streams that flow out of a river, often at high flows

The long-term volume of water that all eligible works are capable of taking will be determined—this process will determine both individual and total floodplain harvesting volumes from eligible development.

Scaling of individual floodplain harvesting volumes based on eligible development will be used in conjunction with account management rules to achieve a volume of entitlement that will not exceed the total LTAAEL and will distribute impacts as equitably as possible across individuals—this will determine a total share component for each individual" (NSW Office of Water 2013)

Table 1 Modelled long term average (1895-2009) total diversions under the Current conditions, Plan Limit CAP, Plan Limit Water Sharing Plan and Plan Limit Compliance scenarios (DPIE Water 2021b).

Diversion component	**Long term average (GL/y)**			
	Current conditions Scenario	***CAP Scenario***	***Water Sharing Plan Scenario***	***Plan Limit Compliance Scenario***
General and High Security	271.3	324.8	304	272.1
Supplementary access	14	25.7	13.6	14
Floodplain harvesting[1]	39.3	12.3	33.2	37.5
TOTAL	**324.6**	**362.8**	**350.8**	**323.6**

The process for determining share components for floodplain harvesting access licences in unregulated water sources is different to the process for regulated water sources. The share component is based on whether an eligible application demonstrates that the area irrigated using water from a flood work is in addition to the area assessed during the volumetric conversion process for unregulated river access licences in the same water source. If the work is in addition to the original unregulated river access licence, then a new access licence may be issued and determined using the volumetric conversion process (NSW Office of Water 2013).

Figure 4 shows the designated Macquarie Valley floodplain and eligible floodplain harvesting properties. Eligibility of floodplain harvesting properties or works which may subsequently be eligible to receive a floodplain harvesting access licence is specified in the policy. The criteria relate specifically to works capable of floodplain harvesting that, on or before 3 July 2008, were:

- constructed on a floodplain in accordance with an approval granted under Part 2 or Part 8 of the *Water Act 1912* or Part 3 of Section 3 of the *Water Management Act 2000*, or
- subject to a pending application for an approval to construct on a floodplain under Part 2 or Part 8 of the *Water Act 1912* or Part 3 of Section 3 of the *Water Management Act 2000*, or
- constructed on a floodplain and it can be proven that the work did not require an approval under Part 2 or Part 8 of the *Water Act 1912*.

Any existing work capable of floodplain harvesting that requires an approval and an application for an approval that was not made on or before 3 July 2008 is not eligible for a floodplain harvesting access licence. However, these flood works may be used for floodplain harvesting if they apply for and are granted an approval and can be linked to a relevant access licence that can account for the take of water from the work. In the Macquarie Valley floodplain, 78 of the 106 applications for floodplain harvesting access were deemed eligible (DPIE Water 2019).

At the time writing this report, some floodplain works are still being assessed for eligibility but are not expected to make a substantial difference to the outcomes identified in this report. There has also been an assessment of some eligible works in the Pillicarwarrina breakout zone (Bulgeraga Ck) that were decided post this analysis that will lead to some modest improvements in outcomes for the greater Macquarie Marshes.

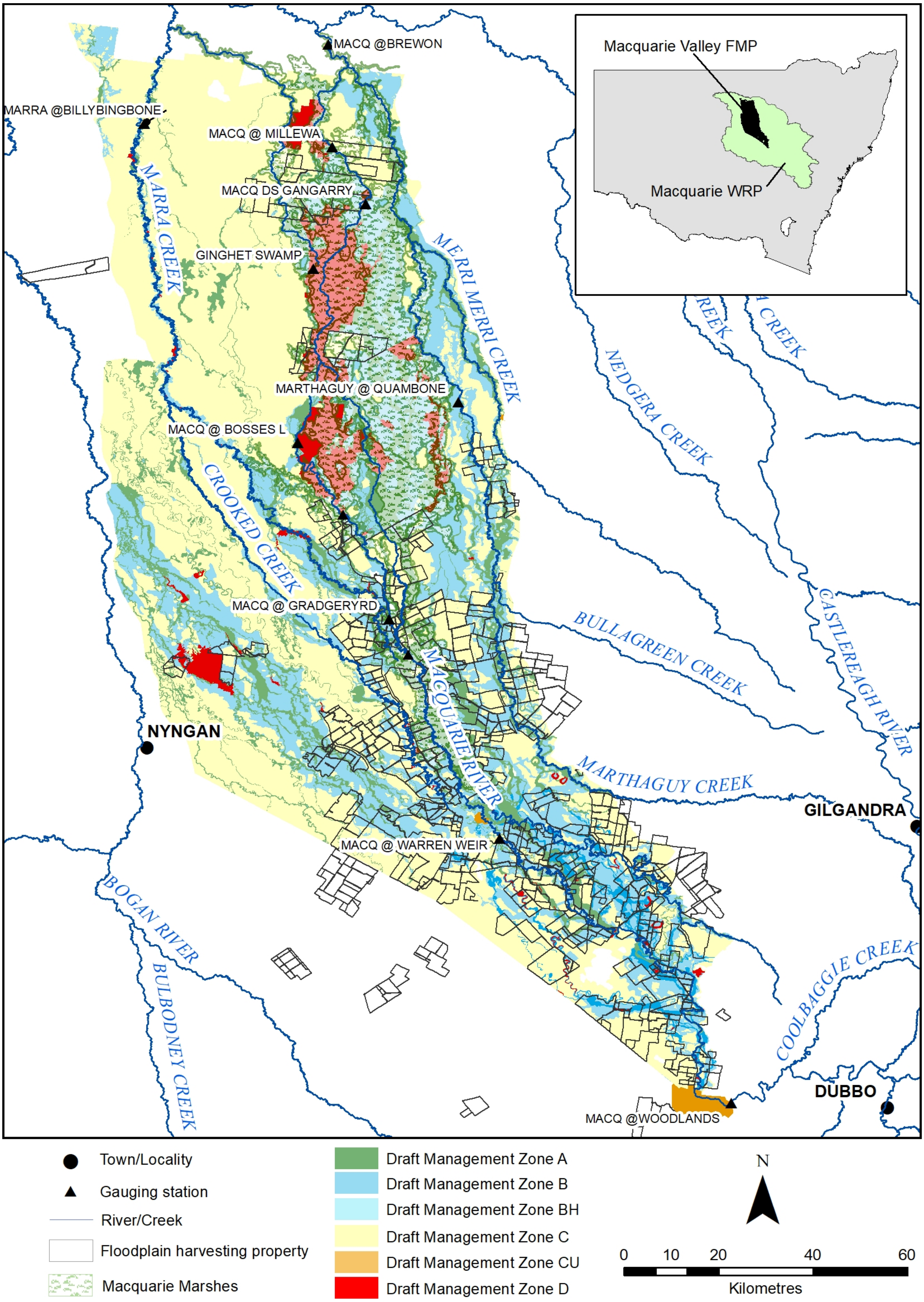

Figure 4 Map of the floodplain management zones (A, B, BH, C, CU and D) set out in the (draft) NSW Macquarie Valley Floodplain Management Plan. Only floodplain harvesting properties eligible for floodplain harvesting access licences are shown. FMP= Floodplain Management Plan

3 Environmental assets and values on the floodplain

3.1 Overview of known assets and values

The Macquarie Valley floodplain is characterised by a network of tributaries, anabranches and distributary streams (Davies et al. 2012). These meandering networks of effluent channels and anabranches include the internationally and nationally recognised Macquarie Marshes wetlands, which support an array of water-dependent environmental values. These values include native fish, native vegetation, waterbirds, frogs, reptiles, macroinvertebrates, and location specific assets, such as the nationally important Ramsar listed Macquarie Marshes wetlands (DOI Water 2018). A full list of known environmental values in the Macquarie Valley floodplain, and key geographical assets, is provided in Appendix A and summarised below.

3.1.1 Native fish

At least 19 native fish species are known to occur in the Macquarie-Castlereagh catchment (DPIE EES 2019a). This includes federal-listed threatened species, like the Silver Perch (*Bidyanus bidyanus*) and Murray Cod (*Maccullochella peelii*) (*Environment Protection and Biodiversity Conservation Act 1999*), as well as state-listed endangered Southern purple spotted gudgeon (*Mogurnda adspersa*) and endangered populations of Olive Perchlet (*Ambassis agassizii*; Western Population), Macquarie Perch (*Macquaria australasica*), Flathead Galaxias (*Galaxias rostratus*), Trout Cod (*Maccullochella macquariensis*) and Eel-tailed catfish (*Tandanus*; Murray-Darling Basin) (*Fisheries Management Act 1994*). The floodplain also provides critical food resources, drought refuge sites and important habitat for native fish.

3.1.2 Native vegetation

Several floodplain vegetation species can be considered functionally important and it is highly likely that by meeting the watering requirements of these key species, other vegetation species will benefit (Casanova 2015). The key water-dependent vegetation species include river red gum (*Eucalyptus camaldulensis*), coolabah (*E. coolabah*), black box (*E. largiflorens*), lignum (*Muehlenbeckia florulenta*) and non-woody wetland vegetation, such as reedbeds and water couch meadows. The largest area of river red gum in the northern Murray-Darling Basin is found within the Macquarie Marshes (DPIE EES 2019b). In the northern and western areas of the Macquarie-Castlereagh floodplain, coolabah-black box communities are found. These are listed as an Endangered Ecological Community under the NSW *Biodiversity Conservation Act 2016* and floodplain harvesting is noted as a threat to this community.

3.1.3 Waterbirds

Waterbirds are a group of highly mobile species that can respond to floods over large spatial scales. The Macquarie Marshes alone can support more than 500,000 waterbirds during large floods (DOI Water 2018). There are 77 species of waterbirds recorded to occur in the Macquarie Marshes (DPIE EES 2019b), representing 80% of all waterbird species found in Australia (Brandis et al. 2009). A number of these species are listed under the *NSW Biodiversity Conservation Act 2016* as vulnerable; like the magpie goose (*Anseranas semipalmata*), freckled duck (*Stictonetta naevosa*) and the endangered black-necked stork (*Ephippiorhynchus asiaticus*), Australasian bittern (*Botaurus poiciloptilus*) and Australian painted snipe (*Rostratula australis*). In addition to high waterbird species richness, the Macquarie Marshes are noted for their significance in supporting a diversity of colonial waterbird nesting and breeding (Kingsford and Auld 2005a).

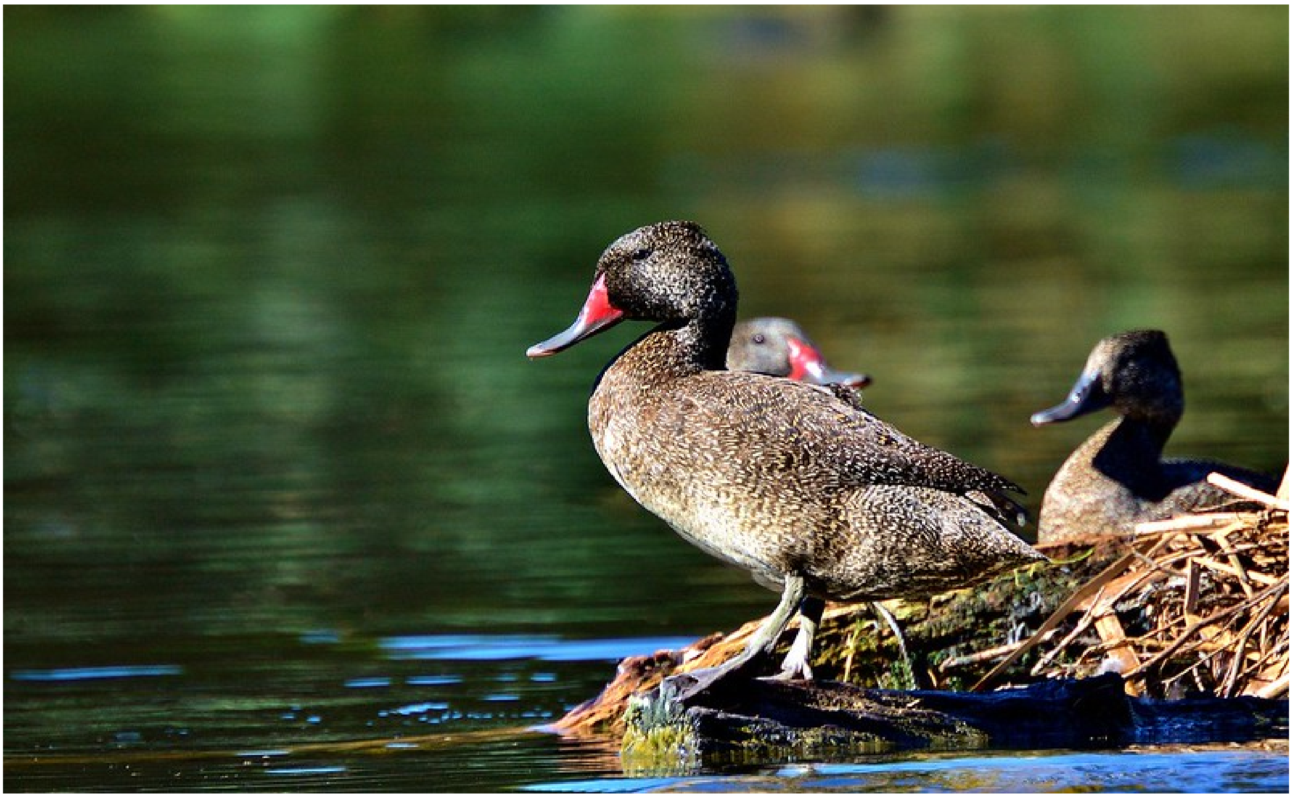

Figure 5 The freckled duck (*Stictonetta naevosa*) has been recorded on the Macquarie floodplain and is listed as vulnerable in NSW under the *NSW Biodiversity Conservation Act 2016* [Image: Laurie Boyle]

3.1.4 Frogs and reptiles

The Macquarie Valley floodplain provides habitat for flow-dependent frogs, turtles and amphibious reptiles (Appendix A). There are at least 17 species of frogs that are known to occur in the Macquarie floodplain (DOI Water 2018), nine of these are considered to have strong flood associations including the Eastern sign-bearing froglet (*Crinia parinsignifera*), Broad-palmed frog (*Litoria latopalmata*) and Salmon striped frog (*Limnodynastes salmini*) (DPI Water 2018). Water-dependent reptiles include the Australian water dragon (*Intellagama lesueurii*) and three species of freshwater turtle.

3.1.5 Wetlands

The Macquarie Marshes are listed as wetlands of international importance under the Ramsar convention 1999 and are considered one of the largest freshwater wetlands in the Murray-Darling Basin (OEH 2013). The Macquarie Marshes Nature Reserve Ramsar site incorporates three separate areas: northern nature reserve, southern nature reserve and U-block (Department of Agriculture, Water and the Environment 2020). The Macquarie Marshes Ramsar sites are part of a larger wetland system (the greater Macquarie Marshes), which is the largest remaining semi-permanent wetland system in inland Australia (DOI Water 2018). The marshes are known to support a rich diversity of waterbirds with times of high floods able to support more than 500,000 individuals (Kingsford and Auld 2005a). Diverse vegetation and waterbird communities are just some important features of these wetlands. These wetlands support a wide range of aquatic species through the provision of aquatic habitats and drought refugia.

3.2 Identifying assets and values in floodplain harvesting areas

Not all environmental values are predicted or known to occur in all areas of the floodplain. Some, such as small-bodied fish, can be restricted to wetlands and refugia. Others, like the river red gum, are widespread. To ensure high confidence in predicted ecological outcomes, only water-dependent environmental values previously recorded, predicted or known to occur near locations where floodplain harvesting occur were used in the assessment of environmental benefits. This provides greater confidence when predicting the environmental impacts of implementing the policy, as changes to floodplain hydrology can be designated to a breakout zone (area) and therefore restrict the predicted ecological responses of assets to that particular breakout zone. Whilst predicting broad scale benefits for the entire floodplain and downstream water sources has a lower confidence due to the hydrological data available (discussed further in Section 4), broad scale outcomes will be explored where feasible.

The approach to identify these values and assets in the Macquarie Valley floodplain is summarised in Figure 6 and the following sub-sections.

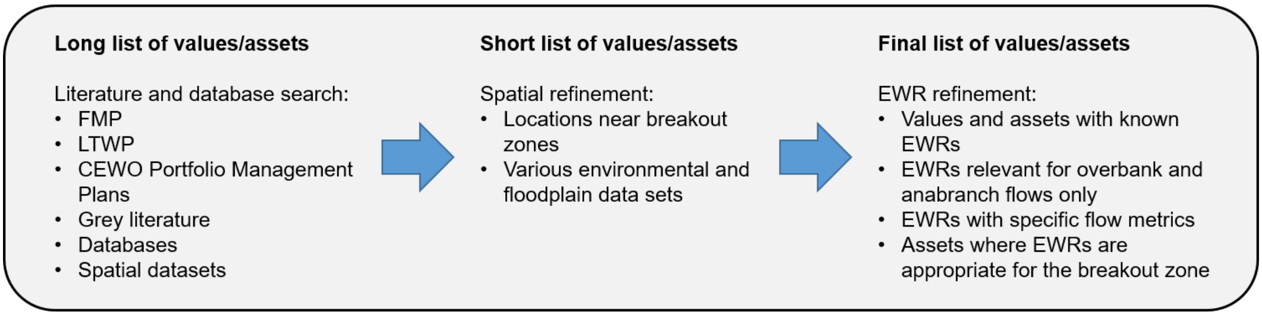

Figure 6 Summary of the approach adopted to identify water-dependent environmental values and assets in floodplain harvesting areas. FMP = Floodplain Management Plan, LTWP = Long-term water plans, CEWO = Commonwealth Environmental Water Office, EWR = environmental water requirement

3.2.1 Literature and database search

A literature and database search were undertaken to identify all potential water-dependent environmental values and assets in the Macquarie Valley Floodplain (Appendix A). The search included species, populations, communities, and specific locations (e.g. wetlands) known to support key environmental values and assets. This generated a ‘long list’ of values and assets.

Key literature included:

- background document to the (*draft) Floodplain Management Plan for the Macquarie Valley Floodplain* (DOI Water 2018)
- *Macquarie-Castlereagh Long-Term Water Plan* (DPIE EES 2019b, 2019a)
- *Macquarie Commonwealth Environmental Water Portfolio Management Plan* (CEWO 2019)
- *Environmental Values and Watering Priorities for the Northern Murray Darling Basin* (SKM 2009)
- *Risk assessment for the Macquarie-Castlereagh water resource plan area* (DOI Water 2018)
- peer-reviewed literature.

Environmental values (which could include species, populations, communities, ecosystem functions) or assets (which are locations, such as wetlands), were selected from the literature if they met the following 3 criteria:

- water-dependent environmental assets or values
- listed as dependent on high flows (i.e. floods) or as benefiting from high flows
- recorded, mapped or predicted to occur within the (draft) Macquarie Valley Floodplain Management Plan (DOI Water 2018) boundary.

3.2.2 Spatial refinement

The next step involved identifying which environmental values and assets occurred within a defined spatial area near the IQQM river system model 'breakout zones'[4] developed by the Department of Planning, Industry and Environment – Water (the department). The spatial refinement was used to restrict the assessment to breakout zones where we have high confidence that the hydrological models represent floodplain flows well based on the documented limitations of the hydrological models described in Appendix D. These river system models are the key sources for predicting hydrological changes on the floodplain before and after implementing the policy. An overview of the river system model is provided in Section 4, with more detail in Appendix C and fully described in the companion Model Build report (DPIE Water 2021a).

Breakout zones are areas of the floodplain where floodwaters break out onto the floodplain and where floodplain harvesting properties access this water on the floodplain (Figure 7). They are often a summary of multiple model nodes where floodplain harvesting properties are accessing water from the floodplain. This could be from a variety of flood runners, anabranches and direct take from the river channel. The end of system (EOS) floodplain breakout represents the location where most of the changes to floodplain hydrology can be detected from the hydrological models developed by the department.

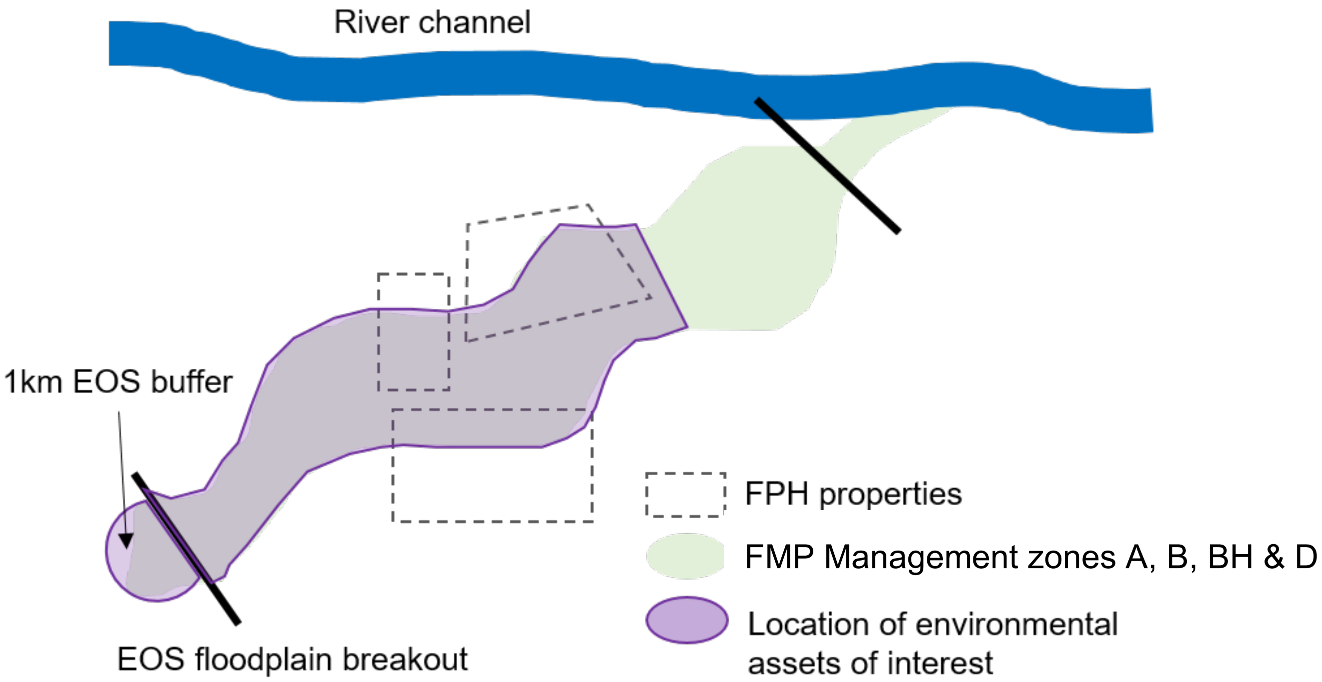

Figure 7 Illustrated depiction of a 'breakout zone'. Breakout zones represent areas where flood waters break out from the river channel onto the floodplain and floodplain harvesting occurs

The upstream and downstream area was restricted by a defined spatial area between the most upstream eligible floodplain harvesting property and a 1 km radius below the end of system floodplain breakout or floodplain harvesting property (whichever was further downstream) in the river system model (Figure 7). Breakout zones provide a high degree of confidence that any modelled changes to overbank flows can be attributed to the asset (i.e. will affect the flow regime where the asset is located). The Macquarie Valley floodplain was split into 10 breakout zones.

