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Environmental outcomes of implementing the Floodplain Harvesting policy in the Namoi Valley

Technical report

December 2022

Acknowledgement of Country

The Department of Planning and Environment acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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Contents

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*). The objective 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* is being implemented in the 5 Northern Basin valleys of NSW Border Rivers, Gwydir, Namoi, Macquarie and Barwon-Darling. The *policy* includes licensing of floodplain harvesting to provide a more sustainable level of water diversions from the floodplain through returning water use to the long-term average annual extraction limit and curtailing future growth.

Using modelled long-term (1895 to 2020) changes to the hydrology of the floodplain, this report provides an assessment of potential outcomes for the environment of implementing the *policy* in the NSW Namoi valley. A set of hydrological metrics and environmental flow requirements (EFRs) were used to test and identify these outcomes for environmental values (e.g. species) including native fish, native vegetation, and waterbirds.

Key findings

The Namoi floodplain was broken into 8 breakout zones to identify hydrological and environmental changes with and without the *policy* implemented. However, the distribution of floodwater across these zones is not equal, with 4 responsible for 82% of the overbank volumes in the valley. Any predicted changes to these 4 zones should be considered the most significant change when reading this report. These zones are the Merah North, Bugilbone, Glencoe and Trilby Park breakouts (Figure 1).

Figure 1 provides a mapped high-level summary of potential outcomes across the Namoi valley for native fish, waterbirds, native vegetation and water volumes. Most environmental flow requirements are predicted to have no change or small increases under the *policy*. The predicted improvements to floodplain hydrology (volumes, durations and timing of floods) suggest that environmental outcomes for the NSW Namoi valley will be primarily beneficial, although limited to minor outcomes at a few breakout zones[1].

[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.

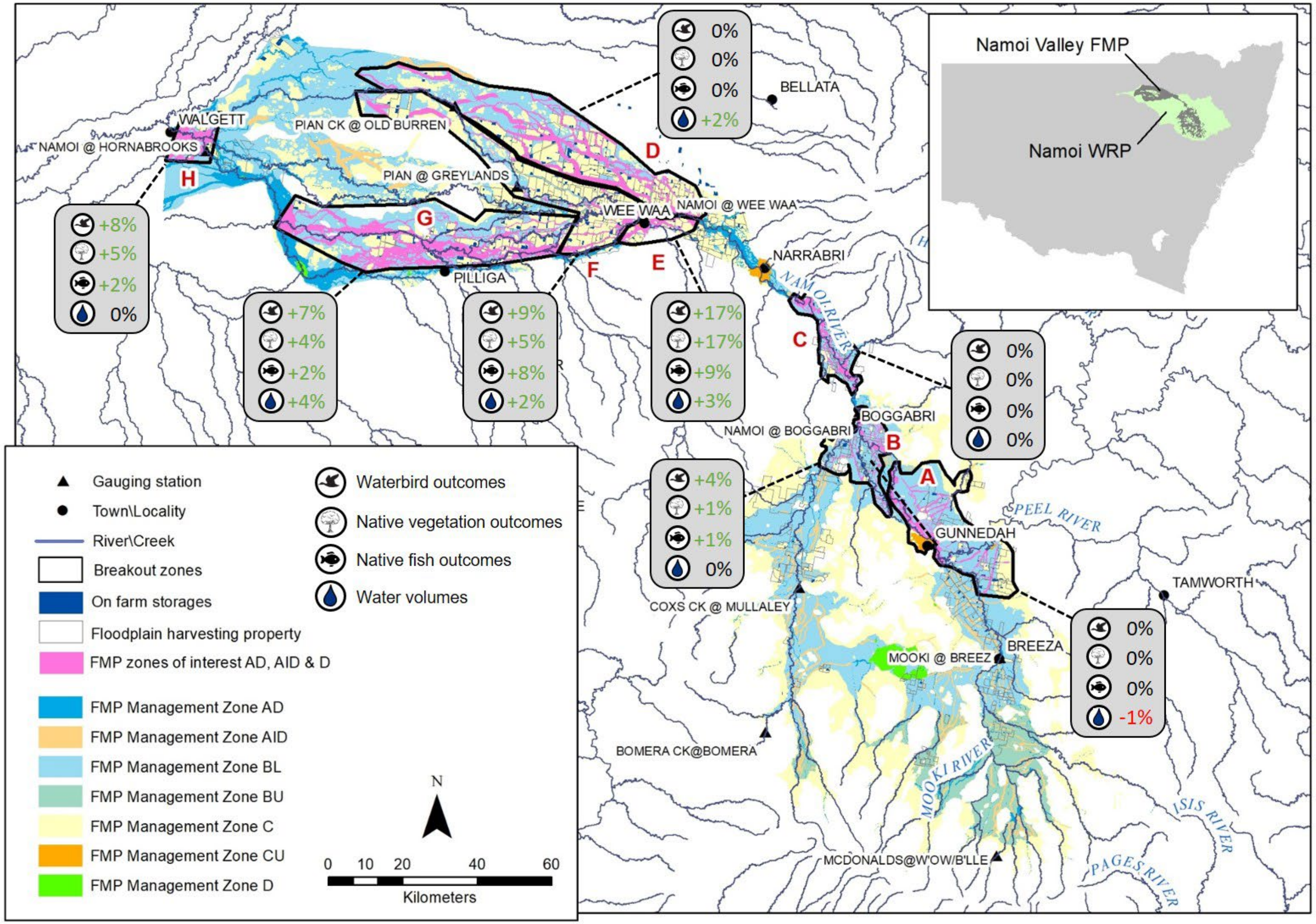

Figure 1 Mapped summary of predicted outcomes for waterbirds, native vegetation, native fish and water volumes for the 8 breakout zones on the NSW Namoi valley floodplain. Percent change values show the predicted change from current (no *policy*) to current with *policy* implemented based on a 125 year simulation period. Values for waterbird, native vegetation and native fish outcomes are the average change in achieving key EFRs at each breakout zone. Water volume outcomes are the percentage change in mean annual volumes during flood years. FMP = *Floodplain Management Plan*. Breakout zones from most upstream to most downstream: A Gunnedah, B Boggabri, C Tarriaro, D Glencoe, E Wee Waa, F Merah North, G Bugilbone and H Trilby Park.

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 policy is predicted to provide relatively small improvements for the majority of hydrological metrics.

The metrics which are predicted to increase the most are the median of annual volumes (flood years only) (+6.1%), total autumn flow volumes (+3.6%), total of autumn days with flow (+4.5%) and total summer days with flow (+2.4%), with greatest percentage decrease in total winter days with flow (-2%). Smaller changes were predicted for most other metrics.

The breakout zones which are predicted to have the greatest percentage change averaged across all metrics are Bugilbone (+5%), Wee Waa (+3%) and Merah North (+2%), with little to no percentage change predicted for Glencoe, Gunnedah, Boggabri, Tarriaro and Trilby Park breakout zones.

Native fish

Outcomes for three native fish guilds - flow dependent specialists (e.g. Golden Perch), generalist species (e.g. Bony Herring) and short-moderate lived floodplain specialists (e.g. Olive Perchlet) are assessed in this report. Whilst some positive outcomes are predicted at specific breakout zones, outcomes for native fish guilds are predominantly small (i.e. <5% improvement on achieving EFRs) when averaged across the floodplain. The largest change is predicted for floods occurring at the appropriate time for recruitment (+10%) and spawning (+6%) in flow dependent fish like Spangled Perch. The flow dependent specialists are likely to benefit the most from the implementation of the *policy*, however these improvements are relatively small and restricted to improvements in only 3 of 8 breakout zones: Wee Waa, Merah North, and Bugilbone. Only one EFR metric was achieved less under the *policy*, this was the timing of flows important for spawning in small-moderate floodplain specialists (-2%).

Waterbirds

There were more than 38 waterbird species predicted or recorded within the Namoi valley breakout zones. Although colonial waterbirds have been recorded within the valley, there are no major nesting sites so this assessment focussed on non-colonial waterbird outcomes. The majority of predicted waterbird outcomes in the Namoi valley were small, however some changes to the frequency of achieving flood events (3, 4, and 5 years in 10) improved in half of the breakout zones. There were also small improvements in the timing of floods important for maintaining habitats and providing breeding opportunities for non-colonial waterbirds. The breakout zone with the greatest improvement was the Wee Waa breakout zone (Figure 1), however this zone contributes less than 2% of the total volume on the Namoi floodplain. In contrast, the Merah North and Bugilbone breakouts contribute more than 50% of the flood volumes in the valley and are predicted to improve waterbird EFR achievement by 9% and 4% respectively. In summary, the *policy* is predicted to provide minimal changes for waterbirds in specific breakout zones, and only for specific flow requirements.

Native vegetation

Modelling indicates that implementation of the *policy* in the Namoi Valley will result in an overall small increase in the achievement of most EFRs for key native vegetation species when averaged across the floodplain. The *policy* is predicted to improve the number of flow days (used as substitute for inundation duration), frequency, and timing of floods, with some small improvement in the EFR achievement of the floodplain's dominant vegetation species. These include lignum, coolabah, black box, river cooba, river red gum and water couch, with lignum expected to have the greatest benefit of these species.

As with native fish and waterbirds, predicted outcomes varied across the floodplain with most improvements in EFR achievement restricted to 3 of the 8 breakout zones. This was predicted for Wee Waa (17%), Merah North (5%), and Trilby Park (5%), including some reductions in specific EFR metrics. The Wee Waa breakout zone however, contributes less than 2% of the total volume on the Namoi floodplain and can result in higher percentage increase in comparison to other breakout zones despite smaller or similar metric unit changes. Taking to account the contribution of each breakout zone and the magnitude of change, Bugilbone is expected to have a greater change for the vegetation assets within this zones. Gunnedah, Boggabri, Tarriaro and Glencoe are not predicted have any increases in in vegetation EFRs.