[4] Refer to Appendix D of companion Model Build report (DPIE Water 2021a) for a description of the derivation of these breakout zones.

The breakout zone, or area of interest, was then further refined[5] to select environmental assets and values which occurred within four ecologically important (draft) *Macquarie Valley Floodplain Management Plan* (FMP) management zones:

- FMP Zone A signifies a major flood discharge zone and is of significant importance to floodplain assets
- FMP Zone BH is important for semi-permanent wetlands, flood-dependent woodlands and fish passage
- FMP Zone B is important for some flood-dependent woodlands and forests
- FMP Zone D is an environmentally sensitive area providing critical refugia and supporting areas of environmental significance such as swamps, billabongs, rocky bars or warrambools[6].

All four zones also support areas of significant cultural importance (DOI Water 2018). Assets that fell within breakout zones and management zones A, B, BH or D were short-listed for assessment, refining the number of environmental assets. Figure 8 summarises the spatial and EWR refinement process.

Important assets and values most likely also occur in the other FMP zones and downstream of the breakout zones. However, refinement to the selected areas (i.e. breakout zones) provides a higher level of confidence in the predicted outcomes. This is because there are uncertainties around return flows and inundation extents not included in the river system models. This translates to uncertainties in the longitudinal and lateral distance that the specific modelled outcomes would extend.

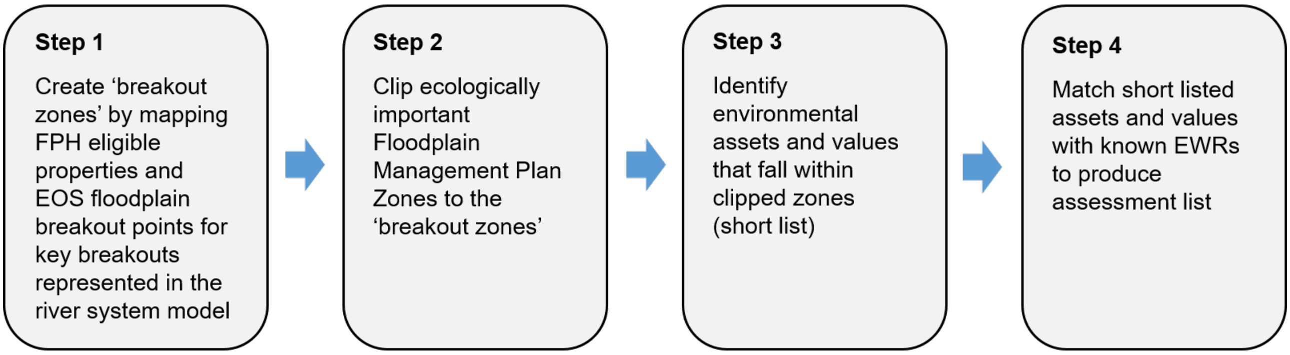

Figure 8 The spatial and EWR refinement process to select environmental assets and values for assessment

3.2.3 Environmental Water Requirement (EWR) refinement

The last step (Step 4 in Figure 8) was to source known and measurable EWRs, documented in the literature, for all the short-listed environmental assets and values identified. Understanding the EWRs of specific values is crucial, as the final assessment approach relies on deriving an ecological interpretation by comparing changes in hydrology after implementation of the policy. The EWRs provide the hydrological metrics of interest (e.g. duration, frequency and timing) for specific assets and allow a comparison of how implementing the policy could influence the frequency of achieving these EWRs.

Refining the list based on environmental assets and values with known EWRs provided a robust approach for predicting the environmental outcomes of implementing the policy (Section 0). As not all water-dependent values have detailed information on the frequency, duration and timing requirements to maintain, reproduce or regenerate, the 'Umbrella Environmental Value' approach was adopted to select key assets from each environmental asset category (described below). This approach was used by Swirepik et al. (2016) to develop river reach-specific EWRs across the Murray-Darling Basin. It recognises that providing water for values with detailed EWR information (e.g. river red gum) should

[5] ArcGIS (10.3.1) computer based mapping and analytics software was used for this task

[6] A warrambool is local language, meaning (in this context) a water overflow channel.

reflect the needs of a broader set of assets and values in the area. The detailed environmental water requirements for the Macquarie Valley floodplain are provided in Appendix C.

3.3 Final list of environmental assets and values

In deriving the final list, the goal was to identify key breakout zones on the floodplain:

- that are of high environmental value *and*
- that are predicted to be affected by changes in overbank flows *and*
- where there is high confidence that the river system model could be used to predict changed hydrological regimes which impact on EWRs.

High level descriptions for assets and values were identified (Table 2) and used to describe the final list of assets and values to be assessed in each of the 10 breakout zones on the floodplain (listed in Table 3). These occur from downstream of Dubbo and support a suite of environmental assets and values including threatened plants, animals, communities and functions. The critical components of each asset's EWRs are detailed in Appendix C.

Figure 9 depicts the breakout zones, Floodplain Management Plan zones, eligible floodplain harvesting properties and hydrological gauges. Figure 10 to Figure 12 provide fine scale maps of key water-dependent environmental assets and values within each breakout zone and management zones of interest. Note, not all data were able to be represented on these maps as many spatial layers overlay each other. Key water-dependent plant community types (PCT)s were the main focus for these maps

Table 2 Categories of values and assets used for final assessment

Category	Description
Value – native fish	Native fish dependent on or gaining significant benefits from floodplains or overbank flows including predicted occurrence of threatened species
Value – native vegetation	Plant Community Types (PCTs) and important plant species
Value– waterbirds	Predicted distributions, recorded and known observations of a variety of waterbirds including species listed as threatened and in international migratory waterbird agreements
Asset – wetlands	A range of lagoons, billabongs and waterholes known to provide important habitat and refuge for a variety of water-dependent communities
Asset – flow-dependent frogs	Predicted distributions, recorded and known observations of a variety of flow-dependent frog species

Table 3 Final list of water-dependent floodplain assets and values and their characterisation for each breakout zone. Key breakout points are the river system model nodes. V = Vulnerable, E = Endangered, C = CAMBA, J = JAMBA, K = ROKAMBA. [1]listed on the *Environment Protection and Biodiversity Conservation Act*, [2]listed in the NSW *Fisheries Management Act* 1994

Key breakout points	Asset/value	Asset/value characterisation
(A) Trangie breakout zone		

Key breakout points	Asset/value	Asset/value characterisation
EOS to floodplain: Trangie cowal, d/s Warren weir, Brichells plain Ck, Ewenmar Ck, Crooked Ck	Native fish	• Recorded: Murray Cod (V)[1], Silver Perch (V)[1], Australian Smelt, Bony Herring, Carp Gudgeon, Flat-headed Gudgeon, Freshwater Catfish, Golden Perch, Mountain Galaxias, Murray-Darling Rainbowfish, Spangled Perch, Un-specked Hardy Head • Predicted: Eel-tailed Catfish – MDB population (E)[2], Olive Perchlet (E)[2], Trout Cod (E)[1,2]
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little egret, little pied cormorant, nankeen night heron, pied cormorant, royal spoonbill, straw-necked ibis, white-faced heron, white-necked Heron, yellow-billed spoonbill • Non-colonial: Latham's snipe (J,K), marsh sandpiper, common greenshank (C,J,K), sharp-tailed sandpiper (C,J,K), common sandpiper, red-necked stint
	Native vegetation	• River red gum, black box, river cooba, lignum shrubland wetland
	Frogs	• Recorded: Eastern sign-bearing froglet, spotted grass frog, green tree frog, broad-palmed frog, Peron's tree frog, desert tree frog
	Wetlands	• Boggy Cowal Swamps and Lagoons
(B) Marthaguy breakout zone		
EOS to floodplain: u/s Birchells connection	Native fish	• Recorded: Australian Smelt, Golden Perch • Predicted: Eel-tailed Catfish – MDB population (E)[2]
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little egret, little pied cormorant, nankeen night heron, pied cormorant, royal spoonbill, straw-necked ibis, white-faced heron, white-necked heron, yellow-billed spoonbill • Non-colonial: Latham's snipe (J,K), marsh sandpiper, common greenshank (C,J,K), sharp-tailed sandpiper (C,J,K), common sandpiper, red-necked stint
	Native vegetation	• Black box, lignum shrubland wetland, river cooba swamp wetland, river red gum
	Frogs	• Recorded: Long-thumbed Frog, Salmon Striped Frog, Spotted Grass Frog, Green Tree Frog
	Wetlands	• Castlereagh Swamps, Lagoons and Dunes
(C) Birchells Plains breakout zone		
Birchells Plains to EOS breakout: d/s Bellevue confluence	Native fish	• Predicted: Olive Perchlet (E)[2], Silver Perch (V)[1]
	Waterbirds	• Colonial-nesting: White faced heron
	Native vegetation	• Black box, river cooba swamp wetland, river red gum
	Frogs	• Recorded: Desert tree frog

Key breakout points	Asset/value	Asset/value characterisation
	Wetlands	• Macquarie Marshes
(D) Gunningbar breakout zone		
EOS to floodplain: d/s Beleringar confluence	Native fish	• Recorded: Murray Cod (V)[1], Australian Smelt, Bony Herring, Flat-headed Gudgeon, Freshwater Catfish, Golden Perch, Murray-Darling Rainbowfish, Un-specked Hardyhead, unidentified Carp-Gudgeon • Predicted: Eel-tailed Catfish – MDB population (E)[2], Olive Perchlet (E)[2], Silver Perch
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little egret, little pied cormorant, nankeen night heron, pied cormorant, royal spoonbill, straw-necked ibis, white-faced heron, white-necked heron, yellow-billed spoonbill • Non-colonial: Latham's snipe (J,K), marsh sandpiper, common greenshank (C,J,K), sharp-tailed sandpiper (C,J,K), black-tailed godwit
	Native vegetation	• Black box, river cooba swamp wetland, river red gum, lignum shrubland wetland
	Frogs	• Recorded: Eastern sign-bearing froglet, salmon striped frog, spotted grass frog, green tree frog, broad-palmed frog, Peron's tree frog, desert tree frog
	Wetlands	• Bugwah Swamps and Lagoons
(E) Wyndabyne breakout zone		
Marthaguy\ Bullagreen to EOS breakout: d/s Quambone, Wyndabyne	Native fish	• Recorded: Spangled Perch • Predicted: Eel-tailed Catfish – MDB population (E)[2]
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little pied cormorant, nankeen night heron, royal spoonbill, straw-necked ibis, white-faced heron, white-necked heron, yellow-billed spoonbill
	Native vegetation	• Black box, river cooba swamp wetland, river red gum
	Frogs	• Recorded: Salmon striped frog, spotted grass frog, desert tree frog
	Wetlands	• Castlereagh Swamps, Lagoons and Dunes
(F) Gradgery breakout zone		
Long Plain Cowal to EOS breakout: Gradgery, Terrigal Ck, Bulgeraga Ck	Native fish	• Predicted: Silver perch, olive perchlet (E)[2], trout cod
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little egret, little pied cormorant, nankeen night heron, royal spoonbill, straw-necked ibis, yellow billed spoonbill • Non-colonial: latham's snipe (J,K)

Key breakout points	Asset/value	Asset/value characterisation
	Native vegetation	• Black box, lignum shrubland wetland, river cooba swamp wetland, river red gum, water couch grassland wetland
	Frogs	• Recorded: Eastern sign-bearing froglet, spotted grass frog, green tree frog, broad-palmed frog, Peron's tree frog, desert frog
	Wetlands	• Macquarie Marshes
(G) Marebone breakout zone		
Oxley Station to EOS breakout: Marebone, d/s Oxley Station, Milmilamd Ck, Marra Ck, Sandy Cowal	Native fish	• Recorded: Flat-head Gudgeon • Predicted: Silver Perch, Olive Perchlet (E)[2], Trout Cod (E)1,2
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little egret, little pied cormorant, nankeen night heron, royal spoonbill, straw-necked ibis, white-faced heron, white-necked heron, yellow-billed spoonbill • Non-colonial: latham's snipe (J,K), marsh sandpiper
	Native vegetation	• Black box, cumbungi, river cooba swamp wetland, river red gum, water couch marsh grassland wetland
	Frogs	• Recorded: Spotted grass frog, green tree frog, Peron's tree frog, desert tree frog
	Wetlands	• Ramsar - Wilgara Wetland • Macquarie Marshes
(H) Wilgara breakout zone		
Bulgarega to EOS breakout: Wilgara, Terrigal Ck	Native fish	• None predicted
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little egret, little pied cormorant, nankeen night heron, pied cormorant, royal spoonbill, straw-necked ibis, white-faced heron, white-necked heron, yellow-billed spoonbill • Non-colonial: Latham's snipe (J,K), marsh sandpiper, common greenshank (C,J,K), sharp-tailed sandpiper, wood sandpiper
	Native vegetation	• Black box, coolabah – river cooba, coolabah open woodland wetland, river cooba swamp wetland, river red gum, water couch marsh grassland wetland
	Frogs	• Recorded: Eastern sign-bearing froglet, spotted grass frog, green tree frog, Peron's tree frog
	Wetlands	• Macquarie Marshes
(I) Glencoe breakout zone		
Kiameron to EOS breakout: Long plain cowal, u/s Bulgeraga Ck bifurcation	Native fish	• None predicted
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little egret, little pied cormorant, nankeen night heron, pied cormorant, royal spoonbill, straw-necked ibis, white-faced heron, white-necked heron, yellow-billed spoonbill

Key breakout points	Asset/value	Asset/value characterisation
	Native vegetation	• Black box, coolabah open woodland, river cooba swamp wetland, river red gum, water couch marsh grassland wetland
	Frogs	• Recorded: Spotted grass frog, broad-palmed frog, Peron's tree frog
	Wetlands	• Macquarie Marshes
(J) Pillicarwarrina breakout zone		
Pillicarwarrina to EOS breakout: Bulgeraga Ck, u/s Bulgeraga Ck bifurcation	Native fish	• Recorded: Australian Smelt, Bony Herring, Golden Perch, Murray-Darling Rainbowfish, Spangled Perch • Predicted: Silver Perch (V)[1], Olive Perchlet (E)[2], Trout Cod (E)1,2
	Waterbirds	• Colonial-nesting: Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, intermediate egret, little black cormorant, little egret, little pied cormorant, nankeen night heron, pied cormorant, royal spoonbill, straw-necked ibis, white-faced heron, white-necked heron, yellow-billed spoonbill
	Native vegetation	• Black box, coolabah open woodland wetland, cumbungi rushland wetland, lignum shrubland wetland, river cooba swamp wetland, river red gum, water couch marsh grassland wetland
	Frogs	• Recorded: Eastern sign-bearing froglet, salmon striped frog, spotted grass frog, green tree frog, broad-palmed frog, Peron's tree frog, desert tree frog
	Wetlands	• Ramsar - Macquarie Marshes Nature Reserve • Macquarie Marshes

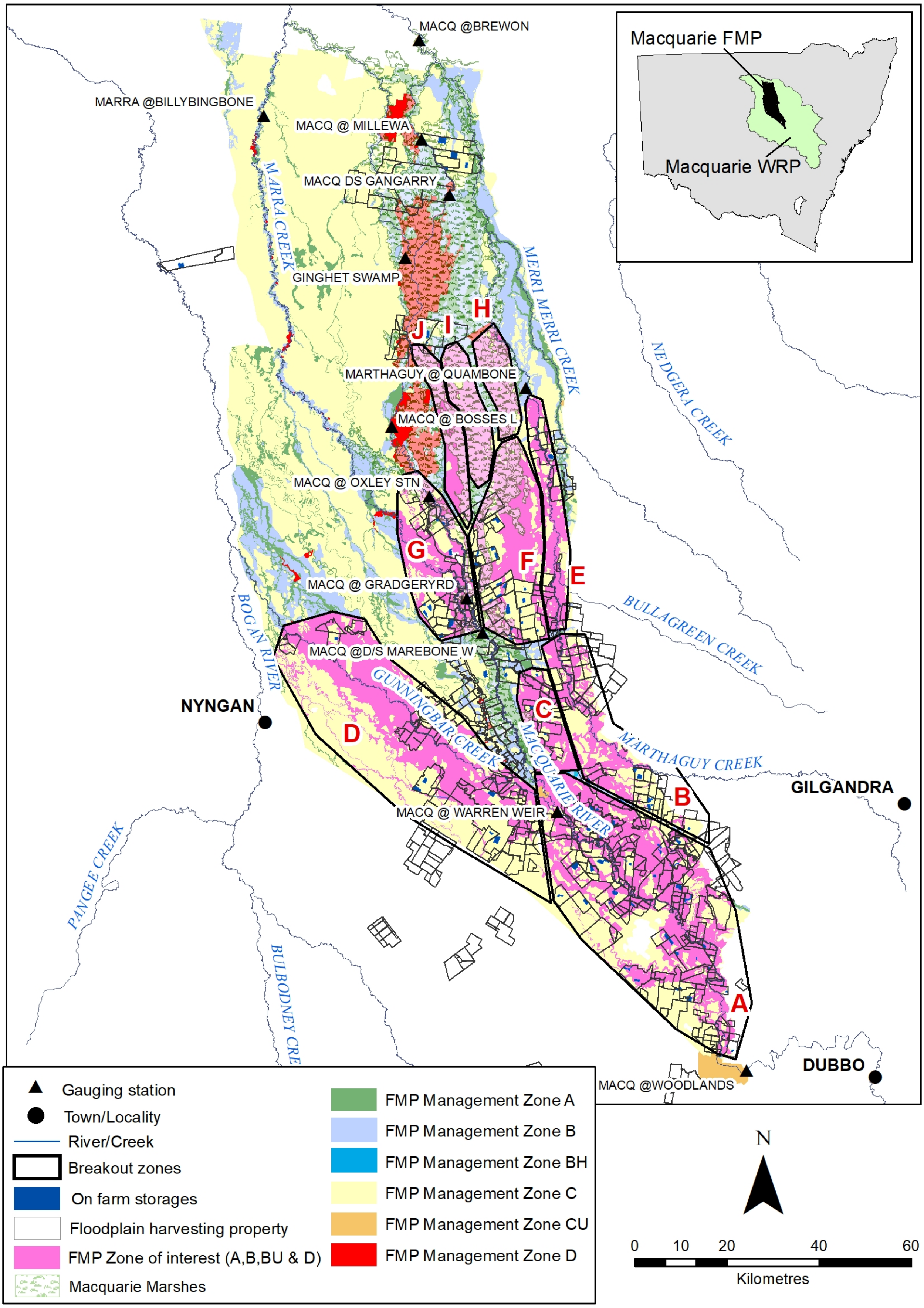

Figure 9 Map of the Macquarie Valley floodplain showing the Floodplain Management Plan (FMP) zones and the breakout zones used to select environmental assets and values for inclusion in this assessment. Breakout zones from most upstream to most downstream: A Trangie, B Marthaguy, C Birchells Plains, D Gunningbar weir, E Wyndabyne, F Gradgery, G Marebone, H Wilgara, I Glencoe, J Pillicarwarrina

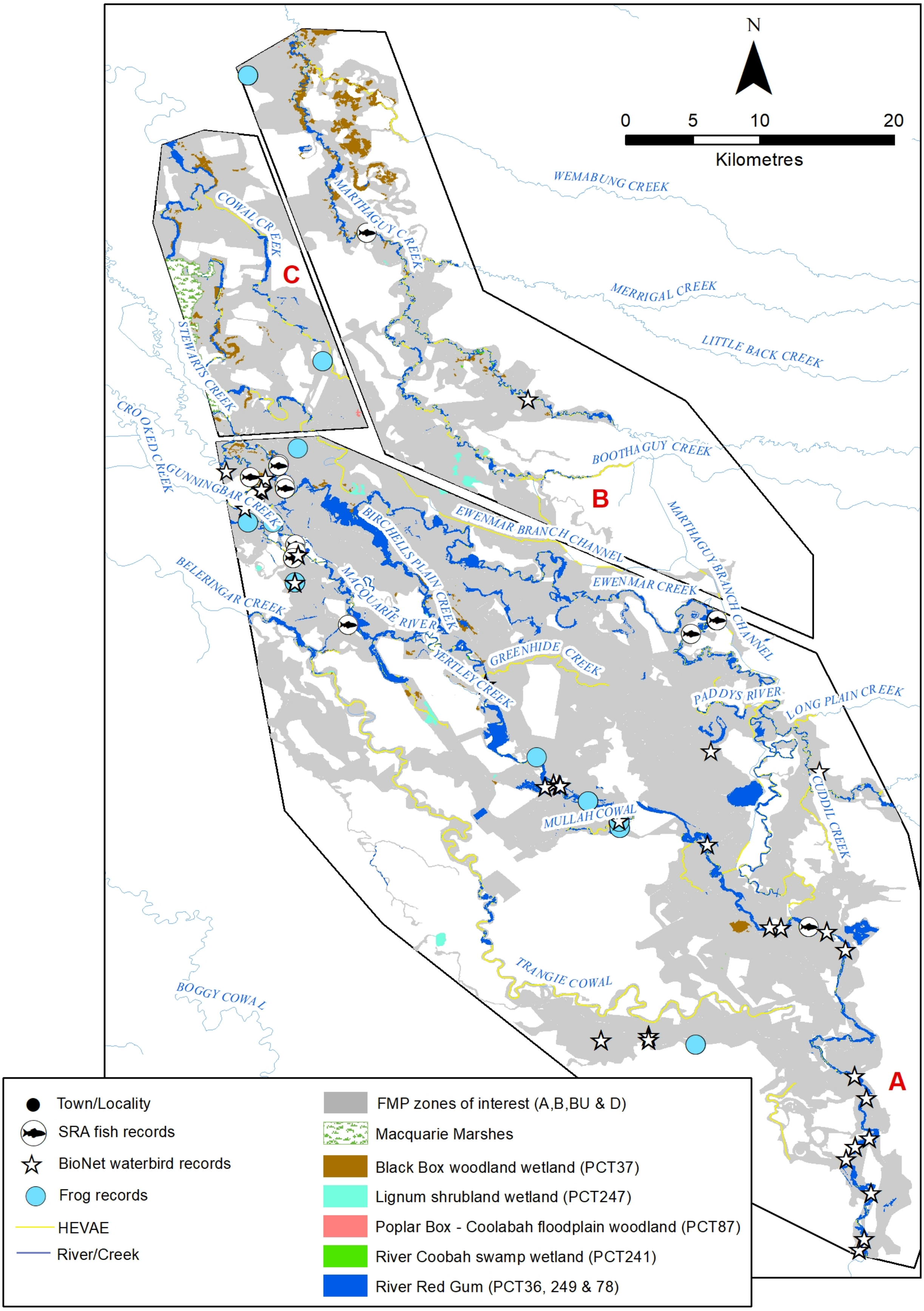

Figure 10 Location of selected water-dependent environmental assets and values at breakout zones A Trangie, B Marthaguy and C Birchells Plains. Appendix B provides details for all data sources including those that were not able to be presented

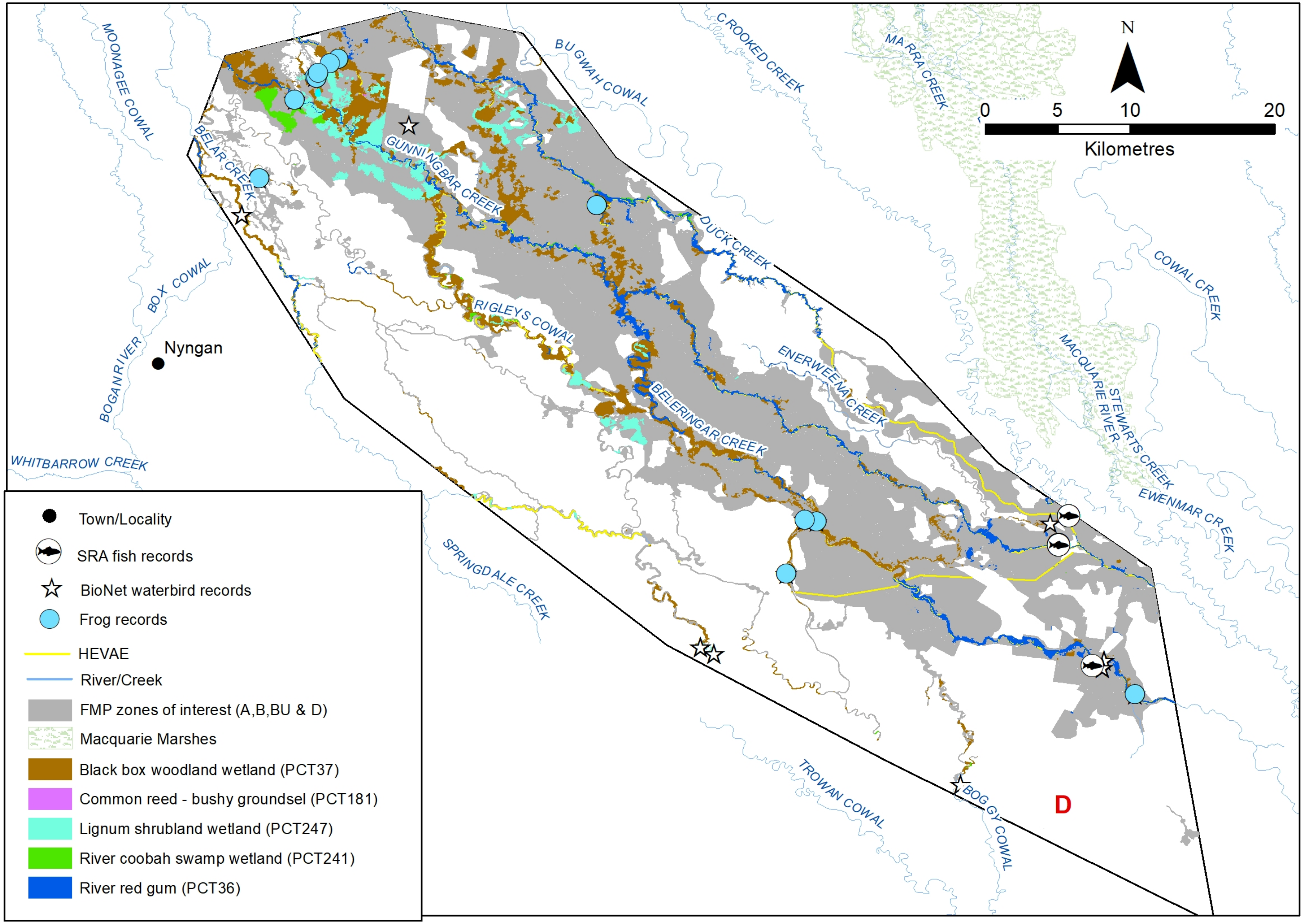

Figure 11 Location of selected water-dependent environmental assets and values at breakout zone D Gunningbar weir. Appendix B provides details for all data sources including those that were not able to be presented

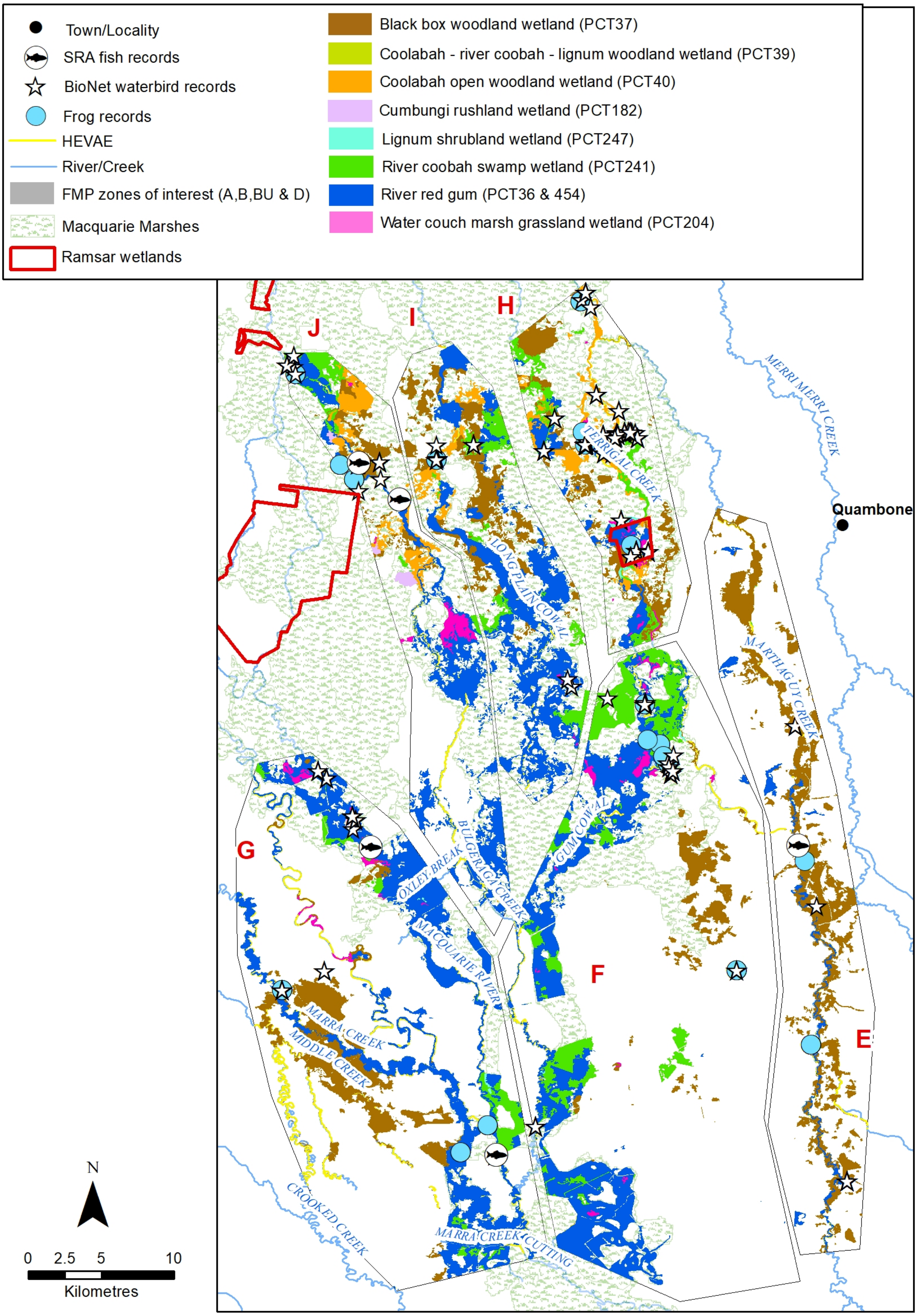

Figure 12 Location of selected water-dependent environmental assets and values at breakout zones E Wyndabyne, F Gradgery, G Marebone, H Wilgara, I Glencoe and J Pillicarwarrina. Appendix B provides details for all data sources including those that were not able to be presented

4 Hydrological changes on the floodplain

4.1 River system model overview

Implementation of the NSW Floodplain Harvesting Policy (the policy) has increased investment in data and modelling to quantify floodplain harvesting more accurately. This section provides a broad overview of the river system models developed by the department. Further information can be found for each model in the Model Build reports for each Valley (e.g. *Building the river system model for the Macquarie Valley regulated river system*) (DPIE Water 2021a).

River system models have been used for many decades to determine water availability, flows and diversions under varying climate conditions, as a critical step in informing the development of water sharing arrangements. The Macquarie Valley model is designed to support contemporary water management decisions in the Macquarie Valley, whether it is a rule change in the Water Sharing Plan, or estimating long term average water balances for components such as diversions for compliance purposes. These models have two overarching objectives:

- to support traditional water policy, planning and compliance uses, such as implementing the Basin Plan and estimating Plan limits
- to determine volumetric entitlements for floodplain harvesting consistent with the 2013 policy.

4.1.1 Modelling platform

The Macquarie Valley model is built using the IQQM software platform. IQQM simulates flows through a system, whether those flows are water, sediment, contaminants, water accounts or water trade. It provides sufficient functionality to simulate the process of water moving out onto floodplains. IQQM models are built from components which are linked, through adding nodes and links, to represent the system to be modelled. There are many types of nodes to represent places where water can be added, diverted, stored, and recorded (for reporting) in a model, including:

- water sources (supply), such as inflows, storages
- water users (demand), such as crops, towns, industries, the environment
- reporting points, such as gauges and environmental assets.

Links can connect, store and route water passing between nodes.

4.1.2 Parameterisation

Each component can be configured to correctly represent the system, a process known as parameterisation (DPIE Water 2021a). Parameters can be assigned directly from the data source or refined through calibration against recorded data to improve the model performance. Parameter values are estimated using one or a mix of the following methods:

- assigned directly, based on measured data, such as survey or remotely sensed data of on-farm storages
- assigned based on published advice from industry or research
- calibrated by systematically adjusting to match recorded data at the site or of system behaviours – this method iteratively checks how well model outputs match recorded data and parameters are adjusted to improve performance.

4.1.3 Modelling approach

The river system model uses a water balance approach that ensures that all flows (in, out and stored) balance over a given time step (such as days, years) and at three spatial scales (farm, reach and river system).

Figure 13 shows the key components of a reach water balance. The Environmental Outcomes reports primarily use the component of breakout flow remaining on the floodplain after it breaks out onto the floodplain and is accessed by floodplain harvesting. Model calibration is conducted on a river reach scale using available recorded data. Once river reach water balances are developed they are combined to represent the entire river system. The model is then validated using a suite of tests to evaluate how well the model performances against observed data over the period of calibration. The Macquarie Valley model validation process is set out in the Model Build report (DPIE Water 2021a).

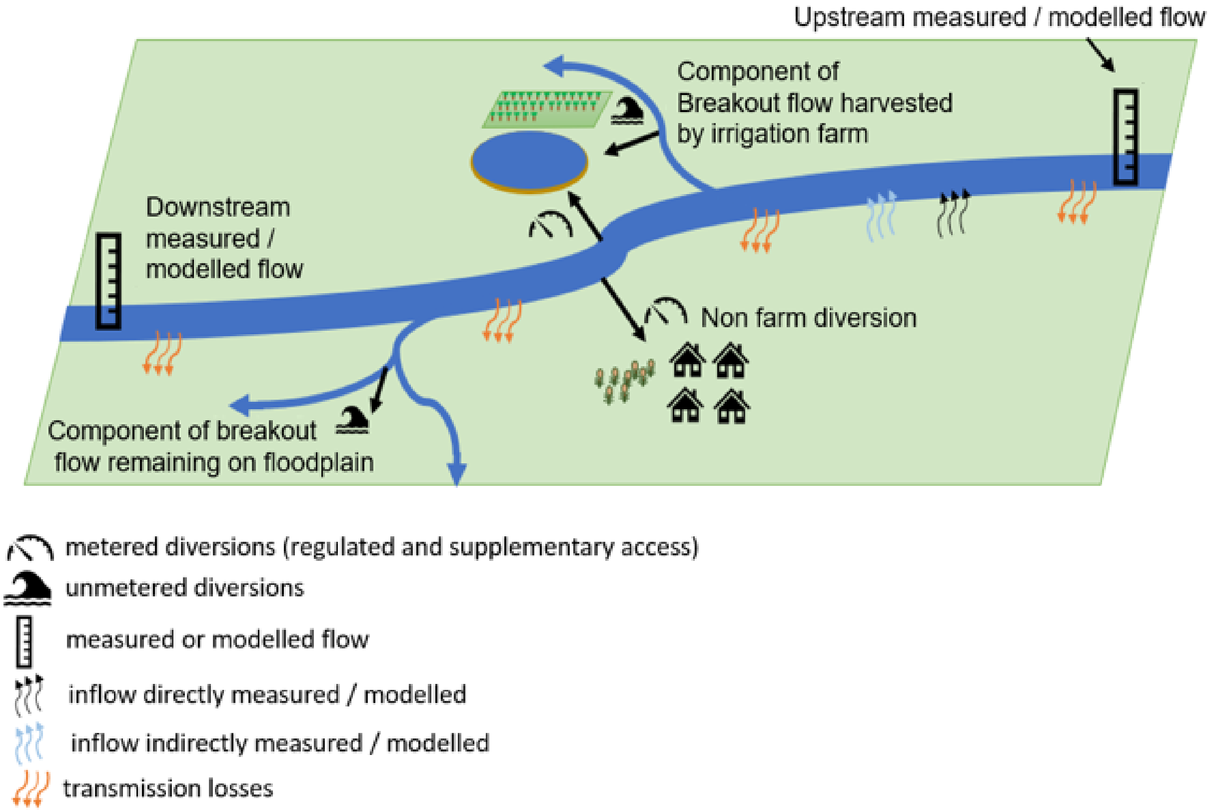

Figure 13 Reach water balance components [Source: Figure 3, DPIE Water 2021a]

The final step involves developing and running different simulated scenarios. Managed river system scenarios include the following characteristics:

> "Fixed development conditions: including catchment and landuse, headwater and re-regulating storages, areas developed for irrigation, on-farm storage volumetric capacity, and pump capacity.
>
> Fixed management arrangements, including all rules, resource assessment and allocation processes, and accounting as set out in the water sharing plan, as well as on-farm decision making regarding crop mix, crop area planting as a function of water availability, and irrigation application rates" (DPIE Water 2021a).

These scenarios are detailed in the companion Scenarios report (DPIE Water, 2021b).

Within the river system model, each breakout zone is represented by:

- a splitter node[7] (to create the overbank water)
- a few additional nodes (e.g. a virtual storage to stop the allocated water from flowing through the breakout zone)

[7] A node type provided in the modelling platform

- all the supply points (water user nodes) to extract the water (for floodplain harvesting)
- a gauge node at the end, called the breakout EOS node (refer to Figure 7 and Figure 13). This is a reporting point in the model, and not an actual gauge.

4.1.4 Available hydrological data

Change in floodplain harvesting pre- and post-implementation of the policy was assessed under two model scenarios:

- current conditions, that is without the policy implemented; the Current Conditions Scenario
- current conditions with floodplain harvesting entitlements and accounting applied; the Plan Limit Compliance Scenario.

Both scenarios are required to identify hydrological changes due to implementing the policy and flow-on environmental floodplain benefits or disadvantages. Each scenario contains:

- modelled daily time-series flow data (in ML/day) for important gauging stations (gauge nodes) in the valley
- modelled daily time-series flow data (in ML/day) to floodplain breakout zones, and an end-of-system (EOS) reporting node. A schema is provided in Figure 7. More details on the modelling are provided in Appendix D and the companion Model Build and Scenarios reports (DPIE Water 2021a, DPIE Water 2021b).

All modelled flow data cover the period from 1895 to 2019.

4.2 Quantifying changes to floodplain hydrology

4.2.1 Identifying ecologically relevant metrics

Magnitude, frequency, duration and timing are all ecologically relevant hydrological features of the floodplain flow regime (Richter et al. 1996, Leigh and Sheldon 2008). The strength of an environmental response is often proportional to the magnitude and duration of a flood (Kingsford and Auld 2005a, Bunn et al. 2006, Woods et al. 2012). Native fish biomass, health and abundance can increase with the magnitude, duration and inundation of a flood (Bunn et al. 2006) whilst inundation extent, duration and variability (i.e. regularity or frequency) are critical to maintain and improve floodplain vegetation species. For example, river red gum forests can survive for long periods without inundation but require periodic flooding (every 1 to 3 years), a flood inundation duration of 2 to 8 months and an inter-flood dry period between events to be in good condition (Roberts and Marston 2000, Wen et al. 2011). Many waterbirds are also sensitive to the magnitude, frequency, duration and timing of floods, particularly to achieve successful recruitment (Kingsford and Auld 2005a). Reduced rates of rise and increased rates of fall can also reduce environmental benefits, especially during breeding events for waterbirds (Kingsford and Auld 2005a, Kingsford et al. 2014).

The timing (e.g. seasonality and frequency) of floods is also critical to achieving a range of ecological outcomes (Robertson et al. 2001, Kingsford et al. 2014, NSW Department of Primary Industries 2015, DPIE EES 2019b). For example, the most common timing for spawning of floodplain specialist fish in the northern basin is September to October. Improving magnitude and duration of floods during these periods would therefore achieve the greatest outcomes for these fish (NSW Department of Primary Industries 2015). These hydrological features are also important for a number of other ecological functions on the floodplain and in the river channel. Therefore, identifying and describing the changes to key metrics of each hydrological feature is the first step in assessing environmental outcomes of implementing the policy.

Flow metrics that describe the ecologically relevant hydrological features of the floodplain have been adapted from Richter et al. (1996) and Leigh and Sheldon (2008) and are shown in Table 4. A mix of summary, parametric and non-parametric measures has been selected to describe these features. Non-parametric measures (such as **medians**) are appropriate for many flow regimes due to the less frequent floods and more frequent low flows. However, **totals** and parametric measures (such as **means**) are useful where a large number of zero flows occur and the median limits meaningful comparisons (e.g. on regulated floodplains) (Walker et al. 1995, Leigh and Sheldon 2008). Using totals (e.g. total duration of summer events) avoids the impact of zeros on the mean and median. Where medians were used, the zero flow periods were removed from the data unless required for meaningful median comparisons. For example, the median magnitude (ML/d) with flow was only calculated on data where flow exceeded 1 ML/day. This ensured that the median of event magnitude (ML/d) was not influenced by the large number of zero flow days on the floodplain.

Table 4 Hydrological feature, period of interest and hydrological metrics adopted to describe magnitude and duration of flow events. Seasonality (timing), frequency and variability are incorporated into each hydrological feature. [1]S = summer, A = autumn, W = winter, Sp = spring

Hydrological feature	Period of interest	Flow metric	Reasoning
Magnitude	Inter-annual	Mean of annual volume (ML)	Provides summary measures of annual volume changes
	Inter-annual	Ratio of median to mean annual volume (ML)	Provides a measure of the changes in regularity of flood volumes
	Seasonal (S/A/W/Sp)[1]	Total of seasonal volumes (ML)	An estimate of changes to seasonal flood volumes over the modelled flow record
	Event	Median of event magnitude (ML/d)	An estimate of the change in the magnitude of flow events
Duration, frequency and timing	Whole record	Number of years with flow (>1 ML/d)	Identifies if there is an increase in the frequency of flooding over yearly timespans
	Whole record	Total number of days with flow (>1 ML/d)	High level summary of the changes in flood duration
	Seasonal (S/A/W/Sp)[1]	Total of seasonal days with flow (>1 ML/d)	Identifies changes to the number of flood days for spring, summer, autumn and winter
	Event	Number, total duration and mean interevent period (days)	Identifies key changes to the number of flow events, the duration of these events and the inter-event period between them
	Event	Total duration of event rise and fall and mean rate of rise and fall	Important metrics for dispersal, fish and waterbird breeding success

For annual, seasonal and event time periods, magnitude (volumes and flow rates) will be described by mean, medians and totals, as well as by skewness in terms of median to mean flow ratio (low values represent high skew, and therefore less regularity of flows, and vice versa). The hydrological metrics in Table 4 describe an aspect of a hydrological feature (i.e. magnitude, frequency, duration or timing) or the variability of a metric. Understanding how implementation of the policy impacts the identified hydrological metrics provides the first level of detail required to predict environmental outcomes on the floodplain.

4.2.2 Methods to quantify changes

The model Current Conditions and Plan Limit Compliance scenarios are the primary source of information used to quantify changes in floodplain flows due to implementing the policy. The hydrological metrics listed in Table 4 were calculated for each modelled flow series[8]. As the end of system (EOS) floodplain breakout flow is the modelled time series where detectable impacts of floodplain harvesting are evident, the analysis is restricted to this model node for each breakout zone.

Results for the EOS floodplain breakout under these two scenarios were compared for the period 1895 to 2019 (Figure 14, Table 5). The Plan Limit Compliance Scenario time-series has the floodplain harvesting diversions incorporated into the EOS breakout model node and therefore represents the change due to implementing the policy. This assessment provides a quantified change in ecologically relevant hydrological metrics before and after implementation of the policy based on a modelled long-term record. All predictions are for the period 1895 to 2019. Running over such a long period ensures that multiple dry and wet periods and climate extremes are captured in the modelling and provides a measure of change under similar climatic conditions when the policy is implemented. Further detail on the limitations and approach used to quantify hydrological changes can be found in Appendix C.

[8] The Time Series Analysis module of the River Analysis Package (RAP) software (Marsh et al. 2003) and Microsoft Excel 2016 were used for this task.