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 to be estimated. At present, little to no environmental benefit is detectable in some downstream floodplain breakouts. It is unclear if 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*. In 2021, the department began a multi-year project to improve return flow estimation.
- incorporate modelling of additional flow thresholds with the flood inundation models to quantify changes to flood inundation extent 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 EFRs (frequency, duration and timing) and any future management options.
- 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 and Environment – Environment and Heritage Group. This is critical to be able to measure real-world outcomes of the *policy.*

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

List of figures

List of tables

1 Introduction

In 2013, the NSW Government introduced the *NSW Floodplain Harvesting policy* (the *policy*). The *policy* is scheduled to be in place by July 2021. 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* also aligns with the objectives of the National Water Initiative, an intergovernmental commitment made by the Council of Australian Governments (COAG) 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).

1.1 Report purpose

This report considers the predicted environmental outcomes (i.e. ecological responses) to changed floodplain harvesting volumes in the Namoi valley after implementing the *policy*. It includes identification of floodplain water-dependent environmental assets and values, 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.

1.2 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 2. Identification of values (such as native fish species) and assets (such as wetlands) is described in Chapter 5. The hydrological assessment (of ecologically relevant flow statistics) is described in Chapter 6. Relating the results of the hydrological assessment with the water requirements of key environmental values and assets is described in Chapter 6.3.3.

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

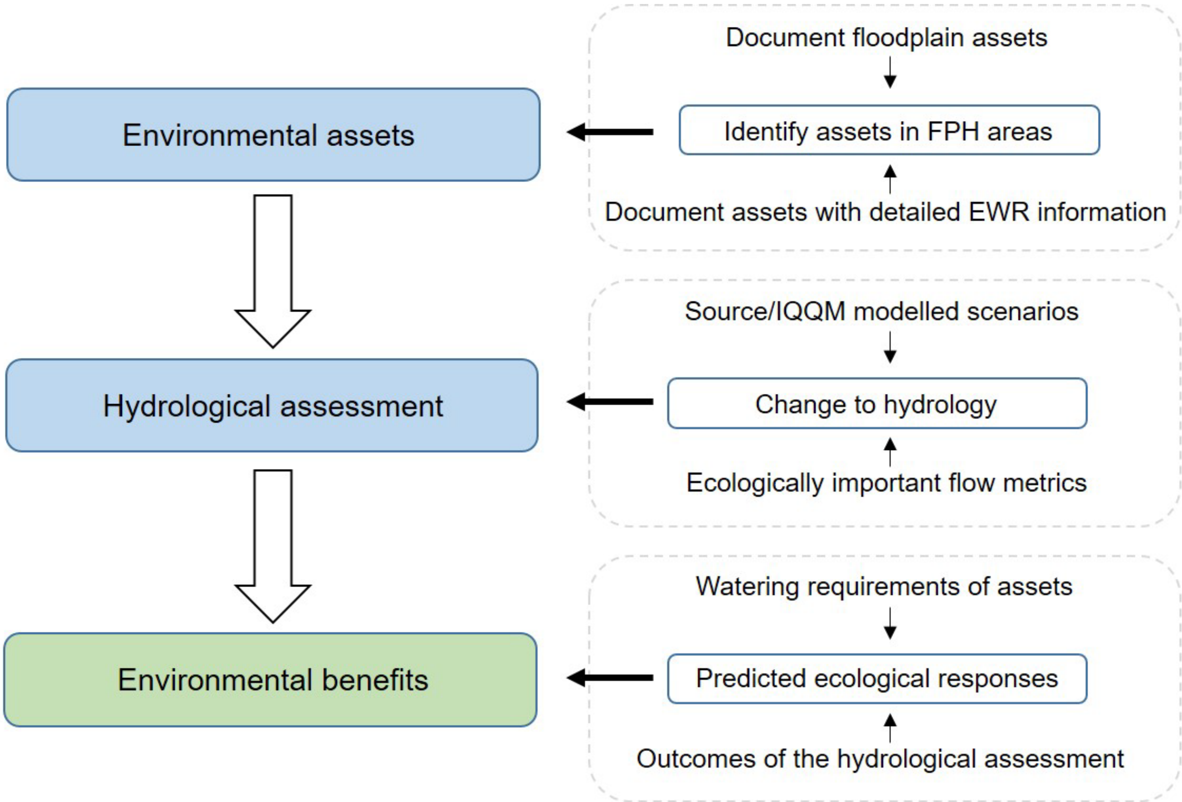

Figure 2 Summary of the approach adopted to identify the environmental outcomes of implementing the *NSW Floodplain Harvesting policy* (FPH = floodplain harvesting; Source/IQQM are river system/hydrological models).

1.3 Companion reports

This report is one of a suite of 3 reports that are prepared for each of the 5 NSW northern basin Valleys. This report describes an assessment the predicted environmental outcomes from implementing the *NSW Floodplain Harvesting Policy*.

This assessment relies on having access to a detailed river system model of the Valley, which represents the physical movements of water onto, through and exiting the Valley and 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 Namoi valley model is described in *Building the Namoi Valley river system model* (DPE Water, 2022a).

Modelling scenarios have been developed which use the river system model, with alternate parameter settings that describe the current condition and condition with the *policy* implemented. How these have been built and used to assign floodplain harvesting entitlements is described in *Floodplain Harvesting Entitlements for Namoi Regulated River System – Model Scenarios* (DPE Water, 2022b). The three reports together serve to describe how the modelling meets the objectives of the *Floodplain Harvesting policy*.

2 Floodplain harvesting in the Namoi

The Namoi (Upper and Lower) Valley floodplain is within the Namoi catchment. The Namoi floodplain extends from the Liverpool plains, becomes narrow at Narrabri and widens westward to Walget reaching the Barwon-Darling River system. The main headwater tributaries of the Namoi River are MacDonald, Manilla, Mooki and Peel Rivers and Coxs Creek, all joining Namoi River upstream of Boggabri. Three major dams regulate water flows: Keep-it Dam on the Namoi River, Split Rock Dam on the Manila River and Chaffey Dam on the Peel River. These large regulating structures capture headwater flows and reduce the magnitude, frequency and timing of downstream overbank flooding (Leigh and Sheldon 2008).

The Namoi Valley has some of the most fertile and productive agricultural lands in the state, representing about 1% of NSW regional product per year (DOI Water 2019). Completion of Keep-it Dam in 1960 provided a regulated water supply that intensified irrigation development (Department of Infrastructure, Planning and Natural Resources (DIPNR 2003). Currently, more than 165,000 hectres of the Namoi floodplain is enclosed by legal floodplain works. These floodplain works include levees, earthworks, banks and channels that act to protect crops, stock and properties from flooding; provide on-farm access; and to manage irrigation, stock and domestic water. These works affect the distribution of floodwater flow on the floodplain and are collectively termed floodworks (DOI Water 2018, 2019). By the 1970s, major flood events demonstrated that the increase in uncoordinated floodworks had already changed traditional flooding patterns (Burton et al. 1994).

A key part of the Healthy Floodplains Project involves the development of valley-wide floodplain management plans for designated floodplains 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 Floodplain Management Plans for the Upper & Lower Namoi Valley Floodplain were published in June 2019 and September 2020 respectively.

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. The portion of FPH diversions within the BDL for the Namoi valley is approximately 46.5 GL, which includes runoff harvesting and overbank flow harvesting. These diversions are currently around 51.3 GL which is 4.8 GL (9.4%) over the BDL. The implementation of the *policy* will bring the average annual diversions back in line with the BDL.

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 licenced individuals. The *policy* ensures that "*share components for individual floodplain harvesting access licences in regulated river water sources will be determined in two steps:*

1. *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.*
2. *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)

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 3 Map of the floodplain management zones set out in the (draft) *NSW Lower and Upper Floodplain Management Plan. Only* floodplain harvesting properties eligible for floodplain harvesting access licences are shown. FMP= Floodplain Management Plan shows the designated Namoi 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 Chapter 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 Chapter 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 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 Namoi valley floodplain, 219 of the 269 applications for floodplain harvesting access were deemed eligible (DPIE Water, 2019).