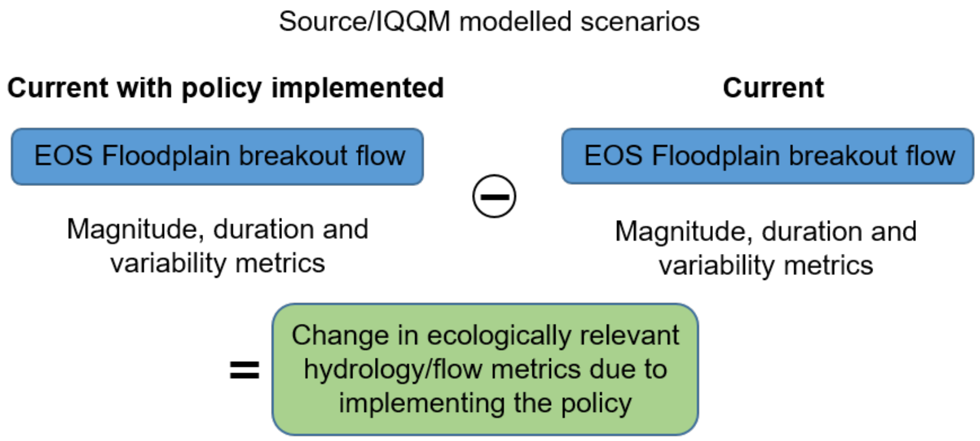

Figure 14 Summary diagram of how modelled breakouts were used to identify changes to floodplain hydrology and assess predicted ecological outcomes

4.3 Hydrological outcomes

4.3.1 Changes to floodplain hydrology

Modelling indicates that the implementation of the policy will result in some small changes to key ecologically relevant hydrological features of the floodplain. These vary with location on the floodplain and the metric of interest. Outcomes are reported for key hydrological features as a percentage change from the current scenario to the scenario with the policy implemented for each breakout zone (Table 5). These interpretations are limited to the modelled outcomes for the end of system breakouts but provide indicative modelled outcomes for a range of locations on the Macquarie Valley floodplain.

Results presented are modelled long-term (over the period 1895 to 2019) changes to the hydrology of the floodplain that would occur under the policy.

Magnitude

Mean annual volumes are predicted to experience limited change (i.e. excluding non-flood years) over all breakout zones (average 0%) (Table 5, Figure 15). The largest predicted percentage increase in mean annual volume is in the Wilgara breakout zone (+1%, 2 GL).

Changes to **total seasonal volumes** across the 124-year simulation period are also predicted to be small or negligible over all breakout zones with <1% change in total volumes for all seasons (Table 5, Figure 15). The largest predicted change is at Wilgara (+6%, 68GL) and Glencoe (+4%, 61 GL) in summer.

Median event magnitudes, which provide a measure of change in flow rates (ML/day) during flow events, are predicted to have no changes averaged across all breakout zones (0%) (Table 5, Figure 15). The highest predicted percentage increase is only +1% in the Wyndabyne breakout zone (E).

Duration

Total number of flow days is predicted to have negligible change when averaged across all breakout zones (0%) (Table 5, Figure 15). The highest predicted percentage change is in the Glencoe breakout zone (+4%, 170 days over total record) and the Wilgara breakout zone (+3%, 114 days over total record). The remaining breakout zones are predicted to have <1% change in total flows.

Seasonal flood durations in general are predicted to have minor changes in all breakout zones across all seasons (Table 5, Figure 15), with the exception of sizeable increases in the Wilgara breakout zone (+15%, 99 total flow days) and the Glencoe breakout zone (+16%, 135 total flow days).

Event based metrics

The **number of flow events** between 1895 and 2019 are predicted to increase in the Wilgara (+23%) and Glencoe (+17%) breakout zones only (Table 5). The remaining breakout zones are expected to have no change or have a small decrease (e.g. Trangie (−2%)).

The mean duration between events (**inter-event period**) is predicted to have the highest percentage reductions in the Wilgara (−19%) and Glencoe (−15%) breakout zones. This equates to a reduction in 81 days at Wilgara and 62 days at Glencoe between events. The remaining breakout zones have negligible changes (Table 5).

Changes of modelled outcomes for the **rise and fall** statistics of flow events are generally low with minor increases in total duration of rises in Wilgara (+4%) and Glencoe (+3%) breakout zones and negligible changes observed elsewhere (Table 5). There are no significant changes in the duration of fall metrics at all breakout zones.

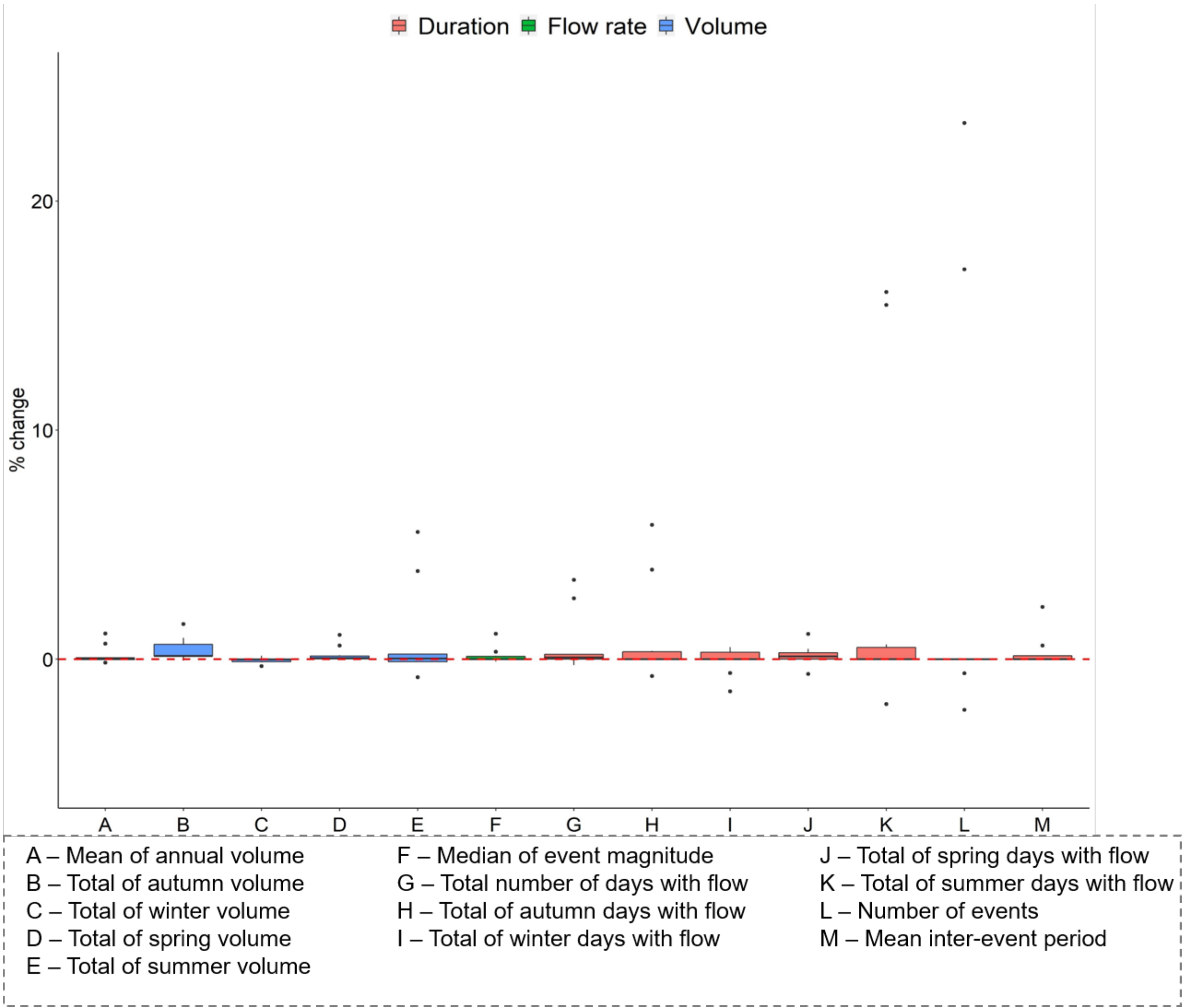

Figure 15 Box plot of percentage change in key hydrological metrics after implementing the policy in the Macquarie Valley. Data represents the medians (bold line inside box), 25th and 75th percentiles (bottom and top of box), minimum and maximum (bottom and top whisker notches) and outliers (points), averaged over the 124-year simulation period across the 10 breakout zones. The outliers in this figure represent the breakout zones with either the largest reduction or increase. This can be used to highlight how many breakout zones are outliers for each metric.

Table 5 Percentage change in ecologically relevant flow metrics after implementation of the policy. Values are averaged over the 124-year simulation period. EC = Event created, i.e. there was no event before implementation of the policy. Only flows >1 ML/day were considered flowing days. *Negative % change is a positive outcome for the value or asset as the mean period between floods (inter-event period) has reduced

Hydro feature	Flow metric	A Trangie %	B Marthaguy %	C Birchells Plains %	D Gunningbar %	E Wydabyne %	F Gradgery %	G Marebone %	H Wilgara %	I Glencoe %	J Pillicarwarrina %	Average %
Magnitude	Mean of annual volume (flood years only)	0	0	0	0	0	0	0	1	1	0	0
	Ratio of median to mean annual volume	−1	5	0	0	8	1	−1	4	−1	0	1
	Total autumn volumes	0	1	0	0	1	0	0	2	1	0	0
	Total winter volumes	0	0	0	0	0	0	0	0	0	0	0
	Total spring volumes	0	0	0	0	0	0	0	1	1	0	0
	Total summer volumes	0	−1	0	0	0	0	0	6	4	0	1
	Median of event magnitude	0	0	0	0	1	0	0	0	0	0	0
Duration, frequency and timing	Total flow days	0	0	0	0	0	0	0	3	4	0	1
	Number of events	−2	0	−1	0	0	0	0	23	17	0	4
	Total autumn days with flow	−1	0	0	0	0	0	0	6	4	0	1
	Total winter days with flow	0	0	1	0	0	0	0	−1	−1	0	0
	Total spring days with flow	−1	1	1	1	1	0	0	0	1	0	0
	Total summer days with flow	1	0	0	0	−2	0	0	15	16	0	3
	Mean inter-event period*	2	0	1	0	0	0	0	−19	−15	0	-3
	Total duration of rises	0	−1	0	0	0	0	−1	4	3	−1	1
	Mean rate of rise	2	1	1	0	0	1	0	−5	−3	0	0
	Total duration of falls	0	0	0	0	0	0	0	0	0	0	0
	Mean rate of fall	−12	−3	−1	0	−1	0	0	−5	−4	0	−2

Case study of hydrological changes

An analysis of the modelled hydrological changes for total annual volumes for a 10 year period with a number of consecutive floods (1970-1979), and hydrographs over a period with lower total volumes (1971) and a year with higher total volumes (1973-1974) were used to highlight changes over a decade and within flow events (Figure 16). Two breakout zones were selected to highlight the potential changes in a zone with the relatively little change (Trangie breakout zone) and one with some expected changes (Wilgara breakout zone).

There are only small changes in total annual volume predicted for the Trangie breakout zone. In most years there is no change, and small decreases predicted for some years. There was an overall total increase of 2GL over the ten-year period. In comparison, Wilgara breakout zone is predicted to have greater change in total annual volumes. The greatest increase in Wilgara was in 1973 (13 GL), with a total increase of 54GL over the ten-year period.

The Trangie hydrograph shows little change after the policy is implemented, with only one extra flow day predicted in the 1971 event. In the 1973-1974 event there were three additional flow days. The Wilgara breakout has slightly higher daily volumes and there is an increase of 11 flow days over summer in January -February associated with low magnitude events (Figure 16) and a three flow day increase at the tail end of the recession. In 1973-1974 there were only four additional flow days associated with the falling limb of the event. The minor hydrological changes associated with policy implementation for these periods show that the change in daily volumes, increase in low magnitude flow events, and a slight increase in flow days on the recession of large events are the key drivers of change.

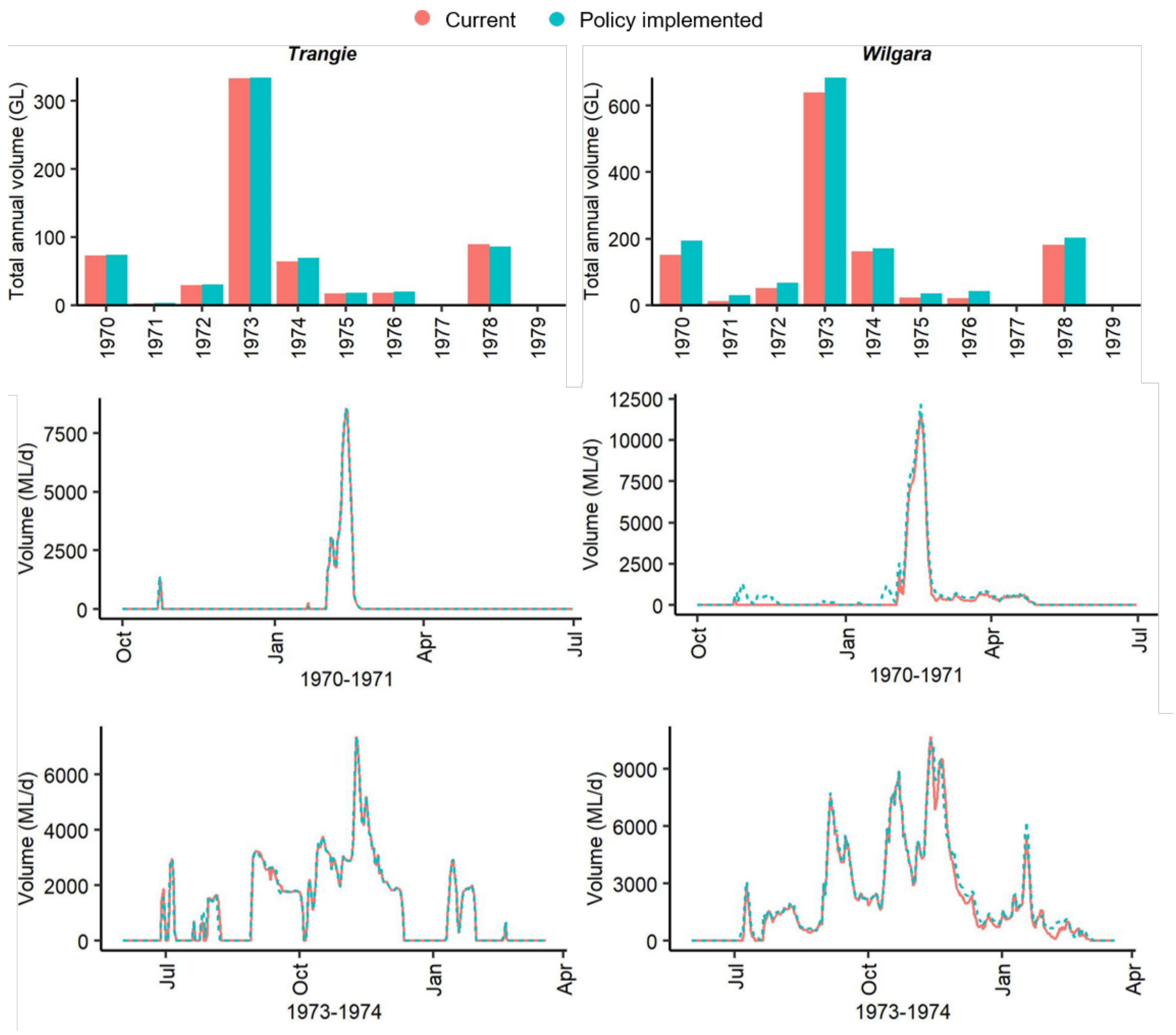

Figure 16. Modelled total annual volumes (GL/year) 1970-1979 and floodplain breakout volume (ML/d) during 1971 and 1973-1974 at the breakout zone with the smallest predicted change (Trangie) and the largest predicted change (Wilgara) to hydrology. Data represents the volumes remaining after FPH diversions have been applied.

5 Predicted ecological outcomes

The results presented in this section are based on long-term (1895 to 2019) simulated hydrological changes where the policy is implemented across the entire 124-year simulation period. Using this lengthy historical period captures variability in climate that is likely into the future. This provides a sound basis for predicting hydrological change and consequent changes in meeting environmental water requirements under implementation of the policy. Nevertheless, results presented in this report should be interpreted as indicative of what may be achieved under the policy.

5.1 Assessment approach

Understanding the summary statistics for hydrological changes in section 4 is the first step in identifying the benefits of implementing the policy for specific environmental asset (e.g. wetlands) and value categories (e.g. native fish).

In addition, using known environmental water requirements (EWRs) (provided in Appendix C) increases our ability to predict whether improvements in environmental outcomes can be expected under different hydrological scenarios. Most EWRs represent a flow regime requirement (i.e. magnitude, duration, timing, frequency and maximum inter-event frequency), all of which must be met. The approach used in this report was to break each flow regime requirement into specific EWR metrics (e.g. timing). Using this approach provides a breakdown of what components or metrics of the EWR regime are increased or decreased with the policy implemented.

In addition, the assessment of flood inundation durations and gauge based flow magnitudes (ML/d) are a common component of EWRs, particularly LTWP EWRs. These requirements could not be included in the EWR assessment as the hydrological river system models do not represent flood inundation durations (only days with flow) and are based at floodplain breakouts not flow gauges. While duration EWRs are available for some assets or values in the valley, this assessment has used **changes to the number of flow days** on the floodplain as an alternate measure of change to flood durations in important seasons (i.e. timing EWRs) for an asset or value. The reasons for substituting a specific EWR duration for this measure are explained in Section 5.2 *Assumptions and limitations*.

For the majority of environmental values (for example, native fish), EWRs were grouped into two common themes: (1) maintenance and (2) regeneration/reproduction. The frequency and timing of events needed for maintenance and reproductive outcomes as well as other relevant EWR metrics were sourced from the literature (sources documented in Appendix C). As most water-dependent environmental values have different requirements for different life stages, knowing what stages benefit under the policy is important. For example, an EWR for seedling germination in a tree species may be met, but the EWR for maintaining the condition of mature trees of the same species is not met, or vice versa. In many cases the specific EWR had an upper and lower bound (for example, 3 to 5 years in 10 required for reproduction in short–moderate-lived floodplain specialists). The lower bound was used to test the EWR outcomes. Whilst the upper bound is a more conservative estimate, using the lower bound provides relative assessment of the minimum requirement to achieve the documented EWR.

Each EWR was tested under the two model scenarios; with the policy implemented (Plan Limit Compliance Scenario) and without (Current Conditions Scenario) (EWR values are listed in Appendix C). This involved first identifying all flow events, including the event duration, in the modelled flow data[9]. As flow was only generated in the models when an overbank flow occurred, any flow above 1 ML/day was considered the start of an event. Events with a spell length or period of 5 days or less between flows (i.e. <=5 days of <1 ML/day flows) were considered one flow event due to the short inter-flow period. The month of, season of, days between, and years between

[9] The 'hydrostats' package in RStudio (R Core Team 2015) was used to identify flood (overbank) events and their spell length. Microsoft Excel 2016 was then used to generate temporal statistics from these data.

events were then generated from the spell length data[9]. These metrics were then tested against the specific frequency and timing EWR metrics assigned to environmental assets and values identified on the valley floodplain. This method allowed a simple quantification of how often each EWR metric was met under the modelled long-term record for both scenarios. The results were also interpreted as a percentage change in EWRs being met after implementing the policy for each asset category to provide a relative measure across breakout zones.

Details of the assets, values and associated EWRs used in this assessment are provided in Appendix C. Considerable time and effort by various authors has been put into developing many of the EWRs used in this assessment. The scientific information which supports each EWR can be sourced from the associated reference in Appendix C. There remains a range of other EWRs within documented literature which could be tested, however we have restricted our assessment to the EWRs listed in Appendix C. Key outcomes are summarised for native fish, waterbirds, native vegetation, flow-dependent frogs and wetlands in this section.

5.2 Assumptions and limitations

As previously stated, the results presented here are modelled, and therefore provide only an indication of possible changes once the policy is implemented. Essentially, all interpretations in this report are high-level predicted changes based on modelled hydrological scenarios and should be treated as a tool for decision making, not as a measure of actual outcomes which will be observed in the future. A range of factors may inhibit modelled and predicted outcomes becoming observed outcomes. Some of these are discussed below.

The predicted ecological outcomes are based on the best available information and are assessed from EWRs sourced from previous studies listed in Appendix C, expert opinion and a documented understanding of the impacts of hydrological changes on water-dependent floodplain environmental assets and values. Predictions are limited to assets and values for which there is some understanding of the surface water requirements of the asset. Understanding, predicting or quantifying the changes at the spatial and population scale is not possible with the available information. For example, it is not possible to suggest how much the population of Olive Perchlet will improve or deteriorate with the information available. Instead, outcomes are assessed at the asset/value scale and inferred outcomes (positive or negative) are suggested based on improvement in meeting environmental water requirements and hydrological metrics.

It is assumed that if a documented EWR is met, then an environmental benefit (positive outcome) is achieved. In reality, there may be other factors which could influence whether these outcomes are actually achieved. For example, vegetation community composition and condition may be spatially and temporally variable according to seasonal climatic conditions and the inundation regime, both of which are key drivers of floodplain plant community dynamics. If vegetation species are under significant stress due to climatic conditions such as drought, then the expected outcomes of meeting an EWR may not be achieved due to the prior condition of the vegetation. Another key limitation is that impacts are spatially and temporally variable, just as the distribution of a plant community can be spatially variable. For example, lignum can occur in dense stands or intergrade into different communities such as coolibah woodlands. Impacts are therefore difficult to measure without monitoring. Also, species respond at different time scales depending on the nature of the impact.

Issues such as land clearing will continue to be a major and ongoing threat to native vegetation, however this is out of the scope of the policy implementation process. The assessment is also limited as it does not assess and spatially map the short- or long-term impacts of different types of floodplain harvesting structures on ecological outcomes, which may vary spatially and temporally depending on the nature of the structure (location, size, function). The assumption is that volumes of water returned to the floodplain are able to pass through unhindered. In reality, ongoing monitoring is required to ensure that flood works capable of harvesting floodwater comply with their licence conditions to ensure that they do not inhibit or divert floodwaters which are intended to pass through the system for the environment and downstream users.

Unless otherwise identified, predicted outcomes for areas outside the identified breakout zones (such as downstream benefits) have much lower confidence than those outcomes expected within the breakout zones. These are examples of issues which are not considered in this analysis.

5.2.1 Duration EWRs

Most, if not all, documented floodplain duration EWRs are linked to (a) the duration of a specific flood magnitude/event volume at a flow gauge or to (b) the minimum inundation period required for the EWR. For example, the *Macquarie-Castlereagh Long term Watering Plan—Part B* (DPIE EES 2019a) suggests a >1,900 ML/day event at the Bells Bridge (Carinda) (421012) flow gauge for 10 days will achieve an overbank/small wetland flow event in the Southern Macquarie Marshes. This is expected to provide a sufficient inundation period for a range of environmental values. However, our assessment does not use flow gauges because the river system models consider overbank flows as a 'loss' and do not model return flows into downstream gauging stations. This means that the impacts from implementing the policy are not detected at flow gauges, only on floodplain breakout nodes. Therefore, detecting changes to event durations at flow gauges under the two modelled scenarios is not possible. Instead, floodplain breakout nodes represent the duration of flowing water on the floodplain, but they do not accurately represent the duration of inundation once flow ceases.

It is most likely that the duration of inundation provided by modelled floods (where flow on the floodplain is greater than 1 ML/day) is actually much longer than represented by the river system models. This is due to the fact that many floodplain areas should remain inundated once simulated flow ceases. After flow ceases, the combination of water take, groundwater recharge, transpiration and evaporation will reduce flood waters in these inundated areas. However, it remains unclear how long each area would remain inundated after flow ceases in the model and therefore how long the actual flood inundation duration may be for a variety of floods. This report does not attempt to predict actual periods of inundation after floodplain flows cease due to the issues raised and other assumptions and limitations in the hydrological models that underpin this ecological assessment (more detail is provided in Appendix D

Where a duration EWR could not be tested (e.g. native vegetation and waterbirds), an **indication of changes to flood durations was calculated using the change in total flow days for each calendar month.** This allows a high level assessment of the change to the number of flow days in important seasons or months (e.g. timing EWRs) for different assets and values. For example, floods during spring and summer months are required for maintenance of lignum on the floodplain. Therefore, an assessment of the change to the number of flow days during spring and summer months can provide insight into outcomes for flood durations for this floodplain value. It is important to highlight that this is not an assessment of achieving a duration EWR. Instead, it is a test to identify if there is a change in the number of flow days during the required EWR timing (season/month).

5.3 Changes to monthly flow durations

As reported above, where a duration EWR could not be tested, the substitute was to calculate the total flow days (>1 ML/day) for each month[10]. The data were interpreted as a percentage change in the number of flow days per month, after implementing the policy. Figure 17 represents the summary statistics (median, 25th and 75th percentiles) across all 10 breakout zones. The outliers in this figure represent the breakout zones with either the largest reduction or increase. This can be used to highlight how many breakout zones are outliers for each month. Percentage change results are in Table 6.

[10] The 'hydrostats' package in RStudio (R Core Team 2015) was used to calculate monthly flow days. Microsoft Excel 2016 was then used to generate summary statistics from these data.

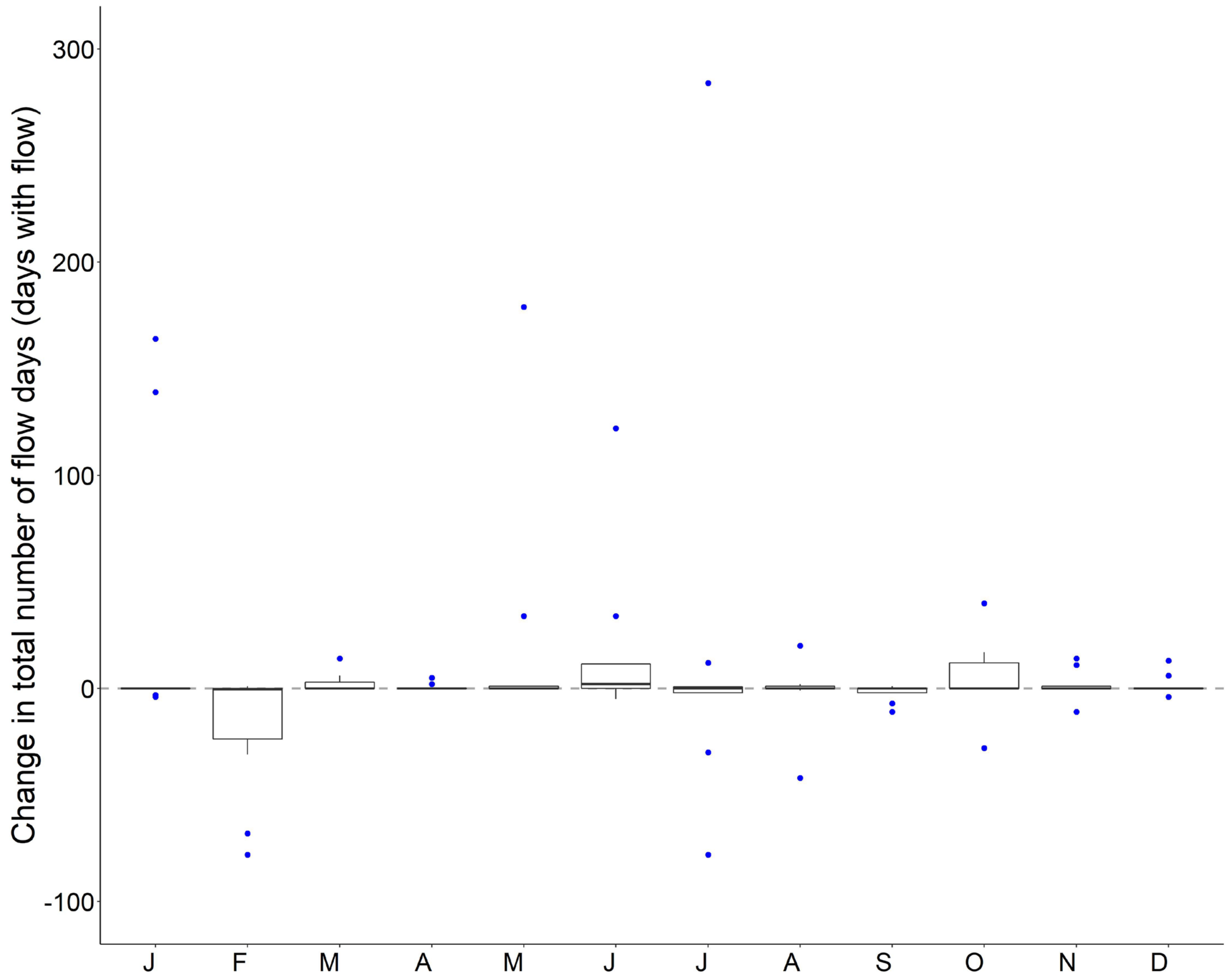

Figure 17 Box plot of change in total number of flow days in each month after implementing the policy in the Macquarie Valley. Values are averaged over the 124-year simulation period across all 10 breakout zones. Number of flow days is based on modelled flow >1 ML/day. Boxes show the medians (bold line inside box), 25th and 75th percentiles (bottom and top of box), minimum and maximum (bottom and top whiskers) and outliers (points) for the 10 breakout zones

Table 6 Percentage change (increase or decrease) in duration (total number of flow days in each month) for each breakout zone after implementing the policy. Values are averaged over the simulation period. Only flows >1 ML/day were considered flow days

Hydro feature	Breakout zone	Jan %	Feb %	Mar %	Apr %	May %	Jun %	Jul %	Aug %	Sep %	Oct %	Nov %	Dec %
Duration	A Trangie	0	2	0	-3	0	0	0	0	-1	-1	-2	0
	B Marthaguy	0	0	0	0	0	0	0	0	0	0	0	0
	C Birchells Plns	0	1	0	0	0	8	−4	1	0	0	0	0
	D Gunningbar	0	0	0	0	0	0	0	0	0	0	0	0
	E Wyndabyne	0	−8	0	0	0	0	0	0	0	0	0	0
	F Gradgery	−1	−1	1	0	49	−17	0	0	0	5	0	−2
	G Marebone	0	0	0	0	0	1	0	1	1	0	1	0
	H Wilgara	434	−15	32	0	89	−41	30	0	−2	9	14	14

Hydro feature	Breakout zone	Jan %	Feb %	Mar %	Apr %	May %	Jun %	Jul %	Aug %	Sep %	Oct %	Nov %	Dec %
	I Glencoe	161	−33	2	1	−26	21	1	3	−3	17	20	12
	J Pillicarwarrina	0	0	0	0	0	1	0	1	1	0	1	0

There is little expected change in the number of flow days in each month for most breakout zones (Table 6, Figure 17). However, the Gradgery, Wilgara and Glencoe breakout zones are predicted to have the greatest percentage changes (Table 6). Gradgery is predicted to have a 49% increase in May followed by a 17% decrease in June with no major changes in the remaining months. Wilgara and Glencoe breakout zones are expected to have the highest increases in January with an increase of 434% (139 flow days) and 161% (164 flow days) respectively. Wilgara is also expected to have an 89% increase in May followed by the highest monthly decrease (41%) in flow days in June (Table 6).

The information presented in this section is used in the following sections to assess whether flood durations in important periods (e.g. EWR timing) for an asset or value are predicted to improve.

5.4 Native fish

Fourteen different fish species were either predicted to occur or recorded across the 10 breakout zones. These species can be grouped into four native fish guilds based on NSW DPI Fisheries Northern Basin fish guild groupings (NSW Department of Primary Industries 2019). Not all breakout zones had predicted or recorded observations of a native fish species from each fish guild (Table 3). This assessment only considered a fish guild if it occurred in the breakout zone. The fish guilds, species and relevant breakout zones are summarised as:

- flow-dependent specialists, such as Silver Perch, Spangled Perch and Golden Perch. Species from this guild were recorded in breakout zones A, B, C, D, E, F, G and J
- generalists, which include a number of species such as Bony Herring and Australian Smelt that benefit from improved floodplain outcomes. Representative species from this guild were identified in breakout zones A, B, D, G, and J
- short–moderate-lived floodplain specialists such as Olive Perchlet. Predicted to occur in breakout zones A, C, D, F, G and J
- in-channel/river specialists such as the iconic Murray Cod (Figure 18) and Eel-tailed Catfish. The relevant breakout zones for this fish guild are A, B, D, E, F, G and J.

5.4.1 Metrics

Using specific EWRs for native fish allowed a quantified measure for native fish maintenance and reproductive success for each of the fish guilds. The EWR metrics were categorised by:

- egg development – flow durations required to achieve successful egg development. These durations refer to a flow peak of a set number of days (5–14 days depending on guild). Modelled flow at the breakout nodes represent peak flow periods allowing this duration EWR to be tested using the river system models
- maintenance – the frequency and timing (seasonality) needed to maintain native fish
- reproduction – the flood frequency required to provide sufficient reproduction opportunities
- recruitment – the timing (seasonality) of flow events required for effective recruitment
- spawning, habitat and food – native fish often require flow events during specific seasons due to seasonality preferences for spawning. This also relates to the timing of flow events for spawning habitat, food resources and refugia for recruits.

Specific EWRs were not available for all fish species. However, the outcomes for a native fish guild can provide some insight into the implications for other species within that guild (e.g. outcomes for Murray Cod give insight to potential benefits for Eel-tailed catfish). The majority of native fish EWRs were sourced from *Fish and Flows in the Northern Basin* (NSW Department of Primary Industries 2015, 2019) and the Long Term Water Plans developed by DPIE EES (DPIE EES 2019b, 2019a).

In total, 10 EWR metrics and 30 tests were undertaken for native fish.

Figure 18 The iconic Murray Cod, a species which would be impacted by changes to floodplain harvesting practices [Photo: Guo Chai Lim]

5.4.2 General hydrological impacts

Impacts of implementing the policy are limited across all breakout zones. Overall, the predicted improvements in key hydrological metrics do not translate into substantial ecological improvements for native fish at the breakout zone where fish species are known or predicted to occur (Table 3). The **number of flow events** and **total days with flow** are predicted to increase and the **inter-event period** to reduce in Wilgara and Glencoe breakout zones – however no fish guilds have been documented using the available predictive and recorded datasets. It is important to note that this does not mean they would not occur or use these floodplain areas, but native fish outcomes were not assessed in these breakout zones. The remaining breakout zones have limited predicted changes in all flow metrics.

5.4.3 Impacts on fish guild-specific EWRs

On average across the floodplain where there are fish records or predictive occurrence (DPIF MaxEnt 3.3.3 species distribution models), there are no substantial changes in the number of EWRs achieved for all EWR metrics important for native fish (Table 7, Figure 19). Of the 30 metrics tested, there is a minimal 1% increase in the frequency for reproduction for floodplain and river specialists and a 1% increase in the interflow periods for reproduction in generalists (Table 7). There is also a small negative change (−1%) for recruitment for all fish guilds. With minimal expected change, no fish guilds assessed are expected to benefit or be disadvantaged from the implementation of the policy.

The guild-specific EWR results for the Wilgara and Glencoe breakout zones are not included in Table 7 as no native fish are predicted or recorded to occur there, based on the datasets used in this report (Appendix B). However, these zones will have the largest hydrological improvements in the Macquarie Valley and while there are no predictive occurrences or known records of what fish are present based on the data used in this assessment, these breakout zones will see improvements for all guilds if they occur in these zones. The average percentage increase of EWR metrics for each fish guild is expected to range between 14% and 17% for the Wilgara breakout zone and between 15% and 22% for the Glencoe breakout zone.

Table 7 Percentage change in frequency of achieving EWRs for native fish in the Macquarie Valley floodplain after implementing the policy. Values represent average (minimum and maximum) predicted outcomes, averaged over the simulation period across the relevant breakout zones for each fish guild (See Section 5.4.1). S-M FP = short–moderate lived floodplain; N/A = no EWR available; n = number of breakout zones assessed

Hydro feature	EWR metric	S-M FP specialists (n=6)	Generalists (n=5)	Flow-dependent specialists (n=7)	River specialist Murray Cod (n=7)
Duration	Egg development	0% (−2, 1)	0% (0,0)	0% (−1, 0)	0% (0, +2)
Frequency	Maintenance	−1% (−2, 0)	0% (−1, +2)	0% (−2, +2)	0% (−2, +2)
	Maintenance (interflow)	0% (−2, +2)	0% (−1, +2)	0% (−2, +2)	0% (−2, +2)
	Reproduction	+1% (−2, +5)	N/A	0% (−2, +3)	+1% (−2, +3)
	Reproduction (interflow)	0% (−2, +2)	+1% (−2, +3)	N/A	N/A
Timing	Maintenance	N/A	0% (-2, 0)	0% (-2, 0)	0% (-2, 0)
	Recruitment	-1% (-4, 0)	-1% (-7, 0)	-1% (-6, 0)	-1% (-7, 0)
	Spawning	+0% (-4, +5)	N/A	0% (-1, - 1)	0% (-2, +1)
	Spawning habitat	0% (0,0)	0% (-2, 0)	N/A	N/A
	Food, refugia	0% (-2, 0)	N/A	N/A	N/A

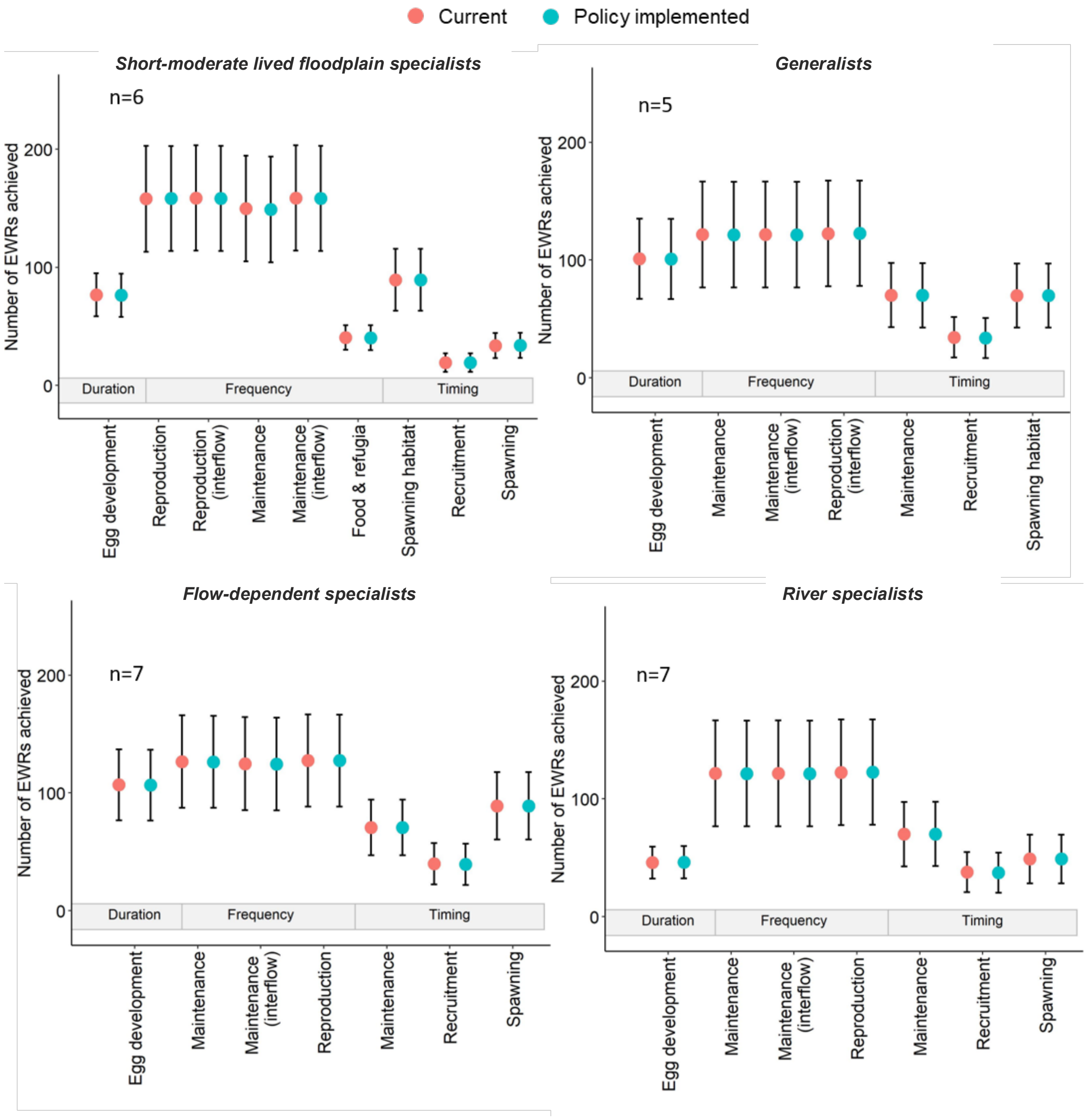

Figure 19 Average number of EWRs achieved for native fish with (Policy implemented) and without (Current) the policy implemented in the Macquarie Valley over the 124 year simulation period and across the relevant breakout zones. The grey horizontal rectangles identify the hydrological feature (duration, frequency, timing) and the x axis labels are the EWR metric. Error bars represent the standard error; *n* = number of breakouts assessed

5.5 Native vegetation

The key water-dependent native vegetation values used in this assessment are listed by their plant community types (PCTs) in Table 3. Seven vegetation species were selected for this assessment. They represent key umbrella species for a range of other vegetation values and have detailed EWR information documented. Although other species are predicted, known or recorded on the floodplain (e.g. poplar box), EWR information was not available and therefore outcomes were not assessed for these species. The vegetation species and associated breakout zones used to assess vegetation specific outcomes are:

- black box open woodland, present in all 10 breakout zones (A–J)
- river cooba shrubland, present in all 10 breakout zones (A–J)
- river red gum (forest and woodland), present in 10 breakout zones (A–J)
- lignum shrubland, present in 5 breakout zones (A, B, D, F, J)
- water couch (non-woody wetland), present in 5 breakout zones (F, G, H, I, J)
- coolabah (woodland and wetland), present in 3 downstream breakout zones (H, I, J)
- cumbungi dominated wetland community, present in one breakout zone (G).

5.5.1 Metrics

This assessment tested native vegetation EWRs based on two key hydrological features – **frequency and timing of flow events** – for two key life-stages requirements – **maintenance of established vegetation** and **regeneration or reproduction**. Where there was insufficient information for a specific hydrological feature or life stage, the EWR was not assessed. Specific values for each EWR metric vary for each native vegetation species (detailed in Appendix C). Most EWR values were sourced from (Roberts and Marston 2011, DPIE EES 2019b).

As flood duration is a critical EWR metric for native vegetation, we substituted with **total flow days in key months/seasons** as an indicator of outcomes for duration EWRs[11]. The full list of key months/seasons is Appendix C. The key months (i.e. timing) where changes in flow days are of interest are primarily spring and summer for most vegetation values, with autumn and winter important for some.

It is important to recognise that the number of years of watering ‘required’ to achieve specific outcomes is dependent on vegetation condition which is spatially variable according to the historical inundation regime across the floodplain (Casanova 2015). This study does not address this issue.

[11] The reason for this substitution is set out in Section 5.2. In short, duration of flood water on the floodplain is not modelled.

Figure 20 Cumbungi, an emergent aquatic plant, is an important component of plant communities on the Macquarie Valley floodplain [Photo: Ed Dunens]

5.5.2 General hydrological impacts

Modelling of key hydrological metrics suggests limited improvement for native vegetation assets under the policy (Table 5, Figure 15), with greatest changes limited to Wilgara and Glencoe breakout zones. The vegetation assets in 8 of the 10 breakout zones (A, B, C, D, E, F, G, J) are unlikely to benefit from the introduction of the policy. Wilgara (H) and Glencoe (I) breakout zones have the greatest predicted changes with increases in the **number of flow events, total summer days with flow,** and reduction in **mean inter event periods.** Greater increases in spring and summer volumes and flow durations are desirable, as many species require flow events over the warmer months to enable seedling establishment and to avoid desiccation.

The **duration of floods** required for most vegetation values varies but is often at least two months of inundation. On a valley scale, there is negligible change in duration, frequency and timing metrics (Table 5, Figure 15 and Figure 17). However, at specific locations, total flow days (Table 5) and monthly durations (Table 6) are predicted to increase.

Predicted increases in monthly summer durations are highest in January at Wilgara (434%, 139 flow days) and Glencoe (161%, 164 flow days). Despite a reduction in February, over the summer period there is a net improvement in the duration or number of flow days in summer (Table 6). Summer is a critical period for maintenance, regeneration and reproduction for most vegetation values including river red gum, lignum, coolabah and water couch.

Spring is also a critical month for most native vegetation species. The highest percentage change in spring total flow days (Table 5) is at Wilgara and Glencoe breakout zones, however the change is minimal (<1%) and unlikely to provide substantial outcomes for native vegetation.

Events during autumn and winter months are important for lignum dispersal and post-flood recession germination (Roberts and Marston 2011). Predicted changes are limited to small increases in total flow days in autumn at Wilgara (6%) and Glencoe (4%) breakout zones. Gradgery (F) and Wilgara (H) breakout zones have the highest predicted monthly increase in May with a 49% increase and 89% increase respectively.

No major changes are predicted for winter months which are expected to have no ecologically significant change for all breakout zones (Figure 17, Table 6). Slight changes in flow days during any autumn and winter months are likely to have limited ecological improvements for vegetation, particularly lignum.

5.5.3 Impacts on native vegetation specific EWRs

Modelling indicates that implementation of the policy will result in limited increases in the achievement of EWRs of key native vegetation assets (Table 8, Figure 21). However, the predicted changes, although small when averaged across the floodplain, are expected to be beneficial for native vegetation values in specific locations.