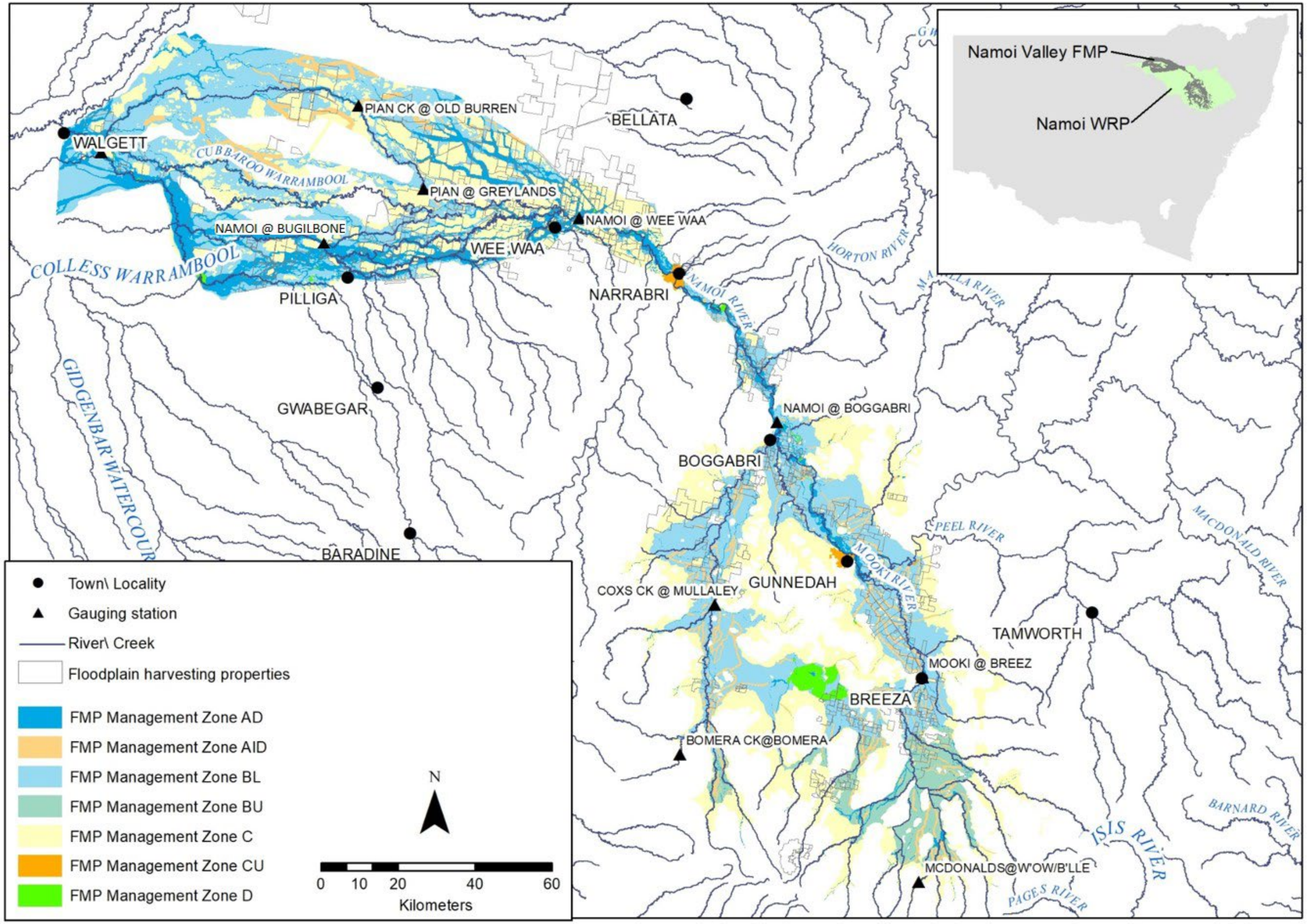

Figure 3 Map of the floodplain management zones set out in the *Floodplain Management Plan for the Lower Namoi* and *Upper Namoi Valley. Only* floodplain harvesting properties eligible for floodplain harvesting access licences are shown. FMP= Floodplain Management Plan

3 Environmental assets and values on the floodplain

3.1 Overview of known assets and values

The Namoi Valley floodplain is characterised by wetland and lagoon complexes. These wetlands include intermittently connected anabranches and floodplain pools (lagoons, waterholes, and billabongs) which support an array of water-dependent environmental values. These values include native fish, native vegetation, waterbirds, frogs, reptiles, macroinvertebrates, important ecosystem functions (e.g. productivity) and location specific assets such as state listed important lagoons (DOI Water, 2018, 2019a). A full list of known environmental values in the Namoi Valley floodplain, and key geographical assets, is provided in Appendix A and summarised below.

3.1.1 Native fish

All of the 16 native fish species found in the Namoi Valley are recorded or predicted to occur in the various anabranches, floodplain pools and wetlands of the Namoi floodplain (DOI Water, 2019b, 2020). This includes common species like bony bream (*Nematalosa erebi*) and spangled perch (*Leiopotherapon unicolor*) which colonise floodplain habitats after inundation, and provide food for aquatic (e.g. turtles) and terrestrial predators (e.g. waterbirds). Floodplain habitats are also significant for golden perch (*Macquaria ambigua ambigua*), a flow responsive fish which moves on medium to high flows and has recently been found by the department in several Namoi floodplain pools. Floodplain flows also provides critical food resources, drought refuge sites, and habitat for native fish on the floodplain, but also through return flows back into the river channel.

In addition to supporting common native fish, floodplain flows, return flows to rivers, and flood habitats are important for threatened species. For example, those listed under federal legislation, like the Silver Perch (*Bidyanus bidyanus*) and Murray Cod (*Maccullochella peelii*) (*Environment Protection and Biodiversity Conservation Act 1999*), as well as the state-listed endangered Southern Purple Spotted Gudgeon (*Mogurnda adspersa*), Eel-tailed Catfish (*Tandanus tandanus*; Murray-Darling Basin), Flathead galaxias (*Galaxias rostratus*) and endangered populations of Olive Perchlet (*Ambassis agassizii*; Western Population) (*Fisheries Management Act 1994*).

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 of the Namoi floodplain include river red gum (*Eucalyptus camaldulensis*), coolabah (*Eucalyptus coolabah*), lignum (*Muehlenbeckia florulenta*), river cooba (*Acacia stenophylla*) and river oaks (*Casuarina cunninghamiana*) (DOI Water, 2018, 2019a; DPIE-EES, 2020a)

3.1.3 Waterbirds

Waterbirds are a group of highly mobile species that can respond to floods over large spatial scales. There are more than 40 species of waterbirds either recorded or predicted to occur in the Namoi Floodplain. A number of these species are listed as endangered under the *NSW Biodiversity*

Conservation Act 2016, like the Black-necked stork (*Ephippiorhynchus asiaticus)* and Australian Bittern (*Botaurus poiciloptilus*) (Figure 4). Internationally important species have also been recorded in the floodplain, including the Latham's snipe (*Gallinago hardwickii*) and pacific golden plover (*Pluvialis fulva*) (DPIE-EES, 2020a).

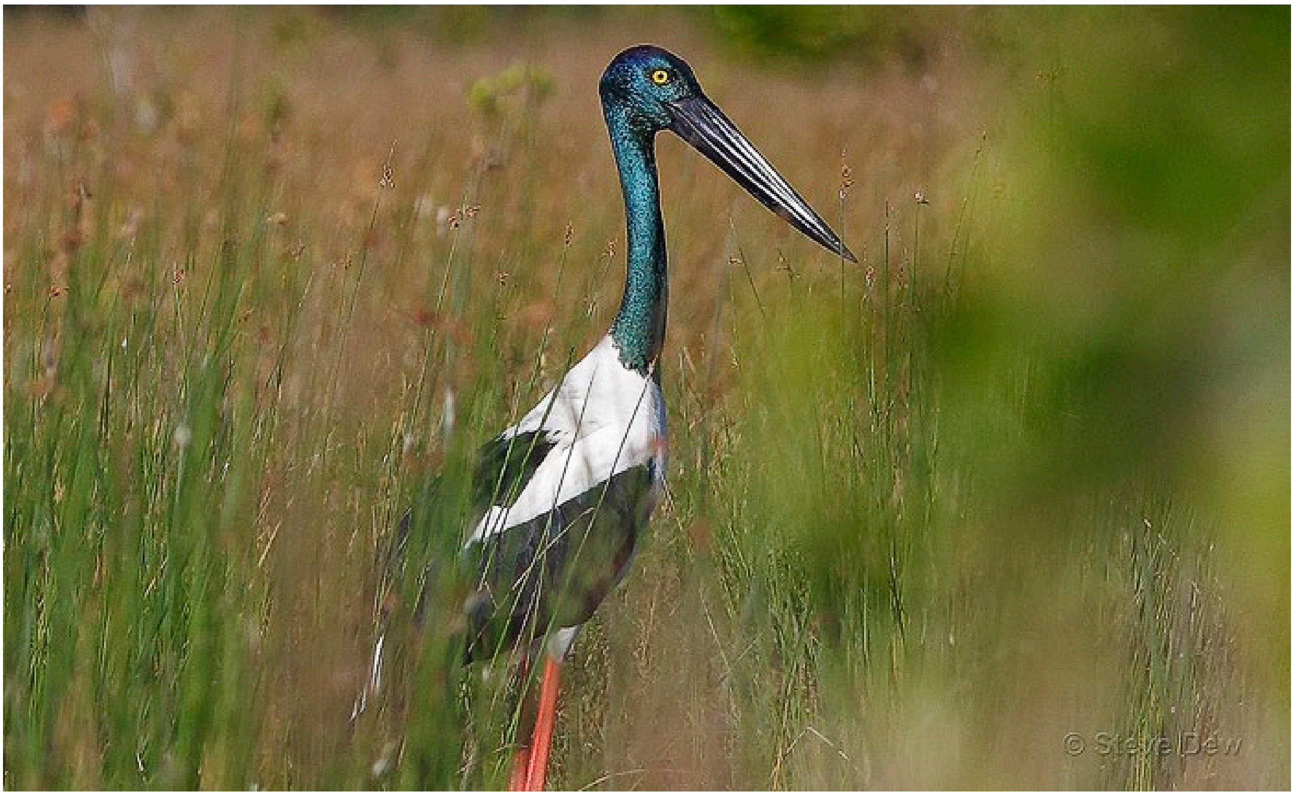

Figure 4 The Black-necked stork, the only stork found in Australia, has been recorded in the Namoi floodplain and is listed as endangered in NSW under the *NSW Biodiversity Conservation Act 2016* [Image: Steve Dew; flickr.com]

3.1.4 Frogs and reptiles

The Namoi valley floodplain provides habitat for flood dependant frogs, turtles and amphibious reptiles (Appendix A). There are at least 12 species of frogs that are known to occur in the Namoi floodplain (DOI Water, 2018, 2019a). Seven of these are considered to have strong flood associations include the eastern sign-bearing froglet (*Crinia parinsignifera*), Broad-palmed frog (*Litoria latopalmata*) and salmon striped frog (*Limnodynastes salmini*) (DOI Water, 2018, 2019b). Water-dependent reptiles include the Eastern water skink (*Eulamprus quoyii*) and four species of freshwater turtle.

3.1.5 Wetlands

A nationally important wetland system, noted for providing an important bird habitat, is situated in the Namoi catchment to the south of Gunnedah – Lake Goran (DPIE-EES, 2020a). Other significant lagoons and wetlands have been identified in the *Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources 2020*. These wetlands support a wide range of aquatic species through the provision of aquatic habitats and drought refugia.

3.1.6 Ecosystem functions

A variety of ecosystem functions are linked to floodplain inundation. One of the key functions supported by overbank flood events is increased productivity for the floodplain and the connected riverine environment (McGinness and Arthur 2011). The Namoi River system provides a wide range of aquatic habitats and is ecologically important. The floodplain downstream of Narrabri contains large areas of anabranches and billabongs. When flooded these areas are considered to be important and work on similar rivers has established they provide large amounts of dissolved organic carbon, which is essential to aquatic ecosystem functioning (CSIRO 2007).