Averages of predicted changes across the floodplain range from −1% to 13%, with the greatest change expected for coolabah (present in three breakout zones) and the least change expected for lignum (present in five breakout zones) (Table 8). The predicted increases to vegetation metrics are driven by Wilgara and Glencoe breakout zones which have the greatest improvement in hydrology metrics. As such, vegetation that occurs in these breakout zones – black box, coolabah, river red gum, river coobah, water couch – are expected to have the greatest improvement (average of 14% to 19% improvement for all metrics) (Table 14). Conversely, lignum and cumbungi vegetation assets (which do not occur in these breakout zones) will have little to no improvement. Breakout zone specific outcomes for native vegetation EWRs are summarised in Section 5.8.

Improvements to native vegetation will likely have flow-on benefits for other environmental values on the floodplain, including waterbirds, native fish and key ecological functions. Native vegetation can help to support many animals through the provision of refuge, feeding and breeding habitat. Additionally, vegetation is crucial for sustaining ecological function and can play an important role in increasing productivity, improving water quality and reducing erosion.

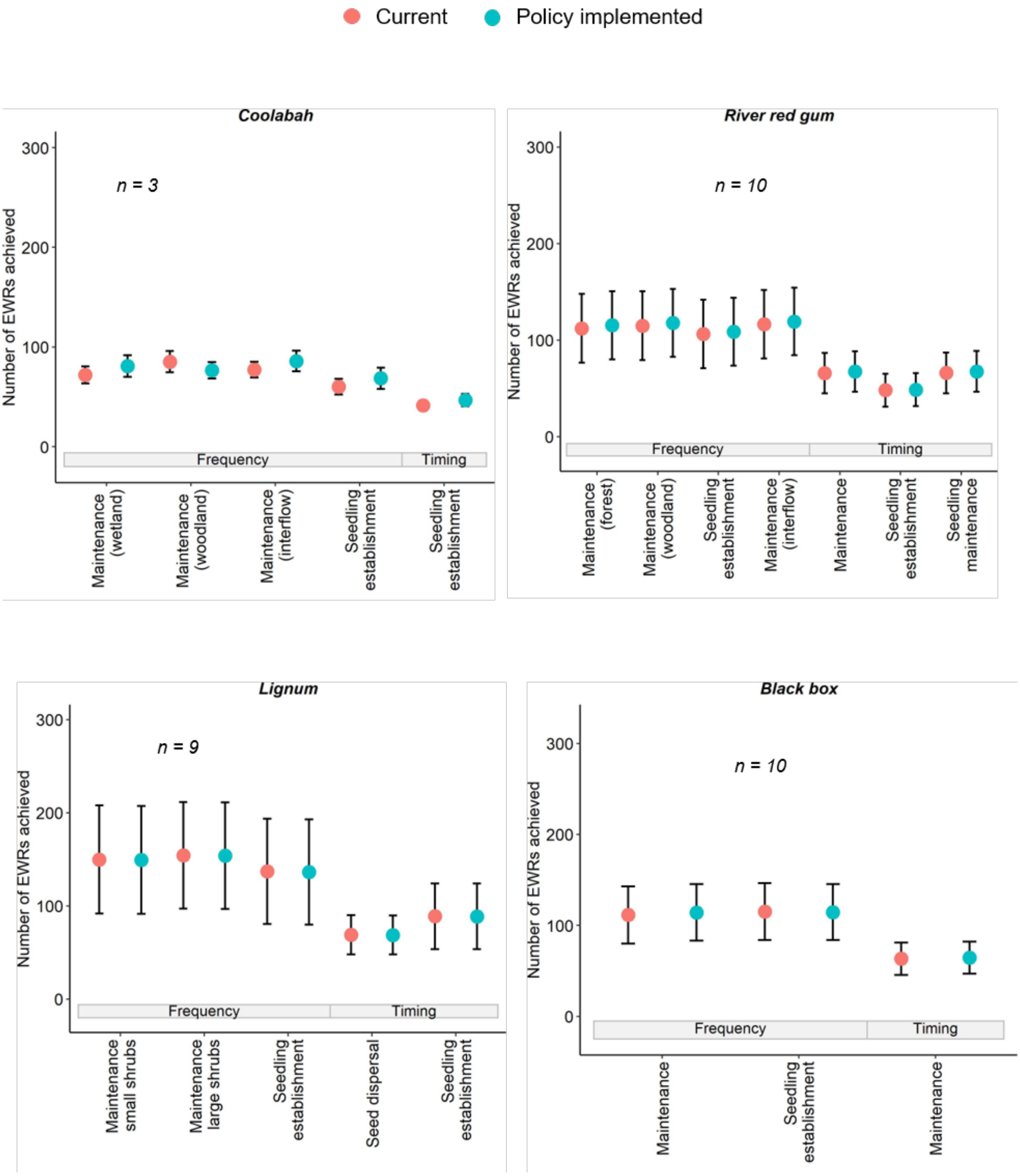

Figure 21 Average number of EWRs achieved for native vegetation (coolabah, river red gum, lignum, black box) with (Policy implemented) and without (Current) the policy implemented in the Macquarie Valley over the 124-year simulation period and across the 10 breakout zones. The grey horizontal rectangles represent the hydrological feature whilst the x axis labels are the EWR metric. Error bars represent the standard error

Table 8 Percentage change in frequency of achieving EWRs for native vegetation in the Macquarie Valley floodplain after implementing the policy. Values represent average (minimum and maximum) predicted outcomes, averaged over the simulation period across the relevant breakout zones. n = sample size or the number of breakouts in which a value was present; N/A = no EWR available

Hydro feature	EWR metric	Lignum (n = 5)	Coolabah (*n* = 3)	River coobah (*n* = 10)	River red gum (*n* = 10)	Black box (*n* = 10)	Water couch (*n* = 5)	Cumbungi (*n* = 1)
Frequency	Maintenance	Small shrubs 0% (−2, −2)	Wetland +12% (+2, +21)	+4% (-2, +22)	Forest +4% (-2, + 22)	+4% (+2, +22)	+8% (-1, +23%)	+2%
		Large shrubs 0% (−2, +3)	Woodland +11% (+1, +18)		Woodland +4% (−2, + 21)	N/A		
	Seedling establishment	-1% (−2, 0)	+13% (0, + 23)	N/A	+4% (−2, +23)	+4% (−2, +23)	N/A	0
	Maintenance (interflow)	N/A	+11% (+1, +17)	N/A	+4% (-2, +22)	N/A	N/A	N/A
Timing	Maintenance	N/A	N/A	N/A	+4% (-2, +24)	N/A	+6% (−1, +14)	+3%
	Seedling establishment	0% (−2, 0)	+11% (0, +24)	N/A	+2% (-2, +14)	+3% (−1, +24)	N/A	N/A
	Seedling maintenance	N/A	N/A	N/A	3% (-2, +24)	N/A	N/A	N/A
	Seedling dispersal	0% (−2, + 3)	N/A	N/A	N/A	N/A	N/A	N/A

5.6 Waterbirds

There were 26 waterbird species predicted or recorded to occur across all breakout zones. The list of species covers colonial-nesting and non-colonial waterbirds from 5 functional feeding groups identified in Brandis and Bino (2016). These are shorebirds, piscivores, large waders, herbivores and ducks. Eighteen colonial waterbird species have either been recorded or predicted to occur in any one breakout zone.

5.6.1 Metrics

This assessment focussed on environmental water requirements to **maintain habitat and provide breeding opportunities for colonial-nesting and non-colonial waterbirds**.

Metrics assessed for waterbird outcomes are **flood volumes, frequency of floods, flood duration** and **timing of floods**. Metrics used in this report are adapted from peer-reviewed scientific literature and the NSW Long-Term Water Plans specific for the Macquarie-Castlereagh (DPIE EES 2019b).

Colonial-nesting waterbirds

Environmental water requirements for **breeding outcomes** of colonial-nesting waterbirds are summarised below (and in Table 9), together with a short description of the associated metrics.

Duration metrics

- the number of flow days above 1,250 ML/d (50 days or more) and 1,500 ML/d (40 days or more) at Oxley station flow gauge (421022) required to achieve the highest breeding probability (Bino et al. 2014). This EWR relates to flood duration and flow rate at specific locations in the valley.
  - metric is the number of floods with more than 40 days with flow (with and without the policy implemented) occurring in the breakout zone which includes Oxley station flow gauge (421022) and those breakout zones downstream from that gauge
- July and December is a period critical for breeding events (Arthur et al. 2012, Bino et al. 2014) and longer flood durations are important for breeding success.
  - metric is the total number of flow days in the months between July and December.

Frequency and flood volume metrics

- Analyses of historical flows and colonial waterbird breeding in the Northern Basin established that breeding events are linked to large floods (Brandis and Bino 2016), Specifically, flow volumes in the 3 months before breeding (September–November) (Kingsford and Auld 2005a).
  - metric is the difference (with and without the policy implemented) in cumulative volume of flow events which occurred in the 3 months before September, October and November.

Timing metric

- metric is the number of floods occurring between July and December

Other (based on native vegetation outcomes)

- The requirements to maintain critical breeding habitat (native vegetation) to improve breeding success for colonial waterbirds. The vegetation species include lignum (*Muehlenbeckia florulenta*) and river red gum (*Eucalyptus camaldulensis*). Both of these are important for breeding success of colonial waterbirds (Bino et al. 2014).
  - metrics are the outcomes for the lignum and river red gum from Section 5.6.

Non-colonial waterbirds

Environmental water requirements for **breeding outcomes** of non-colonial waterbirds are summarised below (and in Table 10), together with a short description of the associated metrics.

Timing and duration metrics

- The timing and duration of flows are critical for breeding events (DPIE EES 2019b).
  - metric 1 is the number of flow days in spring and summer for ideal breeding conditions
  - metric 2 is the number of flow days in autumn and winter for opportunistic breeding conditions

  - metric 3 is the number of flow events occurring in spring and summer for ideal breeding conditions
  - metric 4 is the number of flow events occurring in autumn and winter for opportunistic breeding conditions.

Other (based on native vegetation outcomes)

- The requirements to maintain critical breeding habitat (native vegetation) to maintain non-colonial waterbirds. The vegetation species include: lignum (*Muehlenbeckia florulenta*) and river red gum (*E. camaldulensis*) (DPIE EES 2019b)
  - metrics: outcomes for lignum and cumbungi from Section 5.6.

Not all species were recorded in all breakout zones. However, due to the highly mobile nature of waterbirds, achievement of the waterbird EWRs was assessed for all species based on the colonial and non-colonial grouping. Only breakout zones which captured the key hydrological changes in the northern, southern and eastern management regions outlined in (Bino et al. 2014) were assessed for colonial waterbirds. This included an area where up to 16 waterbird breeding colonies have been recorded (Bino et al. 2014). The breakout zones assessed for colonial waterbird outcomes were Wyndabyne (E), Gradgery (F), Marebone (G), Wilgara (H), Glencoe (I) and Pillicarwarrina (J). Outcomes for non-colonial waterbirds were assessed for all 10 breakout zones.

This assessment assumes that meeting an EWR results in a beneficial outcome. In reality, the response of waterbirds to flooding can be influenced by a variety of factors not incorporated into this assessment. Therefore, the predicted waterbird outcomes reported herein are a measure of potential outcomes with and without the policy implemented.

Further details of the EWR values used are provided in Appendix C .

5.6.2 General hydrological impacts

The reduced temporal variability, frequency and volume of river flows due to water resource development has significantly impacted waterbirds worldwide (Lemly et al. 2000, Nilsson et al. 2005, Dudgeon et al. 2006). Improvements or reductions in these hydrological features are therefore expected to influence outcomes for waterbirds. Modelling of key hydrological metrics suggests very little improvement in a number of these features (Table 5, Figure 15). Only two (Wilgara and Glencoe) of the 10 breakout zones are predicted to have any positive outcomes for hydrological metrics of significance to waterbirds.

The **frequency of flow events** is predicted to increase slightly in the Glencoe and Wilgara breakout zones, while all other zones remain relatively unchanged. In addition, the **inter-event period** is predicted to decease in these two breakout zones. This suggests that the periods between flow events will only decrease in a small area of the floodplain through implementation of the policy. Improvements to summer flow durations and volumes are expected for Wilgara and Glencoe, but no other breakout zones.

In general, implementation of the policy is not expected to improve temporal variability, flood frequency, volume and number of flow days in the valley. Further improvements in these metrics are desirable as the Macquarie Valley is of national and international significance for waterbirds.

5.6.3 Impacts on waterbird specific EWRs

Colonial-nesting waterbirds

Outcomes vary across the six breakout zones where colonial-nesting waterbirds are known to breed, but on average, implementing the policy is predicted to provide little to no benefit for colonial-nesting waterbirds (Table 9, Figure 22). The total number of flow days between July and December, an important breeding period, is not expected to change. However, the Glencoe breakout zone is expected to have an extra 36 days (1%) with flow during the colonial waterbird breeding period. This not considered a substantial improvement.

No change is predicted for the frequency of floods with 40 or more days of flow and very little change is predicted for the three-month cumulative volumes important for significant colonial waterbird breeding events (Table 9, Figure 22).

Along with these direct measures, changes to key habitats (e.g. native vegetation) indirectly influence waterbird outcomes, either positively or negatively. For example, the predicted outcomes for native vegetation should have a range of flow-on effects for waterbirds. No substantial change is predicted for cumbungi or river red gum vegetation values and therefore there are no indirect benefits to colonial-nesting waterbirds in the Macquarie Valley floodplain.

Table 9 Percentage change in achievement of EWRs for colonial-nesting waterbirds in the Macquarie Valley floodplain after implementing the policy. Values represent average (minimum and maximum) predicted outcomes, averaged over the simulation period across 6 breakout zones (E,F,G,H,I,J)

Hydro feature	EWR metric	EWR detail	Colonial-nesting waterbirds (n= **6)**
Duration	Breeding	Number of flow days between July and December	0% (0, +1)
	Breeding	Number of floods with at least 40 days of flow	0% (0, 0)
Frequency and flood volume	Breeding: 3-month volume prior to breeding	Cumulative 3-month volume of floods before Sep (Aug, July, June)	+1% (0, +8)
		Cumulative 3 month volume of floods before Oct (Sep, Aug, July)	+1% (0, +8)
		Cumulative 3 month volume of floods before Nov (Oct, Sep, Aug)	+1% (0, +5)
Timing	Breeding	Number of floods occurring between July–December	+3% (0, +9)

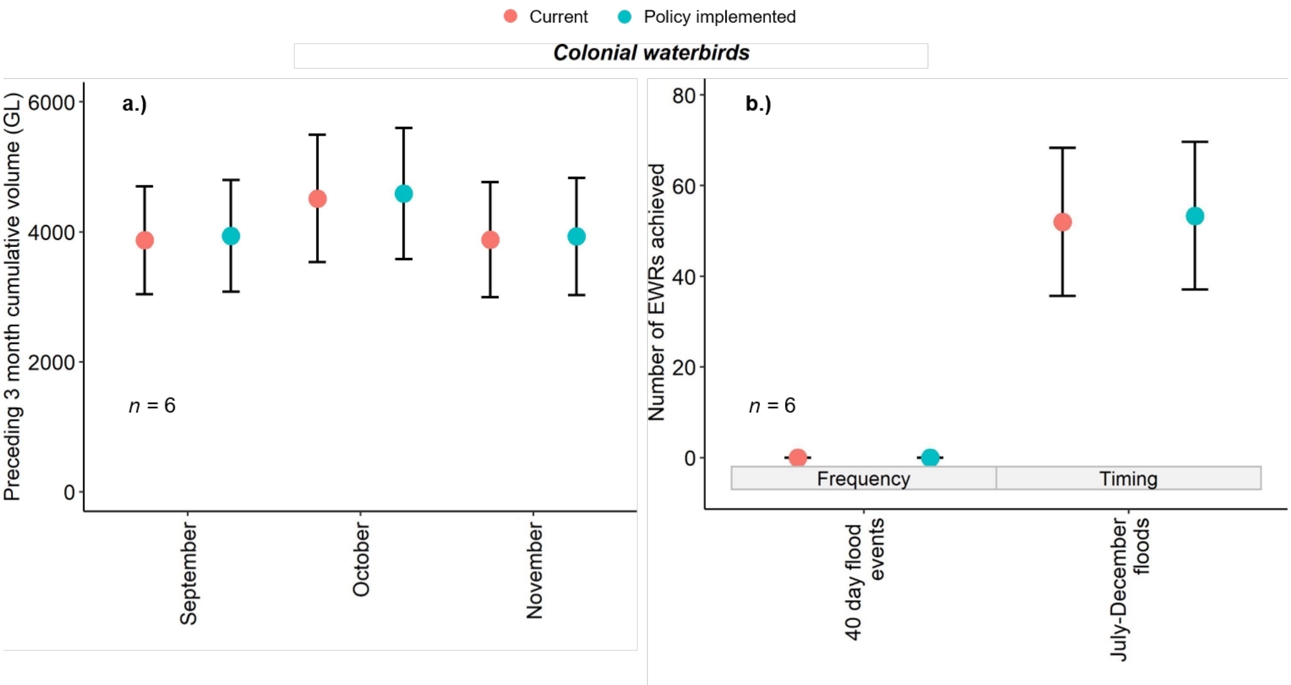

Figure 22 a) Average cumulative volume in the three months preceding important colonial breeding periods for colonial waterbirds, and b) Average number of EWRs achieved for colonial waterbirds with (policy implemented) and without (current) the policy implemented. Data represents outcomes over the 124 year simulation period and across the 6 breakout zones (n). The grey horizontal rectangles represent the hydrological feature whilst the x axis labels are the EWR metric. Error bars represent the standard error

Non-colonial waterbirds

Outcomes vary across the 10 breakout zones where non-colonial waterbirds are known to occur, but on average, only small benefits for some EWRs important for non-colonial waterbirds are predicted under the policy (Table 10).

The total number of predicted flow days for ideal breeding conditions (spring and summer) increased by an average of 1% or 27 days across the 10 breakout zones. This increase is driven by predicted increases of 5% or 158 extra days with flow for the Glencoe and 4% increase (108 extra days) in the Wilgara breakout zone. Opportunistic breeding outcomes are not expected to increase.

There is little to no predicted change to the timing of flow events occurring in spring–summer (5% change on average) and autumn–winter (1% change on average). No substantial change is predicted for vegetation values and therefore there are no additional indirect benefits to non-colonial waterbirds on the Macquarie Valley floodplain.

Table 10 Percentage change in achievement of EWRs for non-colonial waterbirds in the Macquarie Valley floodplain after implementing the policy. Values represent average (minimum and maximum) predicted outcomes, averaged over the simulation period across the n=10 breakout zones

Hydrological feature	**EWR metric**	EWR detail	**Non-colonial** waterbirds (n= **10)**
Duration	Breeding: ideal conditions	Total number of flow days during spring and summer	+1% (-1, +5)
	Breeding: conditions for opportunistic breeding	Total number of flow days during autumn and winter	0% (0, +1)
Timing	Breeding: ideal conditions	Number of spring and summer flow events	+5% (-2, +28)
	Breeding: conditions for opportunistic breeding	Number of autumn and winter flow events	+1% (-2, +4)

5.7 Wetlands: Macquarie Marshes

A variety of wetlands occur on the Macquarie Valley floodplain, including numerous significant anabranches, lagoons, wetlands, watercourses and billabongs. Of particular importance is the greater Macquarie Marshes, which includes Ramsar listed areas of wetlands of international significance (Department of Agriculture, Water and the Environment 2020). The four portions of the Macquarie Marshes Ramsar sites cover approximately 10% of the area of the greater Macquarie Marshes. These sites include the southern and northern sections of the Macquarie Marshes Nature Reserve, U-block and part of the private property Wilgara. The Marshes support important flow-dependent flora and fauna species including one of the largest colonial waterbird breeding sites in Australia (DPIE EES 2019b).

Other significant lagoons and wetlands have been identified in the Macquarie Valley but were not assessed in this report.

5.7.1 Metrics

EWRs for the Macquarie Marshes were sourced from Part B of the Macquarie-Castlereagh LTWP (DPIE EES 2019a). Only EWRs from appropriate planning units in the Macquarie-Castlereagh LTWP Part B that included the wetlands of interest assessed in this report were used in this assessment. These outcomes were not directly targeted for the wetlands themselves, but aimed to provide environmental outcomes for the values that each wetland or group of wetlands supports. These values include native fish, native vegetation, waterbirds, and flow-dependent frogs. For example, overbank and wetland events are listed as supporting a broad range of foraging habitats for waterbirds in the Macquarie Marshes. Therefore, **overbank** and **wetland flows** were included as EWRs of interest for the Macquarie Marshes, along with any other important EWRs listed for this wetland system.

As mentioned in the waterbirds section, this report uses data from modelled nodes on the floodplain and not from gauging station nodes. Therefore, frequency EWRs were simplified to reflect a change in achieving different flood frequencies for the Macquarie Marshes in specific breakout zones. The metrics are:

Frequency metrics

- the frequency of flow events of 2, 5, 6, 7, 8 and 9 years in 10 years
- the frequency at which that the maximum inter-event period was satisfied (4 and 5 years maximum between floods).

Duration metric

- the duration of floods (number of flow days) between August and March

Timing metric

- the number of floods occurring between August and March.

Details of the EWRs are provided in Appendix C

The selected **frequency and timing** EWR metrics from the Macquarie LTWP were only assessed for the breakout zones likely to influence outcomes in the greater Macquarie Marshes. This does not include assessments for Ramsar sites below the most downstream breakout zones. It is likely that the outcomes for the greater Macquarie Marshes will reflect outcomes for some of the Ramsar sites, however generalising outcomes from the identified breakout zones is undesirable due to the uncertainties explained in Appendix section D.2 *Assumptions and limitations*. The wetlands and associated breakout zones used in this assessment are:

- greater Macquarie Marshes which occurs in breakout zones Birchells Plains (C), Gradgery (F), Wilgara (H), Glencoe (I), and Pillicarwarrina (J)
- the Wilgara Ramsar site which is located in the Marebone (G) breakout zone.

5.7.2 General hydrological impacts

Modelling suggests that implementation of the policy will provide no substantial increase in the **mean annual volumes and total seasonal volumes** for the breakout zones which are most likely to influence outcomes in the greater Macquarie Marshes (Table 5). Seasonal volumes are also not expected to improve, apart from small increases in total summer volumes estimated over more than 100 years for the Wilgara (6%, 68GL) and Glencoe (4%, 61GL) breakout zones which incorporate part of the Marshes.

On average, the predicted **total number of flow days** increase in January by 116%. However, this is solely due to large improvements in the Wilgara (+434%, 139 more days with flow) and Glencoe (+149%, 164 more days with flow) breakout zones (Table 11). Total days with flow are also expected to improve during summer at these two breakout zones. These are the only improvements expected for the Macquarie Marshes.

The only predicted increases in the **number of flow events** between 1895 and 2019 are at Wilgara (23%) and Glencoe (17%) breakout zones (Table 5). The remaining breakout zones which are expected to influence the greater Macquarie Marshes the most are expected to have no change or have a small decrease.

Table 11 Percentage change in the duration (total number of flow days) in each month after implementing the policy for the relevant breakout zones which are likely to influence hydrological outcomes for the greater Macquarie Marshes and the Wilgara Ramsar site. Values are averaged over the 124-year simulation period. Only flows > 1 ML/day were considered flow days

Hydro feature	Breakout zone	Jan %	Feb %	Mar %	Apr %	May %	Jun %	Jul %	Aug %	Sep %	Oct %	Nov %	Dec %
Duration	**Greater Macquarie Marshes (average)**	**119**	**−10**	**7**	**0**	**23**	**−6**	**6**	**1**	**−1**	**6**	**7**	**5**
	C Birchells Plains	0	1	0	0	0	8	−4	1	0	0	0	0
	F Gradgery	−1	−1	1	0	49	−17	0	0	0	5	0	−2
	H Wilgara	434	−15	32	0	90	−41	31	0	−2	9	14	14
	I Glencoe	161	−33	2	1	−26	21	1	3	−3	17	20	12
	J Pillicarwarrina	0	0	0	0	0	1	0	1	1	0	1	0
	Wilgara Ramsar site												
	H Wilgara	434	−15	32	0	90	−41	31	0	−2	9	14	14

5.7.3 Impacts on specific EWRs for wetlands

Greater Macquarie Marshes

The outcomes for the greater Macquarie Marshes as a whole are difficult to predict as the achievement of EWRs in some breakout zones are expected to improve, while other zones remain unchanged (Table 12). The **frequency**, and **timing** of flow events is predicted to improve in only two (Wilgara and Glencoe) of the five breakout zones which incorporate part of the greater Macquarie Marshes. Improved outcomes from the Wilgara breakout zone include:

- an increase in floods occurring between August and March (19%),
- improved flood frequency, and
- reduced inter-event frequency (-12%)

Similar outcomes are expected for the Glencoe breakout zone (Table 12).

Achievement of key EWRs for the Marshes were unchanged in the Birchells, Gradgery and Pillicarwarrina breakout zones indicating no benefit to these areas once the policy is implemented. The Wilgara Ramsar site is within the Wilgara breakout zone and is predicted benefit from improvements in this breakout (Table 12).

Table 12 Percentage change in frequency of achieving EWRs in the breakout zones supporting the greater Macquarie Marshes (breakout zones C, F, H, I, J) and the Wilgara Ramsar site (breakout zone H, right-most column) after implementing the policyValues are averaged over the 124-year simulation period

Hydro feature	EWR metric	C Birchells Plains	F Gradgery	H Wilgara	I Glencoe	J Pillicarwarrina
Frequency	9 years in 10	−1%	−1%	+55%	+87%	0%
	8 years in 10	−1%	−1%	+73%	+71%	0%
	7 years in 10	−1%	−1%	+58%	+55%	0%
	6 years in 10	−1%	−1%	+40%	+41%	0%
	5 years in 10	−1%	−1%	+38%	+43%	0%
	2 years in 10	−1%	−1%	+26%	+31%	0%
	Inter-event <4yrs	−1%	0%	+12%	+15%	+2%
	Inter-event <5yrs	−1%	0%	+12%	+15%	+2%
Timing	August – March	−1%	0%	+19%	+21%	0%

5.8 Flow-dependent frogs

The Macquarie floodplain contains important refugia and habitat for frog species including anabranches, lagoons, wetlands, watercourses and billabongs. Changes to the timing, frequency and duration of floods reaching these habitats is likely to have a range of benefits to maintenance and breeding outcomes for flow-dependent frogs. Up to 20 frog species (Appendix A, Table 16) are either predicted to occur or are recorded in the floodplain breakouts. This assessment only considers the outcomes for 8 of these species due to their strong association with floods (DPI Water 2018). These species were either predicted or recorded in all breakout zones. The species include the eastern sign-bearing froglet (*Crinia parinsignifera*), salmon striped frog (*Limnodynastes salmini*), green tree frog (*Litoria caerulea*), broad-palmed frog (*Litoria latopalmata*), Peron's tree frog (*Litoria peronei*), Fletchers frog (*Lechriodus fletcheri*), spotted grass frog (*Limnodynastes tasmaniensis*), and desert tree frog (*Litoria rubella*). At least one of these species is predicted to occur or its presence recorded in each breakout zone. This report generalises the predicted outcomes for all of these frog species.

5.8.1 Metrics

To identify the impact of changes in hydrological features important to frogs we used specific **duration, frequency and timing** EWRs adapted from the expected frog outcomes in the Macquarie-Castlereagh LTWP (DPIE EES 2019b). These are likely to maintain habitat or provide reproduction opportunities for frogs. The metrics selected were categorised into **maintenance** of habitat and **reproduction**:

Maintenance metrics

- improved flood frequency (average) and flood duration across all seasons which should maintain refuge for core wetlands and off-channel waterholes

Reproduction or breeding metrics

- at least one flow event every two years to support breeding events
- the timing and duration of floods in October to March for spring to summer breeders
- the timing and duration of floods in July to April for flexible breeders.

Further details for the EWRs are provided in Appendix C. In total, 7 water requirements for flow-dependent frogs were tested.

5.8.2 Impacts on specific EWRs for flow-dependent frogs

The predicted percentage change in frequency metrics for frog EWRs is very low (Table 13). Across all breakout zones, spring to summer breeders and flexible breeders which are capable of breeding across seasons are predicted to have a small percentage increase. While the increase is small averaged across all breakout zones, some areas are predicted to have greater change. Wilgara and Glencoe breakout zones have the greatest percentage change in predicted **number of flow days** (16%) in summer. This equates to 99 additional summer flow days in Wilgara and 135 flow days for Glencoe over the 124-year simulation period. Wilgara and Glencoe have a 35% (8 more events) and 31% (11 more events) increase in events occurring for spring to summer breeders, respectively. These breakout zones are also expected to have decreases in **inter flow period** (-10% and -12%) which should provide some outcomes for flow-dependent frog habitat maintenance. There is very little change expected at the other breakout zones. Longer durations and more frequent flows in these areas would provide greater outcomes for frogs.

Table 13 Percentage change in the frequency of achieving asset-specific EWRs for flow dependent frogs in the Macquarie Valley floodplain after implementing the policy. Values represent average (minimum and maximum) predicted outcomes, averaged over the 124-year simulation period across the 10 breakout zones

Hydro feature	EWR metric	% change
Frequency	Maintenance (inter-event frequency)	−2% (−12, +2)
	Breeding	0% (0, 0)
Timing	Breeding: spring to summer breeders (Oct-Mar)	+7% (0, +35)
	Breeding: flexible breeders: Jul-Apr	+3% (−2, +15)

6 Breakout zone specific changes to EWRs

The average percentage change in the achievement of all tested EWRs for a given asset (or group of values) was calculated for native fish, waterbirds and native vegetation for each of the 10 breakout zones (Table 14). Summarised outcomes for these 3 key environmental value categories at each breakout zone provide an assessment of zone specific outcomes on the Macquarie Valley floodplain. The average percentage change represents a high-level summary of the predicted increase or decrease in the number of EWRs met after implementation of the policy. For the majority of environmental values, implementing the policy resulted in no modelled improvements at most breakout zones, with some breakout zones predicted to see moderate improvements and others with minor changes.

Native fish were not recorded or predicted to occur in all breakout zones using the available datasets in Appendix B. In the zones with native fish present, between seven and nine **native fish** EWRs were tested for each fish guild, depending on the available EWR information (Table 7). Breakout zone specific changes were summarised by averaging the percentage change for these EWRs at each breakout zone. There is very little change in predicted EWR achievement expected for all four native fish guilds. A small reduction (−2%) is predicted for the Trangie breakout zone and slight increases (+1%) at the Marebone and Pillicarwarrina breakout zones. None of these changes are likely to be of significance for native fish in the Macquarie Valley.

Up to seven different EWRs were tested for **native vegetation** (Table 8) and averaged for each vegetation value (i.e. species) (Table 14). On average, native vegetation values are expected to see a positive change in EWR achievement at Wilgara and Glencoe breakout zones only. The greatest improvements are predicted for Glencoe (+18 %) and Wilgara (+16%). These breakout zones support the Macquarie Marshes and a diverse array of native vegetation species. The modelling suggests that there will be little improvement (≤1%) for vegetation in the remaining breakout zones.

For **waterbirds**, six EWR metrics for colonial-nesting waterbirds (Table 9) and four EWR metrics for non-colonial waterbirds (Table 10) were tested and averaged for each relevant breakout zone (Table 14). The average achievement of these metrics reduced slightly in one breakout zone and increased by 5% or less in four breakout zones. Little to no change is predicted for the other five breakout zones. An improvement of 14% in achieving non-colonial waterbird EWRs in the Wilgara and Glencoe breakout zones is predicted. Greater improvements in the Wyndabyne, Gradgery, Marebone, Wilgara, Glencoe and Pillicarwarrina breakout zones are desirable due to the significance of these zones for colonial-nesting waterbirds.

Overall, implementation of the policy is unlikely to influence the achievement of EWRs in the 10 breakout zones by any more than 5% (when averaged for each environmental value) improvement or a 2% reduction depending on the location. These outcomes suggest that a greater focus on improving environmental outcomes across all breakout zones of the Macquarie Valley may be required in the future or that modelled return flows need to be incorporated into the river system models to detect impacts in these breakout zones.

Table 14 Percentage change in the number of EWRs met for a given environmental value after implementation of the policy for the 10 breakout zones of the Macquarie Valley Floodplain. Values represent average, (minimum and maximum) predicted outcomes, averaged across EWR metrics for each group unless a value was not recorded within that breakout zone. Not present = where an environmental value was not recorded in the breakout zone and the EWR was not assessed for that value

Asset/value category	Environmental asset	A Trangie	B Marthaguy	C Birchells Plns	D Gunningbar	E Wyndabyne	F Gradgery	G Marebone	H Wilgara	I Glencoe	J Pillicarwarrina
Native fish	Short–moderate-lived floodplain specialists	−1% (−4, 0)	Not present	0% (−1, 0)	+0% (0, 0)	Not present	0% (−4, +5)	+1% (0, +5)	Not present	Not present	+1% (0, +5)
	Generalists	−2% (−7, 0)	0% (0, 0)	Not present	+0% (0, 0)	Not present	Not present	+1% (0, +3)	Not present	Not present	+1% (0, +3)
	Flow-dependent specialists	−2.0% (−6, 0)	0% (0, 0)	0% (−1, 0)	0% (0, 0)	0% (0, 0)	−1% (−3, +1)	+1% (0, +3)	Not present	Not present	+1% (0, +3)
	River specialist – Murray Cod	−2% (−7, 0)	0% (0, 0)	Not present	+0.2% (0, +0.8)	0% (0, 0)	0% (−2, +2)	+1% (0, +3.)	Not present	Not present	+1% (0, +3)
	Average of all native fish guilds	**−2%**	**0%**	**0%**	**0%**	**0%**	**0%**	**+1%**	**Not present**	**Not present**	**+1**
Waterbirds	Non-colonial waterbirds	−2% (−2, −2)	0% (0, 0)	+3% (+2, +3)	0% (0, 0)	0% (0, 0)	−1% (−1, −1)	+1.4% (0, +3)	+14% (0, +30)	+14% (+4, +24)	+1.4% (0, +3)
	Colonial-nesting waterbirds	Not present	Not present	Not present	Not present	0% (0, 0)	+4% (0, +8)	0% (0, 0)	+2% (0, +2)	+2% (0, +8)	0% (0, 0)
	Average of all waterbird groups	**−2%**	**0%**	**+3%**	**0%**	**0%**	**+3%**	**0%**	**+5%**	**+5%**	**0**
Native vegetation	Black box	−2% (−2, −2)	0% (0, 0)	−1% (−2, −1)	0% (0,0%)	0% (0,0%)	−1% (−1, 0)	+1% (0, +3)	+18% (+9, +23)	+19% (+14, +24)	+1% (0, +3)
	Coolabah	Not present	Not present	Not present	Not present	Not present	Not present	Not present	+18% (+9, +23)	+17% (+14, +24)	+1% (0, +2)

Asset/value category	Environmental asset	A Trangie	B Marthaguy	C Birchells Plns	D Gunningbar	E Wyndabyne	F Gradgery	G Marebone	H Wilgara	I Glencoe	J Pillicarwarrina
Native vegetation	Cumbungi	Not present	Not present	Not present	Not present	Not present	Not present	+2% (0, +3)	Not present	Not present	Not present
	Lignum	−2% (−2, −2)	0% (0, 0)	Not present	0% (0, 0)	Not present	−1% (−1, 0)	Not present	Not present	Not present	+2% (0, +3)
	River coobah (only 1 EWR tested)	−2%	0%	−1%	0%	0%	0%	3%	22%	14%	3%
	River red gum	Not present	0% (0, 0)	0% (−1, 0)	0% (0, 0)	0% (0, 0)	0% (−1, 0)	1% (0, +2)	16% (+5, +23)	18% (+14, +24)	1% (0, +2)
	Water couch	Not present	Not present	Not present	Not present	Not present	−1% (−1, −1)	1% (0, +2)	19% (+14, +23)	16% (+14, +17)	1% (0, +2)
	Average of all native vegetation	**−2%**	**0%**	**−1%**	**0%**	**0%**	**−1%**	**1%**	**17%**	**17%**	**1%**

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Appendix A Summary of all recorded water-dependent floodplain environmental assets and values in the Macquarie Valley

These data are based on available literature and spatial datasets.

Table 15 Legend for Table 16

Used in	Legend / acronyms
Specific asset descriptions	V = Vulnerable, E = Endangered, C = CAMBA, J = JAMBA, K = ROKAMBA [1]listed threatened species on the NSW Biodiversity Conservation Act (2016), [2]listed on the national EPBC Act, [3]listed in the *NSW Fisheries Management Act (1994)*
Source	FMP - Floodplain Management Plans, LTWP - long-term water plans, HEVAE - high ecological value aquatic ecosystems, SKM - Sinclair Knight Merz, SRA - sustainable rivers audit, WSP - water sharing plan

Table 16 Recorded water-dependent floodplain environmental assets and values and where the information was sourced from

Asset type	Source	Specific asset
Ecological asset type – wetlands	FMP	• Floodplain watercourses – drainage lines, lagoons, billabongs, waterholes and lakes • Semi-permanent wetland – shallow freshwater wetland sedgeland (PCT53), water couch marsh grassland (PCT204), sedgeland – forbland wetland (PCT 447) • Floodplain wetlands – river cooba swamp wetland (PCT241), lignum shrubland wetland (PCT 247), Nitre Goosefoot shrubland wetland (PCT160) and Rats Tail Couch sod grassland wetland (PCT 242)
Ecological asset type – other floodplain ecosystems	FMP	• Flood-dependent forest/woodland (wetlands) – river red gum open forest/woodland wetland (PCT36) • Flood-dependent woodland – blackbox woodland wetland (PCT37), coolabah-river cooba-lignum woodland wetland (PCT39), coolabah open woodland wetland (PCT40), poplar box-coolabah floodplain woodland (PCT87), carbeen +/- coolabah grassy woodland (PCT628)
Endangered Ecological Communities	HEVAE, FMP	• Lowland Darling River EEC, Marsh Club-rush Sedgeland EEC, Carbeen Open Forest EEC, coolabah-Black Box Woodland EEC

Asset type	Source	Specific asset
Important lagoons and wetlands (FMP, WSP listed)	WSP, FMP	• Greater Macquarie Marshes, Boggy Cowal Swamps and Lagoons, Castlereagh Swamps, Lagoons and Dunes, Bugwah Swamps and Lagoons, Ramsar - Wilgara Wetland, Ramsar - Macquarie Marshes Nature Reserve
Native vegetation	LTWP, SKM, HEVAE	• River red gum, black box, coolabah, lignum, non-woody wetland, braid fern (E)2, shrub sida (E)2, cyperus conicus (E)2, common reed
Native fish	LTWP, SRA Fish dataset, HEVAE, SKM	• Flow-dependent specialists – Golden Perch, Silver Perch (V)[2], Spangled Perch • Generalists – Australian Smelt, Carp Gudgeon, Mountain Galaxias, Flathead Gudgeon, Murray-Darling Rainbowfish, Bony Herring, Unspecked Hardyhead • Short–moderate-lived floodplain specialists – Southern Purple Spotted Gudgeon (E)[3], Olive Perchlet – Western population (E)[3], Rendahl's Tandan, Flathead Galaxias • In-channel specialists – Murray Cod (V)[2], River Blackfish, Eel-tailed Catfish – MDB population (E)[3], Darling River Hardyhead, Trout Cod (E)[1,2]
Water birds	LTWP, BioNet, HEVAE, SKM	• Ducks – Australasian grebe, Australasian shoveler, chestnut teal, freckled duck (V)[1], great crested grebe, grey teal, hardhead, hoary-headed grebe, musk duck, Pacific black duck, pink-eared duck, blue-billed duck (V)[1] • Herbivores – Australian wood duck, black-tailed native-hen, black swan, dusky moorhen, Eurasian coot, plumed whistling-duck, purple swamphen, magpie goose (V)[1] • Large waders – black-necked stork (E)[1,2], brolga (V)[1], royal spoonbill, yellow-billed spoonbill, Australian white ibis • Piscivores – Australian gull-billed tern (C), whiskered tern, Australasian darter, little pied cormorant, great cormorant, little black cormorant, pied cormorant, Australian pelican, white-necked heron, little egret, white-faced heron, nankeen night heron, white-bellied sea-eagle, intermediate egret • Shorebirds – Australian painted snipe (E)2, banded lapwing, black-fronted dotterel, black-winged stilt, Latham's snipe (J,K), marsh sandpiper (C,J,K), masked lapwing, red-capped plover, red-kneed dotterel, red-necked avocet, sharp-tailed sandpiper (C,J,K), Caspian tern
Other threatened biota	SKM, HEVAE, DPI Fisheries	• River snail (E)[3]
Frogs and reptiles	FMP, HEVAE	• Eastern sign-bearing froglet, broad-palmed frog, crucifix frog, desert tree frog, green tree frog, long-thumbed frog, Peron's tree frog, rough frog, salmon striped frog, Sloane's froglet, small-headed toadlet, spotted grass frog, striped burrowing frog, Sudell's frog, water-holding frog, wrinkled Toadlet, common eastern froglet, Fletchers frog, spotted grass frog, desert tree frog
Groundwater recharge	FMP	• Key areas of groundwater recharge on the floodplain

Asset type	Source	Specific asset
Functions	LTWP	• Nutrient, carbon and primary production

Appendix B Datasets used to refine environmental assets and values in the Macquarie Valley

Table 17 Datasets used to refine assets and values and their source

Dataset	Year	Source / Reference		Details
Macquarie Valley cross section breakouts	2020	DPIE Water	• The department's water modelling team (2020)	• Identifies key breakout points where the river system models will have representative flow data for base case and implementation
Macquarie Valley Flood Management Plan Management Zones	2019	DPIE EES	• NSW Office of Environment and Heritage Floodplain Management Plans • NSW Office of Environment and Heritage (2017) 59-61 Goulburn Street Sydney 2000	• FMP management zones. Based on hydraulic, ecological, cultural and socio-economic criteria. Six zones are included in the FMP: A -major flood discharge zone; B - major flood paths and flood storage; BH – major flood discharge areas in high-level floodways; C- flood fringe and flood protected developed areas; CU – urban areas; D - environmentally sensitive areas
Macquarie Valley Flood Management Plan (2018) flood-dependent and non-flood-dependent vegetation	2019	DPIE EES	• NSW Office of Environment and Heritage, (2015) BRG-Namoi Regional Native Vegetation Mapping • EcoLogical Australia (2015) Development of a Biodiversity Prioritisation Plan for the North West LLS • Hudson & Bacon (2009) Culturally significant lagoons and salt affected sites project	• Composite vegetation map used to inform development of the rural Floodplain Management Plan for the Macquarie Valley Floodplain 2018 derived from various sources. This dataset contains both flood-dependent and non-flood-dependent vegetation communities
Macquarie Valley Flood Management Plan threatened fish distributions (MaxEnt)	2016	DPI Fisheries	• NSW DPI Fisheries Fish Community Status and Threatened Species data • NSW Department of Industry (2016) 161 Kite Street Orange 2800 http://www.dpi.nsw.gov.au/fishing/species-protection/threatened-species-distributions-in-nsw	• MaxEnt predicted distributions of threatened fish species in the Macquarie FMP. Species include: Eel-tailed Catfish, Olive Perchlet, Purple-spotted Gudgeon and the river snail

Dataset	Year	Source / Reference		Details
High Ecological Value Aquatic Ecosystems	2018	DPIE Water	• Healey et al. (2018) Applying the high ecological value aquatic ecosystem (HEVAE) Framework to Water Management Needs in NSW	• HEVAE (high ecological value aquatic ecosystem) - Identifying environmental assets, values and ecosystems functions. This dataset includes: o Endangered Ecological Communities o MaxEnt Threatened Fish distributions o Recorded and known threatened species sightings (waterbirds, fish, invertebrates, plants etc). o Rankings for Diversity, Distinctiveness, Vital Habitat and Naturalness
Wetlands composite	2019	DPIE EES	• Multiple outlined in: • NSW Office of Environment and Heritage Floodplain Management Plans • NSW Office of Environment and Heritage (2017) 59-61 Goulburn Street Sydney 2000	• Priority wetland assets to inform development of the Macquarie Valley FMP 2019
Frog occurrence	2019	DPIE EES	• NSW Wildlife Atlas BIONET	• Spatially representing the occurrence records of frog species within the Macquarie Valley floodplain
BioNet	Extracted October 2020	DPIE EES	• NSW Wildlife Atlas BIONET	• Valid records for waterbirds. List refined to water dependent assets and values based on literature

Dataset	Year	Source / Reference		Details
Sustainable Rivers Audit fish data	2019	DPI Fisheries	• Provided to the department in 2014 by DPI Fisheries	• DPI Fisheries Freshwater Fish Research Database and the Murray Darling Basin Authority (Sustainable Rivers Audit data) • 1. Davies P, Harris J.H., Hillman T.J., Walker K.F. (2008) SRA Report 1: A Report on the Ecological Health of Rivers in the Murray-Darling Basin, 2004-2007. Prepared by the independent sustainable rivers audit group for the Murray-Darling Basin Ministerial Council. Murray-Darling Basin Commission, Canberra • 2. Davies, PE, Stewardson, MJ, Hillman, TJ, Roberts, JR & Thoms, M.C. (2012). Sustainable Rivers Audit 2: The ecological health of rivers in the Murray-Darling Basin at the end of the Millennium Drought (2008-2010). Volume 3. Murray-Darling Basin Authority, Canberra • 3. NSW Department of Primary Industries (2013). Freshwater Fish Research Database, Aquatic Ecosystem Unit, NSW Department of Primary Industries, maintained at Port Stephens, Fisheries Institute, Taylors Beach
Flood-dependent fauna (Fish) - Key Fish Habitat	2020	DPI Fisheries	• NSW DPI Fisheries	• Spatially representing Key Fish Habitat within the Floodplain Management Plan boundary

Appendix C Detailed environmental water requirements of key water-dependent environmental assets and values in the Macquarie Valley

Table 18 Footnotes for Table 19 to Table 23

Footnotes
[1](Roberts and Marston 2011), [2](DPIE EES 2019b), [3](Scott 1997), [4](NSW Department of Primary Industries 2015), [5](Kingsford et al. 2014), [6](SKM 2009), [7](DPI Water 2018), [8](McGinness and Arthur 2011), [9](Reid et al. 2016), [10](Brandis and Bino 2016), [11](NSW Department of Primary Industries 2019), [12](Ballinger et al. 2005), [13](Boulton and Lloyd 1992), [14](Kingsford and Auld 2005), [15](Bino et al. 2014), [16](Arthur et al. 2012), [17](Ocock 2013), [18](McInerney et al. 2020), [19](DPIE EES 2019a)
N/A = No detail or unable to assess accurately, y = years, m = months, d = days, EO = EWR based on the expert opinion of the department's ecohydrologist; Spr=spring; Sum=summer; Aut=autumn; Win=winter

Table 19 Details of environmental water requirements of key native fish values. Substitute improvement measures were used for the maintenance duration metrics, see Section 5.2.1 for more details.