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 linked to a breakout zones with the predicted ecological responses of assets in that 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 6), broad scale outcomes will be explored where feasible.

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

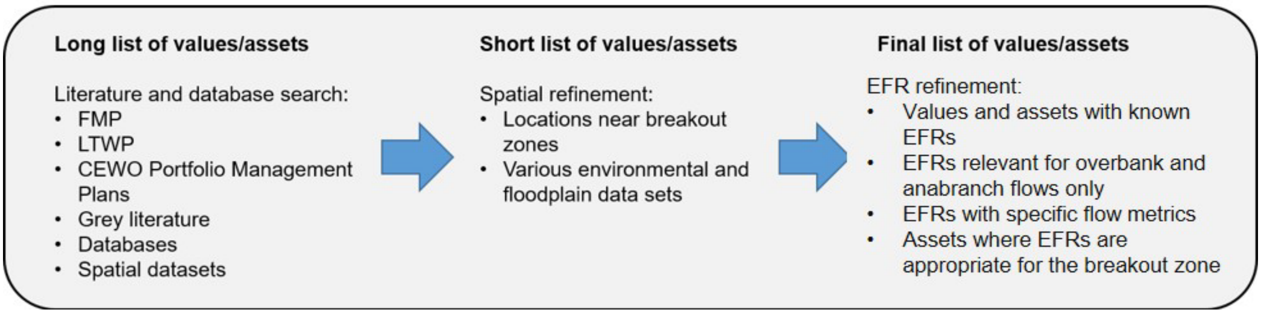

Figure 5 Summary of the approach adopted to identify water-dependent environmental values and assets in floodplain harvesting areas. FMP = Floodplain Management Plan, LTWP = Long-term water plans, CEWO = Commonwealth Environmental Water Office, EFR = environmental flow requirement

3.2.1 Literature and database search

A literature and database search were undertaken to identify water-dependent environmental values and assets in the Namoi Valley Floodplain (Appendix A). The search included species, populations, communities, and specific breakout zones (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 *Floodplain Management Plan for the Lower & Upper Namoi Valley Floodplain* (DOI Water, 2018, 2019a)
- Namoi Long-Term Water Plan (DPIE-EES, 2020a b)
- Environmental Values and Watering Priorities for the Northern Murray Darling Basin (SKM 2009)
- Risk assessment for the Namoi water resource plan area (DPIE-Water, 2019)
- 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 Namoi Valley Floodplain Management Plan boundary.

3.2.2 Spatial refinement

The next step involved identifying those environmental values and assets that occurred within a defined spatial area near the 'breakout zones'[2] as characterised in the river system model. 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 Chapter 4, with more detail in (DPE Water, 2022a).

Breakout zones are areas of the floodplain where floodwaters break out onto the floodplain and where floodplain harvesting properties access water on the floodplain (Figure 6). The river system model has configured 17 high flow breakouts, grouped into 8 'breakout zones', associated with a variety of flood runners, anabranches and direct take from the river channel. The end of system (EOS) floodplain breakout represents the breakout zones where most of the changes to floodplain hydrology can be detected within the DPIE Water river system models.

[2] Refer to Appendix D of *Building the Namoi Valley river system model* (DPIE Water 2022a) for a description of the derivation of these breakout zones.

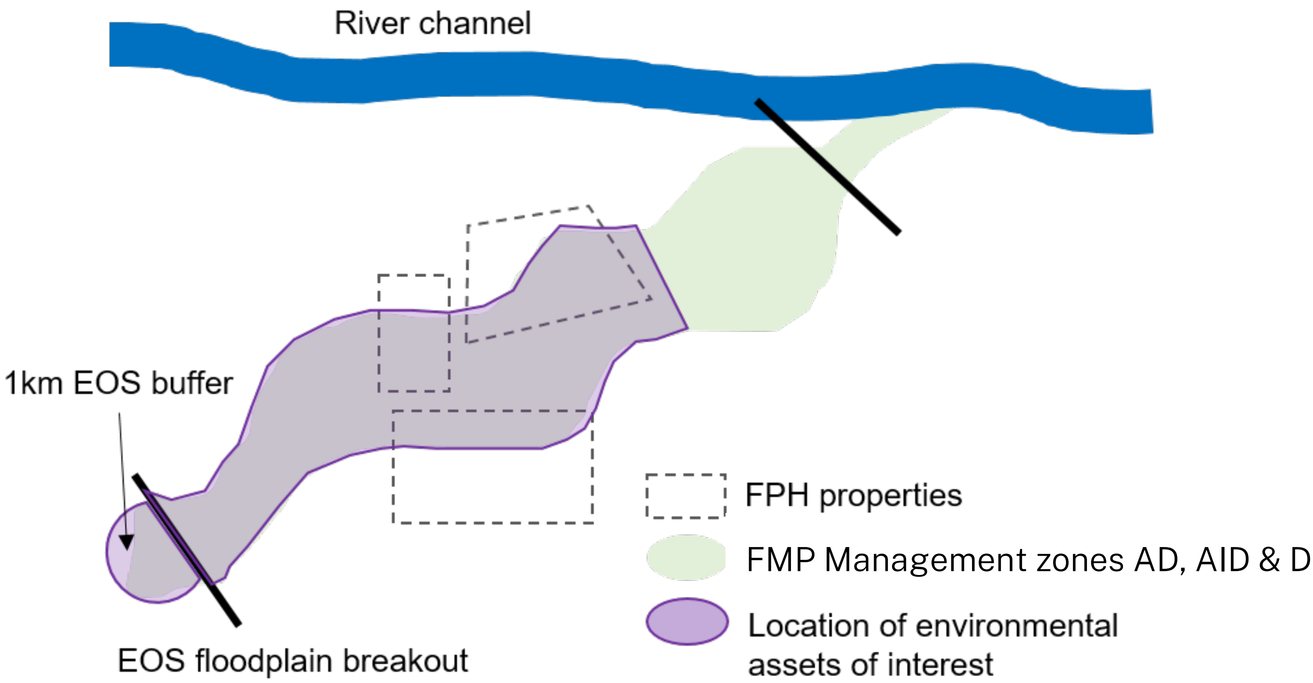

Figure 6 Illustrated depiction of a 'breakout zone'. Breakout zones represent areas where flood waters break out from the river channel onto the floodplain and floodplain harvesting occurs

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 at the asset). The Namoi Valley floodplain was split into 8 breakout zones.

The breakout zone, or area of interest, was then further refined[3] to select environmental assets and values which occurred with important *Namoi Valley Floodplain Management Plan* (FMP) management zones. FMP Zone AD signifies a major flood discharge zone and is of significant importance to floodplain assets, including semi-permanent wetlands. Zones AD & AID are important for flood-dependent woodlands/forests and shrublands and fish passage. Zone D included ecological and cultural assets that have high flood dependency. Environmentally sensitive area providing critical refugia and supporting areas of environmental significance such as swamps, billabongs, rocky bars or warrambools[4]. Culturally significant site could include Aboriginal areas of spiritual significance, resource-use value and heritage registered sites. All three zones also support areas of significant cultural importance (DOI Water, 2018, 2019a) . Assets that fell within Zone AD, AID or Zone D within each breakout zone were short-listed for assessment, refining the number of environmental assets. Figure 8 summarises the spatial and EFR refinement process.

Important assets and values most likely also occur in the other *Floodplain Management Plan* 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

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[3] ArcGIS (10.3.1) was used for this task

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

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.

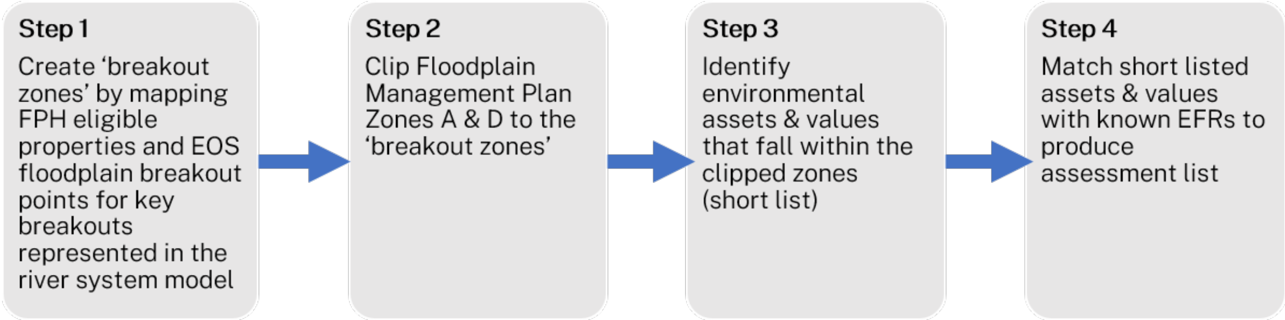

Figure 7 The spatial and EFR refinement process to select environmental assets and values for assessment

3.2.3 Environmental Flow Requirement refinement

The last step (Step 4 in Figure 7) was to identify environmental values on the short list with known and measurable EFRs documented in the literature. Understanding the EFRs 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 EFRs 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 EFRs.

Refining the list based on environmental values with known EFRs provided a robust approach for predicting the environmental outcomes of implementing the *policy* (Section 5). As not all values, i.e. species 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 EFRs across the Murray-Darling Basin. It recognises that providing flows for values with detailed EFR information (e.g. river red gum) should reflect the needs of a broader set of assets and values in the area. The detailed environmental flow requirements for the Namoi 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 a high confidence that the river system model could be used to predict changed hydrological regimes which impact EFRs.

High level descriptions for assets and values were identified (Table 1) and used to describe the final list of assets and values to be assessed in each of the 8 breakout zones on the floodplain (listed in Table 2). These occur from downstream of the town Breeza and supports a suite of environmental assets and values including threatened plants, animals, communities and functions. The critical components of each asset's EFRs are detailed in Appendix C.