Value	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
Short–moderate-lived floodplain specialists	Frequency	Every 2 years[11] Max inter-event period of 4 years[2,11]	≤2 years ≤4 years	3-5 years in 10[4,2] Max inter-event period of 4 years[2,11]	≥3 in 10 years ≤4 years
	Duration	Improved number of flow days during Summer[4]	Total number of flow days in Summer	>10 days to allow egg development[2,4,11]	≥10 days
	Timing	October to April for spawning habitat[2] Summer for increased food resources and to maintain refugia[4]	Oct-Apr Summer	September to October is the most common across species[4] Recruitment enhanced with secondary event after spawning (i.e. summer) [4]	Sep-Oct Spring event followed by Summer

Value	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
	Other	Dispersal dependent on floods and flood size[2]	N/A	Gradual recession of events important for dispersal of larvae and juveniles[4]	Reduced mean rate of flood fall Reduced duration of fall
Generalists	Frequency	1 in 3-5 years[11] Maximum interflow period of 5 years[11]	≥1 in 5years ≤5 years	2 in 10 years[11]	≥2 in 10years
	Duration	Improved number of flow days during Spring-Summer[4]	Total number of flow days in Spr-Sum	5 days[11]	≥5 days
	Timing	Spring to summer[11]	Spr-Sum	September to February flows enhance spawning and provide habitat and resources for recruitment[4]	Spr-Sum
	Other	Improved floodplain metrics will also promote growth and recruitment for these fish via increased floodplain productivity and habitat availability	N/A	Subsequent events enhance recruitment and dispersal outcomes[4]	Sep-Feb with an event no more than 2 months prior
Flow-dependent specialists	Frequency	1 in 3-5 years[11] Maximum interflow period of 4 years[2]	≥1 in 5 years ≤4 years	2-3 in 10 years[4]	≥2 in 10 years
	Duration	Improved number of flow days during spring-summer[4]	Total number of flow days in Spr–Sum	5 days[4]	≥5 days
	Timing	Spring to summer[11]	Spr–Sum	Spring to autumn[4]	Spr-Aut
	Other	Velocities of 0.3 $m.s^{-1}$ required for ideal habitat[11]	N/A	Rapid recession assists with egg dispersal[4] Subsequent events enhance recruitment and dispersal outcomes[4]	N/A

Value	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
In-channel/river specialist: Murray Cod	Frequency	1 in 3-5 years[11] Maximum interflow period of 5 years[11]	≥1 in 5 years ≤5 years	2 in 10 years[11] Maximum interflow period of 2 years[11]	≥2 in 10 years ≤2 years
	Duration	Improved number of flow days during spring-summer[4]	Total number of flow days in Spr–Sum	>14 days to allow egg development and hatching[2,4]	≥14 days
	Timing	Spring to summer[11]	Spr–Sum	September to December for Murray cod[2]	Sep–Dec
	Other	Velocities of 0.3 m.s^{-1} required for ideal habitat[11]	N/A	Subsequent events enhance recruitment and dispersal outcomes[4]	Win–Spr with an event no more than 2 months prior

Table 20 Details of environmental water requirements of key native waterbirds values. Substitute improvement measures were used for the duration metrics, see Section 5.2.1 for more details.

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
Colonial-nesting	Flood volume or frequency	In line with habitat requirements[2] The condition of lignum (*Muehlenbeckia florulenta*) and river red gum (*E. camaldulensis*) is important for breeding success of colonial waterbirds[15]	Relates to native vegetation outcomes	Colonial waterbird breeding in the Northern Basin are linked to large floods[10]. Flow volumes in the 3 months before breeding (September-November)[14] at the Oxley station flow gauge (421022) are most likely to trigger colonial breeding events[14] The number of flow days above 1,250 ML/d (50 days or more) and 1,500 ML/d (40 days or more) at the Oxley station flow gauge (421022) required to achieve the highest breeding probability[15]	Cumulative volume in the 3 months before Sep, Oct and Nov occurring in the breakout which includes the Oxley station flow gauge (421022) and those breakouts downstream from here Number of flow events with flow >40 days. Events must occur in the breakout which includes the Oxley station flow gauge (421022) and those breakouts downstream from here

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
	Duration	In line with habitat requirements[2]	Relates to native vegetation outcomes	Improved number of flow days between July–December[15,16]	Total number of flow days in between Jul-Dec
	Timing	In line with habitat requirements[2]	Relates to native vegetation outcomes	Timing of flow events between July–December[15,16]	Jul-Dec
Non-colonial	Flood volume or frequency	In line with habitat requirements[2] The condition of lignum (*Muehlenbeckia florulenta*) and cumbungi (*Typha domingensis* and *T. orientalis*) in particular[2,EO]	Relates to native vegetation outcomes	None assessed	N/A
	Duration	In line with habitat requirements[2]	Relates to native vegetation outcomes	Duration of flow events during spring and summer for ideal breeding Duration of flow events during autumn and winter for opportunistic breeding	Total number of flow days in Spr-Sum and Aut-Win
	Timing	In line with habitat requirements[2]	Relates to native vegetation outcomes	Inundation of floodplain habitats between spring and summer is the ideal season[2] Inundation of floodplain habitats in autumn and winter for opportunistic breeding[2]	Spr-Sum Aut-Win

Table 21 Details of environmental water requirements of key native vegetation values. Substitute improvement measures were used for the duration metrics, see Section 5.2.1 for more details.

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
Shrublands					
Lignum (shrubland wetlands) *Muehlenbeckia florulenta*	Frequency	Once in 1-3 years for large shrubs[1,14] Once in 7-10 years for smaller shrubs[1,14]	≥1 in 3 years ≥1 in 7 years	Seedlings watered once per 12 to 18 months over first three years: desirable[1]	≥1 in 1.5 years
	Duration	Improved number of flow days during Spring-Summer	Total number of flow days in Spr-Sum	Improved number of flow days during Spring-Summer	Total number of flow days in Aut-Win and Spr-Sum
	Timing	Timing not critical[1]	N/A	Autumn to winter. Flooding for dispersal and post-flood recession germination needs to be within a few months of seed release, which is in autumn[1,14] Seedling establishment before or during summer[1,14]	Aut-Win Spr-Sum
	Other	Depth Not critical, generally less than 1 m.[1]	N/A	Germination temperature dependent (15–30°C), depth shallow (5 to 15 cm), flowering triggered by flooding which can occur within four weeks of flooding[1]	N/A
Forest and woodlands					
Black box *E. largiflorens*	Frequency	Once every 3-7 years[1]	≥1 in 7 years	Small inundations in the first and second year improve seedling establishment[1]	≥1 in 2 years
	Duration	Improved number of flow days	Total number of flow days	Improved number of flow days during Spring-Summer	Total number of flow days in Spr-Sum
	Timing	Not critical[1]	N/A	Spring-summer recession best[1]	Spr-Sum

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
Coolabah *E. coolabah*	Frequency	Wetland: Every 5-10 years in 10[2] Woodland: 1 year in 10[1,2] The maximum inter-event period is 10–15 years[2]	≥2 in 10 years ≥1 in 10 years ≤10 years	Small inundations in the first and second year improve seedling establishment[1]	≥1 in 2 years
	Duration	Improved number of flow days	Total number of flow days	Improved number of flow days during Spring-Summer	Total number of flow days in Spr-Sum
	Timing	Not expected to be important for trees. May be important for understorey and associated plant communities, and for dependent fauna[1]	N/A	Spring-summer recession best Seedlings vulnerable to desiccation in summer[1]	Spr-Sum
	Other	Maximum of 10 years between events[2]	≥1 in 10 years		
River cooba *Acacia stenophylla*	Frequency	Once every 3-7 years[1]	≥1 in 7 years	Not known	N/A
	Duration	Flooding is important but the specific requirements are not known[1]	N/A	Flooding is important but the specific requirements are not known[1]	N/A
	Timing	Not critical[1]	N/A	Not known	N/A

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
River red gum *E. camaldulensis*	Frequency	Forests: every 1–3 years Woodlands: every 2–4 years[1] Floodplain: 3–5 years in 10 Max inter-event period 4–5 years[2]	≥1 in 3 years ≥1 in 4 years ≥2 in 10 years ≤5 years	Follow up flood in 1st or 2nd year is desirable[1]	≥1 in 2 years
	Duration	Improved number of flow days during spring–summer	Total number of flow days in Spr–Sum	Improved number of flow days during spring–summer	Total number of flow days in Spr–Sum
	Timing	Not critical but the best outcomes during spring–summer[1] September–February[2]	Spr–Sum	Flood recession in spring-summer to provide warm moist conditions for germination and seeding growth[1] Seedlings vulnerable to desiccation and heat stress in summer[13]	Spr–Sum
	Other	N/A	N/A	Shallow depths are desirable but where this is unknown, duration is critical[1]	N/A
Wetland and floodplain non-woody vegetation					
Water couch *Paspalum distichum*	Frequency	Every 1–2 years[1]	≥1 in 2 years	Not known	N/A
	Duration	5–8 months[1]	≥5 months	Not known	N/A
	Timing	Start in late winter or spring with flooding over summer critical	Win-Sum	Not known	N/A
	Other	Depth is critical, shallow is best	N/A	Seeds short lived so if regeneration via seeds is desired annual flooding is recommended	≥1 year

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
Cumbungi *Typha domingensis* and *T. orientalis*	Frequency	Once every 1 to 3 years[1]	≥1 in 3 years	Reflood after 2 years desirable[1]	≤1 in 2 years
	Duration	Improved number of flow days during autumn–winter[1]	Total number of flow days in Aut–Win	Improved number of flow days during Summer-Autumn	Total number of flow days between Sum–Aut
	Timing	Starting autumn–winter[1]	Aut–Win	Summer-Autumn: establishment over winter is unlikely[1]	Sum–Aut

Table 22 Details of environmental water requirements of key flow-dependent frogs. Substitute improvement measures were used for the duration metrics, see Section 5.2.1 for more details.

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
Frogs	Frequency	Improved frequency will maintain refuge for core wetlands and off-channel waterholes[EO]	≥ flood frequency	1 to 2 years to support successful breeding[2]	≥1 in 2 years regardless of timing
	Duration	Improved number of flow days across all seasons should improve maintenance of refugia[EO]	Total number of flow days	Spring to summer breeders[2]: Oct-Mar Flexible breeders[2]: Jul-Apr	Total number of flow days between Oct-Mar Total number of flow days between Jul–Apr
	Timing	N/A	N/A	Spring to summer breeders[2]: Oct–Mar Flexible breeders[2]: Jul–Apr	Oct–Mar Jul–Ap

Table 23 Details of environmental water requirements of listed wetlands (maintenance and reproduction combined). Substitute improvement measures were used for the duration metrics, see Section 5.2.1 for more details.

Asset	Hydro feature	Maintenance / regeneration / reproduction	Value used

Listed wetland - Macquarie Marshes (Southern, Northern and Eastern)	Frequency	9-10 years in 10[19]	9 in 10[y]
		8-9 years in 10[19]	8 in 10[y]
		5-10 years in 10[19]	7 in 10[y]
		3-10 years in 10[19]	6 in 10[y]
		5 years in 10[19]	5 in 10[y]
		2-3 years in 10[19]	2 in 10[y]
		Maximum inter-event period of 4 years for LTWP Overbank flow/Small wetland flow 2[19]	≤4[y]
		Maximum inter-event period of 5 years for LTWP Overbank flow/Small wetland flow 3[19]	≤5[y]
	Duration	Improved flood duration between August and March[19]	Total number of flow days between Aug-Mar
	Timing	Flood occurring between August and March[19]	Aug–Mar

Appendix D Further detail on the approach to quantify changes in floodplain hydrology

D.1 River system model outputs

D.1.1 Identifying changes to floodplain flow regimes: what is possible with the available information?

The modelling scenarios (with and without policy implemented) are critical to predicting any environmental benefits for floodplain environmental assets and values through implementing the policy. These scenarios are introduced in the Model Build report (DPIE Water 2021a) and described in detail in the Scenarios report (DPIE Water 2021b). The intricacies of each model are not included in this report. However, it is critical to understand what outputs are produced by each model and the limitations associated with predicting environmental benefits or undesirable outcomes. The outputs, approach and limitations are discussed below.

D.1.2 Available model outputs

The planned implementation of the policy has increased investment in data and modelling to quantify floodplain harvesting more accurately. These models are being used to define floodplain harvesting entitlements. The intent of the policy is to control future growth and to remove existing growth where total diversions exceed plan limits under the Basin Plan 2012. The change in floodplain harvesting pre- and post-implementation of the policy can be assessed through comparing the results of two model scenarios, one that describes the current condition without the policy implemented, and the other describing the condition with the policy implemented.

Both scenarios are required to identify any hydrological changes due to implementation of the policy and any flow-on consequences for floodplain environmental assets and values. For each scenario, modelled daily time-series flow data (ML/day) are available for the end of system (EOS) floodplain breakouts below each floodplain harvesting breakout zone. Modelled data cover the period from 1895 to 2019.

D.1.3 Relating floodplain harvesting take to quantified changes

In addition to providing the two modelled daily flow time series, the department has provided estimates of diversion or ‘water take’ under both scenarios.. This provides descriptive statistics, used to help interpret the changes to the floodplain hydrology. Floodplain harvesting take results are reported at valley scale in the companion Scenarios Report (DPIE Water 2021b).

D.2 Assumptions and limitations

It is important to acknowledge that the outcomes are predictions based on modelled hydrological data for the period from 1895 to 2019, and the following must be kept in mind when interpreting results:

- Predicted outcomes are restricted by the uncertainty and limitations of the river system models and should only be used as a guide to potential outcomes.
- Return flows from the floodplain to downstream waterways are not included in the river system models which limits the interpretation of downstream outcomes. As downstream return flows are likely to be improved by the policy, it is possible that the current report underestimates any environmental benefit that might accrue.
- Flood inundation duration and inundation spatial extent cannot be assessed using the available river system models.

- The adopted approach assumes that meeting an environmental water requirement (EWR) is a positive outcome for an environmental asset or value. In reality, this could be influenced by a range of other factors (e.g. flow path disconnection due to flood works, vegetation clearing) not incorporated into this report.
- Outcomes are only estimated for those breakout zones within 'breakout zones' with licensed floodplain harvesting entitlements and modelled hydrological data.

D.2.1 Modelling flood inundation extent for the policy

The healthy floodplains team at DPIE EES has developed a flood inundation model for a small and large scale flood on the Border Rivers, Gwydir, Macquarie, Namoi and Barwon-Darling floodplains. These models are a mixture of 1D and 2D models using a range of model types. These include TUFLOW, MIKE FLOOD, MIKE 21, MIKE 11 and a variety of others. Each model has the ability to setup and run different magnitude events to identify inundation patterns. This makes them an extremely useful tool when looking at the inundation extent of different flow magnitudes. However, each model run requires significant resources. This assessment would require model runs for a large number of flood magnitudes in each valley. Whilst we acknowledge that this information would be useful, the department's IQQM river system models provide valuable information which can be used to identify hydrological changes and provide some indication of whether inundation would have increased or decreased through changes to flood volumes and durations.

D.2.2 Modelling return flows and downstream impacts

The river system models currently available represent any residual overbank flow as a 'loss' and residual return flows are not simulated (except in a few rare circumstances). These models therefore cannot assist in determining downstream impacts on flows, gauging stations and gauge station based EWRs like those in the *Long-Term Water Plans* developed for each valley by DPIE EES. The assumption is that implementing the policy (and thereby reducing floodplain harvesting take compared to the current situation) will lead to improvements for downstream users and environmental assets and values. Further data collection and research is required to support an analysis of downstream impacts. Compared to the other valley models, the Macquarie IQQM has better accounted for return flows, based on OEH data. However, there will still be significant uncertainty with this representation.

The Independent Peer Review of the policy implementation (Alluvium 2019), Vertessy et al. (2019) report and NRC review (NRC 2019) have all highlighted the importance of improving our understanding of return flows from the floodplain to the river to allow adaptive management over time. This would enhance water management and ensure a balance for environment, social, cultural and economic outcomes. The department recognises the importance of understanding return flows and downstream impacts and is considering what information will be required to increase this understanding in the future. This is discussed further in the future improvements section.

The models can be used to provide daily time-series flow data of breakout flow which can be used to assess what volumes may be available to the floodplain environment in a general sense. The models simplify complex floodplain flow paths into a few breakout relationships. The models also have simplified methods to account for conveyance and natural losses on the floodplain. This means that the breakout flow may not always be relevant to all floodplain environmental assets and values. It is possible that only a portion of the breakout flow reaches the particular floodplain asset. Similarly, it is possible that in small events no water would have reached the asset. For this reason, assets and values within a defined breakout zone were selected for inclusion to restrict predictions in areas where the model data might not apply or where there is a lower confidence in applicability for that part of the floodplain.

D.2.3 Estimating cumulative downstream hydrological changes

Quantifying cumulative downstream changes in hydrology due to implementing the policy is not possible at this point. This is primarily because return flows from floodplain breakout zones are rarely incorporated into the river system model (as discussed above). While quantifying changes to cumulative downstream flows is not possible at this point in time, the volumes returned to the floodplain within each valley can be quantified. This will provide an estimate of how much water will pass through floodplain harvesting areas after implementation of the policy. Caution is required when translating this into perceived downstream benefits. Future improvements in our understanding of return flows and critical pathways may improve our ability to quantify downstream changes through improved river system models and through any monitoring, evaluation and reporting (MER) conducted after implementation.

D.2.4 Identifying impacts on gauging station-based EWRs

Most EWRs established in each Long-Term Water Plan or Commonwealth Environmental Water Portfolio Management Plan are primarily based on a flow at a nearby gauging station. As return flows are not included in the modelled scenarios, there is no detectable impact on a modelled flow series at a gauging station downstream of a floodplain breakout. Therefore, without this information, it is not possible to identify whether gauging station-based EWRs are achieved more or less with upstream floodplain harvesting licensing (implementation) or not. Improvements in modelling of return flows would enable an assessment of upstream impacts on downstream EWR triggers in the future.

D.2.5 Future improvements

The investment in data, method, consultation, review, time and effort has improved our understanding and estimation of floodplain harvesting. Nevertheless, there is still significant uncertainty in that estimate.

Additional data collection, in particular monitoring of harvesting through the floodplain harvesting monitoring strategy, is required to help to address this uncertainty. Information required includes but is not limited to:

- monitoring program to measure floodplain harvesting
- measurement of major floodplain flows and returns
- estimation of floodplain losses
- groundwater recharge estimates
- assessment of measured floodplain harvesting diversions against modelled floodplain harvesting diversions for adaptive management
- monitoring by NRAR of water harvested through the floodplain harvesting monitoring and auditing strategy continues to ensure licensed diversions are adhered
- Lawful structures that allow licensed water take but remain in the flow path of important flood runners will inhibit the modelled benefits predicted within this report. These structures must be monitored to ensure only licenced entitlements are being diverted and flood paths remain connected wherever possible.

Appendix E Glossary

In addition to the information provided in this appendix, the reader is directed to excellent online resources, such as that provided by Water NSW[12].

Table 24 Abbreviations/acronyms used in this report

Abbreviation/ acronym	Description
BDL	Baseline diversion limit
CAMBA	China-Australia Migratory Bird Agreement
CEWO	Commonwealth Environmental Water Office
DOC	Dissolved organic carbon
EOS	End of system
EWR	Environmental water requirement
FMP	Floodplain Management Plan
HEVAE	High ecological value aquatic ecosystems
IQQM	Integrated Quantity Quality Model (NSW in-house river system model)
JAMBA	Japan-Australia Migratory Bird Agreement
LTAAEL	Long term average annual extraction limit
LTWP	Long-term water plan
OFS	On-farm storage
PCT	Plant community type
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SRA	Sustainable Rivers Audit
WSP	Water Sharing Plan

[12] https://www.waternsw.com.au/customer-service/service-and-help/tips/glossary#:~:text=Glossary%20of%20water%20terms%201%20Basic%20landholder%20rights.,7%20Carryover%20Spill%20Reduction.%20...%20More%20items...%20

Table 25 Key terms used in this report

Term	Description
Current Conditions Scenario	Model scenario that uses the best available information on most recent known levels of irrigation infrastructure and entitlements (described in companion Scenarios report (DPIE Water 2020b))
Long-term average annual extraction limit (LTAAEL)	The upper limit on the average of annual extractions from the water source over the period for which an assessment is carried out. (Source: https://www.waternsw.com.au/customer-service/service-and-help/tips/glossary#l)
node	A ‘node’ in the river system model. A location at which information is attached and information is retrieved. Examples of nodes are Irrigator User nodes, splitter nodes, gauge nodes
Plan limit	The authorised long-term average annual extraction limit as defined in the Water Sharing Plan
Plan limit compliance	Compliance with the Plan limit, which is assessed using long-term modelling
Plan Limit Compliance Scenario	Model scenario that results in the lower long-term average diversions from either the conditions set out in the Water Sharing Plan or agreements made under the Murray Darling Basin Ministerial Council on diversions (described in companion Scenarios report (DPIE Water 2020b))
the policy	Shortened term for the *NSW Floodplain Harvesting* Policy