Figure 8 depicts the breakout zones, eligible floodplain harvesting properties and hydrological gauges. Figure 9 to Figure 12 provide fine scale maps of key water-dependent environmental assets and values in each breakout zone. 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 1 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

Table 2 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]NSW Biodiversity Conservation Act 2016, [2]listed on the EPBC Act, [3]listed in the Fisheries Management Act (1994).

Breakout	Key breakout points	Asset/Value characterisation	
(A) Gunnedah	Gunnedah to EOS breakout: d/s Mooki rv weirris crk confluence, Mooki rv and Namoi Rv confluence	Native fish	**Recorded:** Murray cod (V)[2], silver perch (V)[2], bony herring, golden perch, carp gudgeon, Australian smelt, freshwater catfish, Murray-Darling rainbowfish, spangled perch, **Predicted:** olive perchlet (E)[3]
		Waterbirds	**Colonial-nesting:** Australasian darter, Australian pelican, Eastern great egret, little black cormorant, little pied cormorant, nankeen night heron, pied cormorant, straw-necked ibis, white-faced heron, white-necked Heron, yellow-billed spoonbill, Brogla (v) **Non-colonial:** Azure kingfisher, sacred kingfisher, grey teal, Pacific black duck, Australian wood duck, black swan, fork-tailed swift, black-fronted dotterel, masked lapwing
		Native vegetation	Lignum shrubland wetland, river coobah, river red gum
(B) Boggabri	Boggabri to EOS: u/s Coxs crk to Namoi rv confluence, Deadmans Gully, Barbers lagoon	Native fish	**Recorded:** Murray cod (V)[2], silver perch (V)[2], bony herring, golden perch, carp-gudgeon, Australian smelt, freshwater catfish, Murray-Darling rainbowfish, spangled perch, unspecked hardyhead **Predicted:** Olive perchlet (E)[3]
		Waterbirds	**Colonial-nesting:** Australasian darter, Australian pelican, Australian white ibis, Eastern great egret, glossy ibis, great cormorant, little pied cormorant, nankeen night heron, straw-necked ibis, white-faced heron, white-necked heron, yellow-billed spoonbill **Non-colonial:** Latham's snipe (J,K), sacred kingfisher, grey teal, Pacific black duck, Hardhead, Australian wood duck, plumed whistling duck, pink-eared duck, black swan, black-fronted dotterel, masked lapwing, hoary-headed

Breakout	Key breakout points	Asset/Value characterisation	
			grebe, Australian grebe, Eurasian coot, dusky moorhen, black winged stilt
		Native vegetation	Coolabah, river coobah, river red gum, water couch
(C) Tarriaro	u/s Tarriaro to EOS: d/s Boggabri weir site, confluence of Maules crk and Bibbla crk at Namoi Rv	Native fish	**Recorded:** Bony herring, flathead galaxias, golden perch, Murray cod (V)[2], carp-gudgeon, Australian smelt, freshwater catfish, Murray-Darling rainbowfish, spangled perch, unspecked hardyhead **Predicted:** Olive perchlet (E)[3], silver perch (V)[2]
		Waterbirds	**Colonial-nesting:** Australasian darter, Eastern great egret, white-necked heron, white-faced heron, black-necked stork, Australian pelican, little pied cormorant, great cormorant, little black cormorant, pied cormorant, yellow-billed spoonbill, royal spoonbill, glossy ibis, straw-necked ibis **Non-colonial:** Azure kingfisher, sacred kingfisher, grey teal, Australian shoveler, Pacific black duck, hardhead, Australian wood duck, black swan, wandering whistling duck, plumed whistling duck, pink-eared duck, white-throated needletail, masked lapwing, banded lapwing, whiskered tern, tern, small grebe, Eurasian coot, blacked-winged stilt, red-necked avocet
		Native vegetation	River coobah, river red gum, water couch
(D) Glencoe	EOS to floodplain: u/s Glencoe, floodplain floodway to Dundee weir	Native fish	**Recorded:** Murray cod (V)[2], Australian smelt, bony herring, golden perch, unidentified carp-gudgeon, spangled perch **Predicted:** Olive perchlet (E)[3], Eel-tailed catfish – MDB population (E)[3]
		Waterbirds	**Colonial-nesting:** Magpie goose (V,P)[2]
		Native vegetation	Black box, coolabah, river coobah, lignum, river red gum, water couch
(E) Wee Waa	EOS to floodplain: Mollee crk and Bundock crk confluence	Native fish	**Recorded:** Australian smelt, bony herring, golden perch, unidentified carp-gudgeon, Murray cod (V)[2], Murray-Darling rainbowfish, silver perch(V)[2], spangled perch
		Waterbirds	**Colonial-nesting:** Pacific black duck
		Native vegetation	Coolibah, river coobah, lignum, river red gum, water couch
(F) Merah North	EOS to floodplain break: d/s Naomi Rv and Pian Crk bifurcation	Native fish	**Recorded:** Australian smelt, bony herring, golden perch, carp-gudgeon, Murray cod (V)[2], Murray-Darling rainbowfish, silver perch(V)[2], spangled perch, unspecked hardyhead **Predicted:** Olive perchlet (E)[3], Eel-tailed catfish – MDB population (E)[3], purple-spotted gudgeon
		Waterbirds	**Colonial-nesting:** Australasian darter, Australian pelican, intermediate egret, little black cormorant, white necked heron, white faced heron, black-necked stork, **Non-colonial:** Sacred kingfisher, blue-billed duck, freckled duck, Lewin’s rail
		Native vegetation	Coolibah, river coobah, lignum, river red gum, water couch

Breakout	Key breakout points	Asset/Value characterisation	
(G) Bugilbone	EOS to EOS breakout: Myall camp warrambool, Drildool warrambool, Naomi Rv	Native fish	**Recorded:** Australian smelt, bony herring, golden perch, carp-gudgeon, Murray cod (V)[2], Murray-Darling rainbowfish, silver perch(V)[2], spangled perch **Predicted:** Olive perchlet (E)[3], Eel-tailed catfish – MDB population (E)[3]
		Waterbirds	**Colonial-nesting:** Australasian darter, Australian pelican, intermediate egret, little black cormorant, white necked heron, white faced heron, black-necked stork, **Non-colonial:** Sacred kingfisher, blue-billed duck, freckled duck, Lewin's rail
		Native vegetation	Black box, coolabah, river coobah, lignum, river red gum, water couch
(H) Trilby Park	EOS breakout to floodplain: u/s Walgett, confluence of Cubbaroo Warrambool, Cumberdoon warrambool, Pian Crk and Namoi River	Native fish	**Predicted:** Olive perchlet (E)[3], silver perch (V)[2]
		Waterbirds	**Colonial-nesting:** Australasian darter, little black cormorant, little pied cormorant, white-faced heron **Non-colonial:** Sacred kingfisher, grey teal, Pacific black duck, Australian wood duck,
		Native vegetation	Black box, coolabah, river coobah, lignum, river red gum

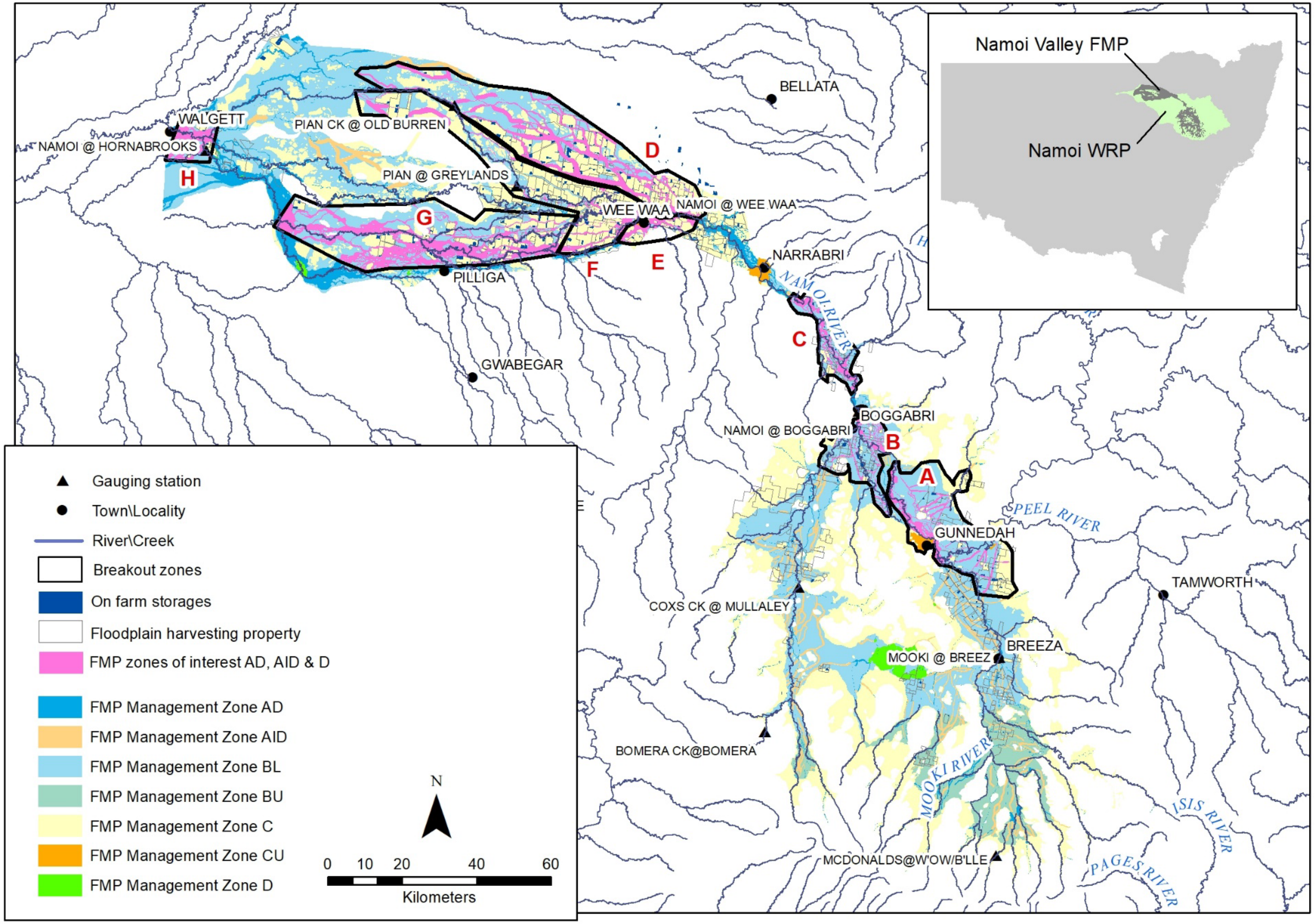

Figure 8 Map of the Namoi floodplain showing the Floodplain Management Plan (FMP) zones and the zones of interest used to select environmental assets and values for inclusion in this assessment. Breakout zones from most upstream to most downstream: A Gunnedah, B Boggabri, C Tarriaro, D Glencoe, E Wee Waa, F Merah North, G Bugilbone and H Trilby Park.

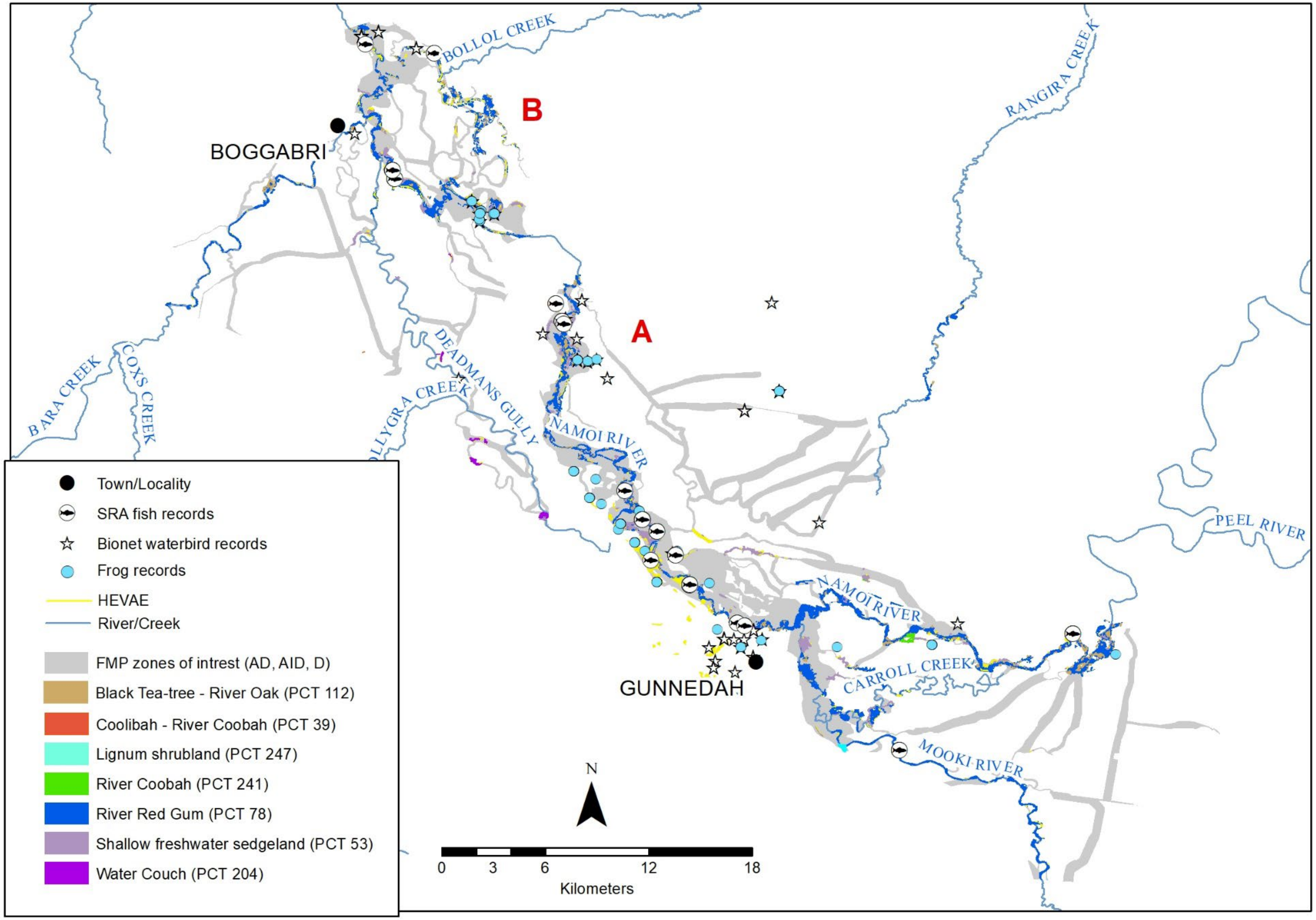

Figure 9 Location of selected water-dependent environmental assets and values at breakout zones A Gunnedah, B Boggabri. Appendix B details for all data sources including those that were not able to be presented.

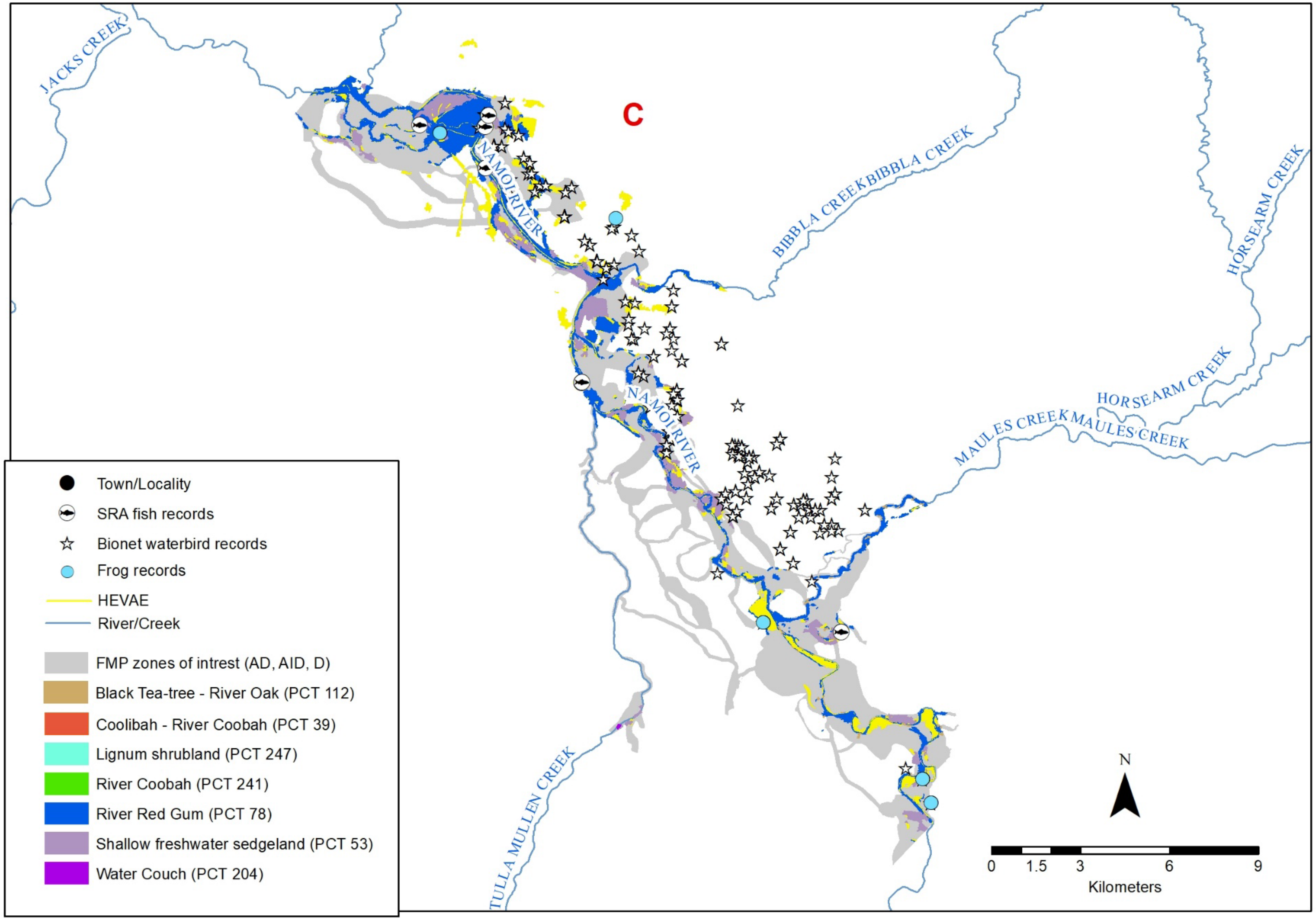

Figure 10 Location of selected water-dependent environmental assets and values at breakout zones C Tarriaro. Appendix B details for all data sources including those that were not able to be presented.

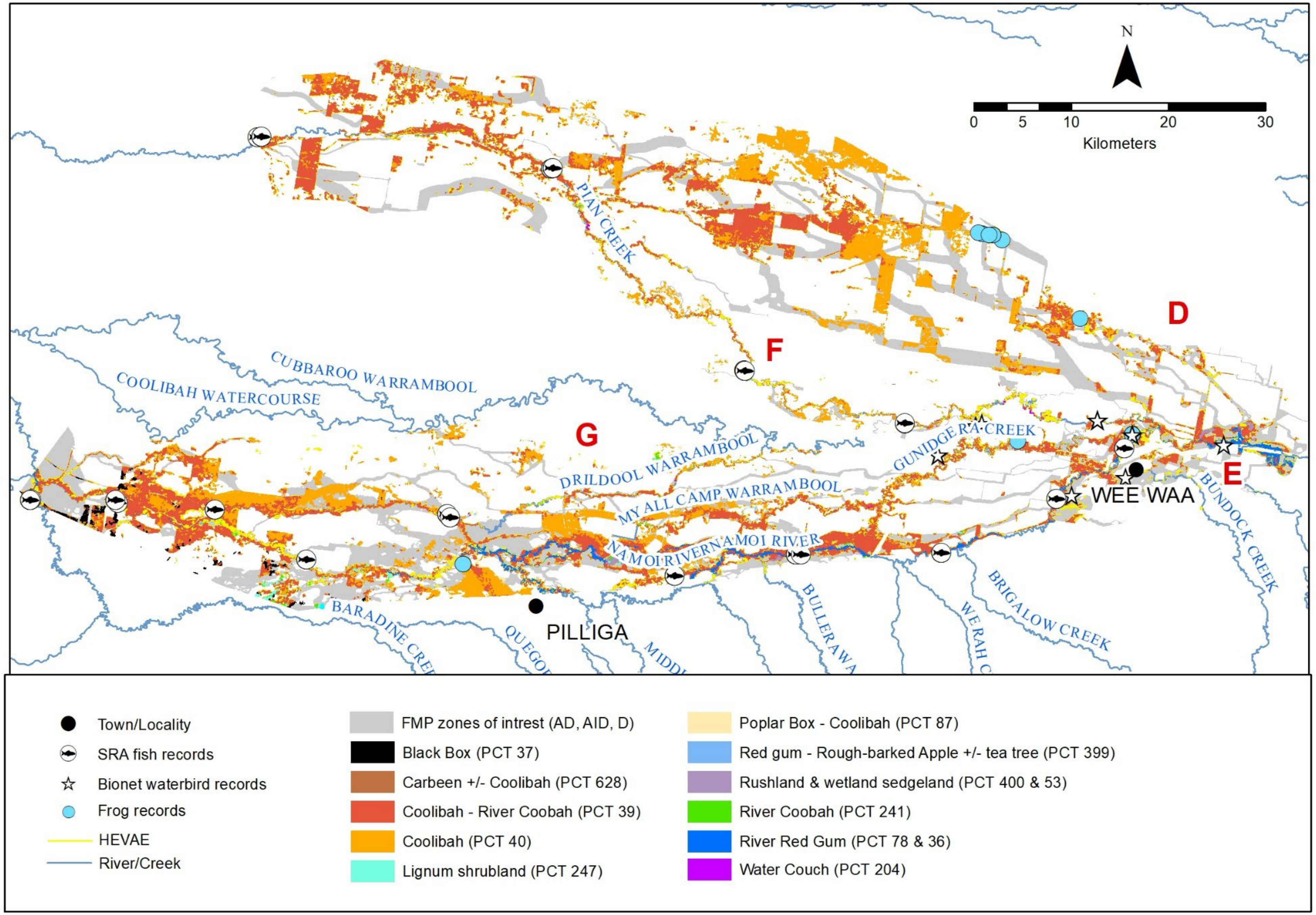

Figure 11 Location of selected water-dependent environmental assets and values at breakout zones D Glencoe, E Wee Waa, F Merah North, G Bugilbone. Appendix B details for all data sources including those that were not able to be presented.

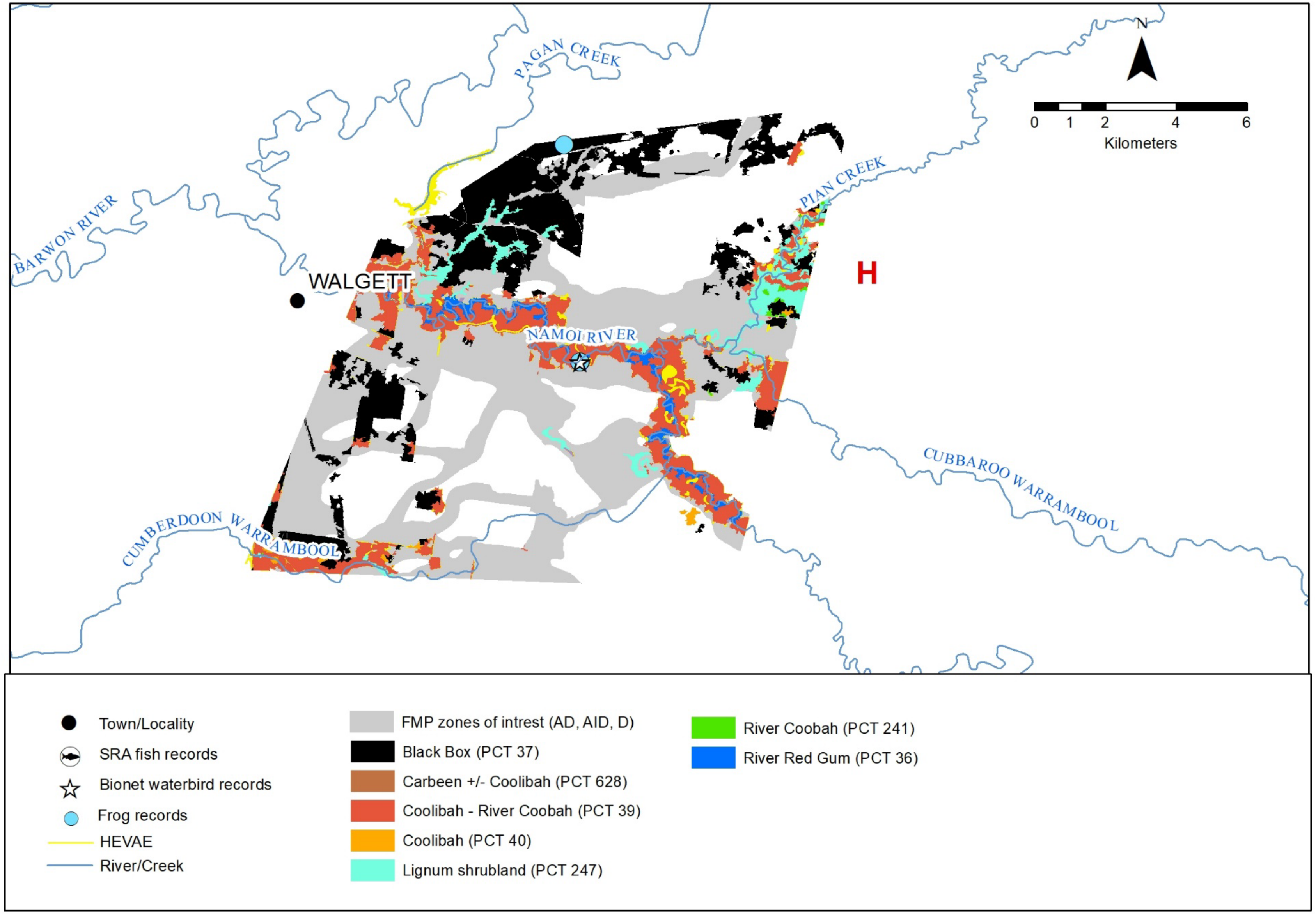

Figure 12. Location of selected water-dependent environmental assets and values at breakout zone H Trilby Park. Appendix B details for all data sources including those that were not able to be presented

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 chapter provides a broad overview of the river system models developed by DPIE Water. Further information can be found for each model in the companion Model Build reports for each Valley (e.g. *Building the river system model for the Namoi Valley regulated river system* (DPE Water, 2022a).

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 Namoi Valley Model is designed to support contemporary water management decisions in the Namoi 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 Namoi Valley river system 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, and
- reporting points, such as gauges and environmental assets.

Links 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 (DPE Water, 2022a). 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, and
- 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 (e.g. days, years etc) 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 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 Namoi Valley model validation process is set out in the Model Build report (DPE Water, 2022a).

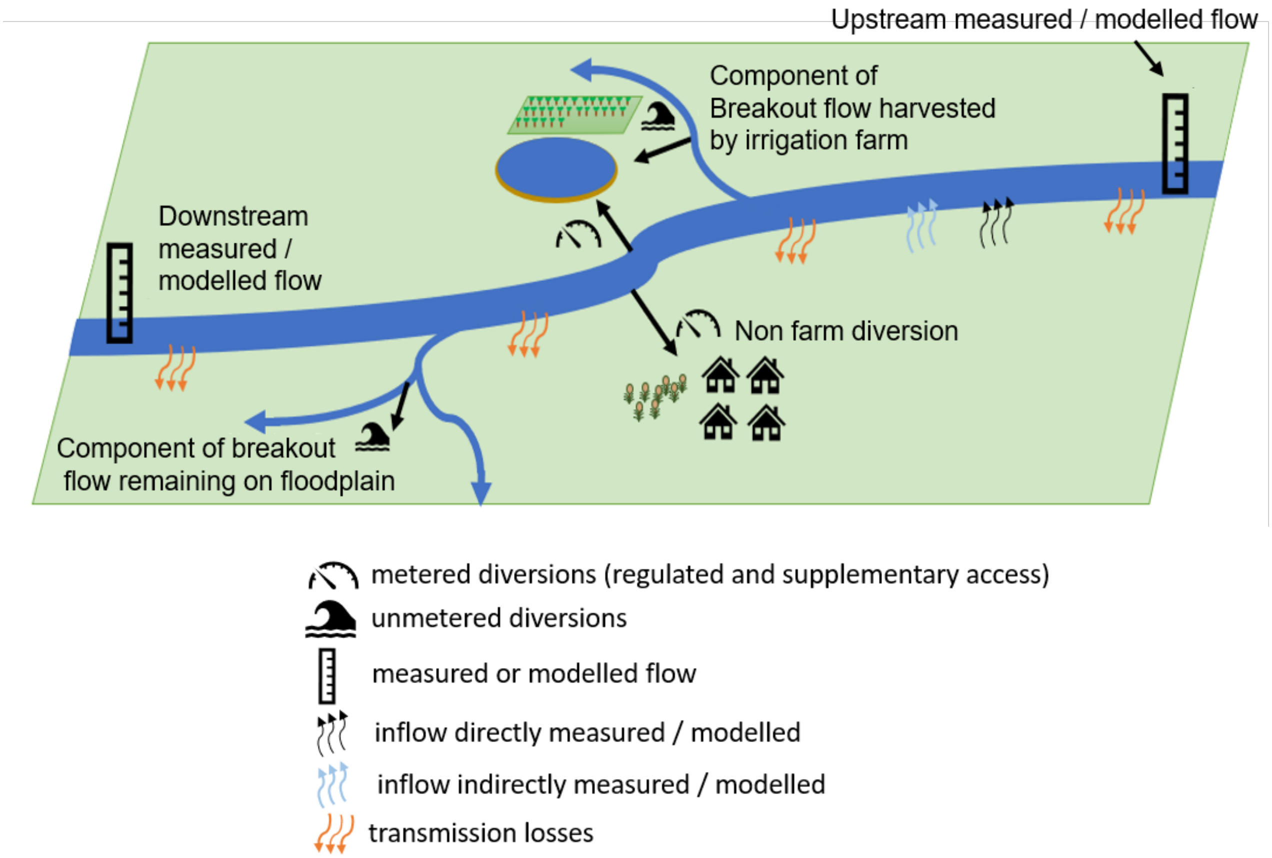

Figure 13 Reach water balance components [Source: Figure 3, DPE Water, 2022s]

The final step involves developing and running different simulated scenarios. Managed river system scenarios includes 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" (DPE Water, 2022b).

These scenarios are detailed in the companion Scenarios report (DPE Water, 2022b).

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

- a *splitter node*[5] (to create the overbank water)
- a few additional nodes (e.g. to stop off allocation water going down the breakout, to represent the virtual storage)
- 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 6 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 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) (via a Source splitter node) to floodplain breakout zones, and an end-of-system (EOS) reporting node (using a Source gauge, called the breakout EOS Node). A schema is provided in Figure . More details on the modelling are provided in Appendix D and the companion Model Build and Scenarios reports (DPE Water, 2022a b).

All modelled flow data covered the period from 1895 to 2020.

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[5] A node type provided in the modelling platform. Modelling terms are identified in this report by blue italics.

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 & Sheldon, 2008). The strength of an environmental response is often proportional to the magnitude and duration of a flood (Kingsford & Auld, 2005; 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 & 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 & Auld, 2005). Reduced rates of rise and increased rates of fall can also reduce environmental benefits, especially during breeding events for waterbirds (Kingsford & Auld, 2005; Kingsford, Lau & O'Connor, 2014).

The timing (e.g. seasonality and frequency) of floods is also critical to achieving a range of ecological outcomes (Robertson, Bacon & Heagney, 2001; Kingsford *et al.*, 2014; NSW Department of Primary Industries, 2015; DPIE EES, 2020). 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 3. 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; while **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, Sheldon & Puckridge, 1995; Leigh & 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 annual median of days with flow was only calculated in years where the days with flow exceeded 1 ML/day. Zero flows were included in the calculation when one scenario had a flow above this threshold and the other scenario did not. This ensured that more flood events in one scenario did not reduce the annual median of days with flow compared to the other scenario with less flood events.

Table 3 Hydrological feature, period of interest and hydrological metrics adopted to describe magnitude and duration of flood events. Seasonality (timing), frequency and variability are incorporated into each hydrological feature. 1S = summer, A = autumn, W = winter, Sp = spring

Hydrological feature	Period of interest	Flow metric	Reasoning
Magnitude	Inter-annual	Mean and median 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 flood 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 flood 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 3 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 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 3 were calculated for each modelled flow series[6]. 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.

[6] The Time Series Analysis module of the River Analysis Package (RAP) software (Marsh, Stewardson & Kennard, M.J., 2003) and Microsoft Excel 2016 were used for this task.

A comparison of results for the EOS floodplain breakout under these two scenarios was undertaken for the period 1895 to 2020 (Figure 14). The Plan Limit 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 2020. 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 D.

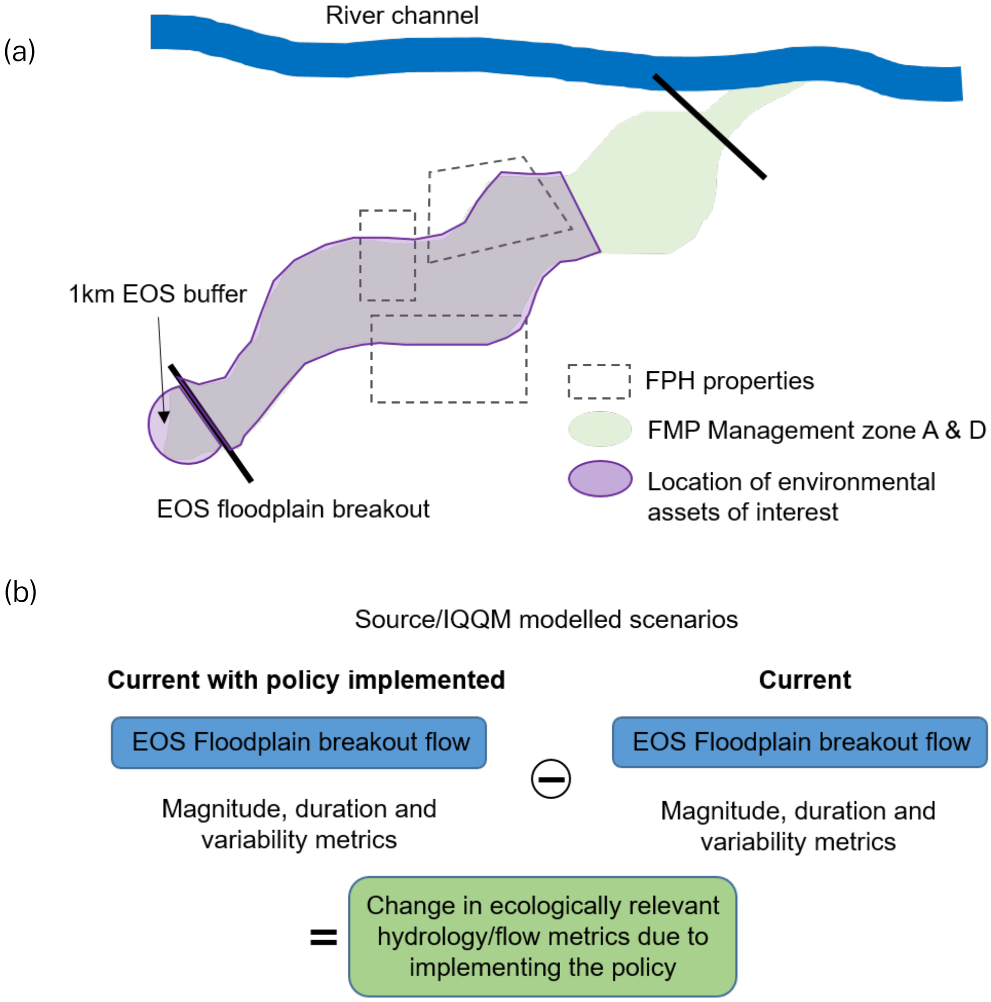


Figure 14 Diagram showing the relevance of the river system model end of system (EOS) floodplain breakout (a) to environmental assets and values and how this model breakout (b) was used to identify changes to floodplain hydrology

4.3 Hydrological outcomes

4.3.1 Modelled floodplain hydrology in the Namoi

This section summarises the temporal (over 125 years) and spatial (8 breakout zones) **distribution of floodwater** in the Namoi valley with the *policy* implemented. The **high level quantification of the significance of each breakout zone** can be used to interpret the relative (%) changes in subsequent sections of this report.

The **total volume** of water remaining on the floodplain or returning to the river is in excess of 30,000 GL across 125 years (Table 4). More than 70% of this water is coming from the Glencoe (D) (27.5%), Merah North (F) (26.2%) and Bugilbone (G) (17.7%) breakout zones. Merah North (F) and Bugilbone (G) also receive the most events across 125 years, with 109 and 107 events respectively. The fourth most significant breakout zone is Trilby Park (H), which receives infrequent floods (38 in 125 years), but the largest median volume (82.6 GL).

Whilst improvements from implementing the *policy* is important across all areas of the floodplain, relative changes in the **Glencoe (D), Merah North (F), Bugilbone (G)** and **Trilby Park (H)** breakout zones could be considered the most significant due to their larger contribution to flood volume, frequency and flow duration in the Namoi valley (Table 4, Table 6).

Table 4 Hydrological summary of the total volume, mean annual volume, median annual volume, total days with flow, total number of years with at least one event, and total number of events across the Namoi valley, and within each breakout zone over the 125 year modelled period. The data presented represent the outcomes with the *policy* in place. The percent of Namoi valley volume indicates the relative contribution of each breakout zone to the Namoi valley as a whole.

Breakout zone	Percent of Namoi valley volume	Total volume (GL)	Mean annual volume (GL)	Median annual volume (GL)	Total days with flow	Total number of years with 1 or more events	Total number of events
(A) Gunnedah	6.9	2,094.7	123.2	35.6	257	18	22
(B) Boggabri	5.1	1,537.4	32.0	2.1	626	49	87
(C) Tarriaro	4.3	1,302.5	42.0	19.8	370	32	46
(D) Glencoe	27.5	8,354.6	208.9	20.7	322	41	67
(E) Wee Waa	1.3	388.3	19.4	7.4	206	21	32
(F) Merah North	26.2	7,934.9	149.7	56.2	857	54	109
(G) Bugilbone	17.7	5,358.5	99.2	57.8	1199	55	107
(H) Trilby Park	11.1	3,371.3	116.3	82.6	828	30	38
Namoi valley total	100%	30,342.2					

4.3.2 Changes to floodplain hydrology

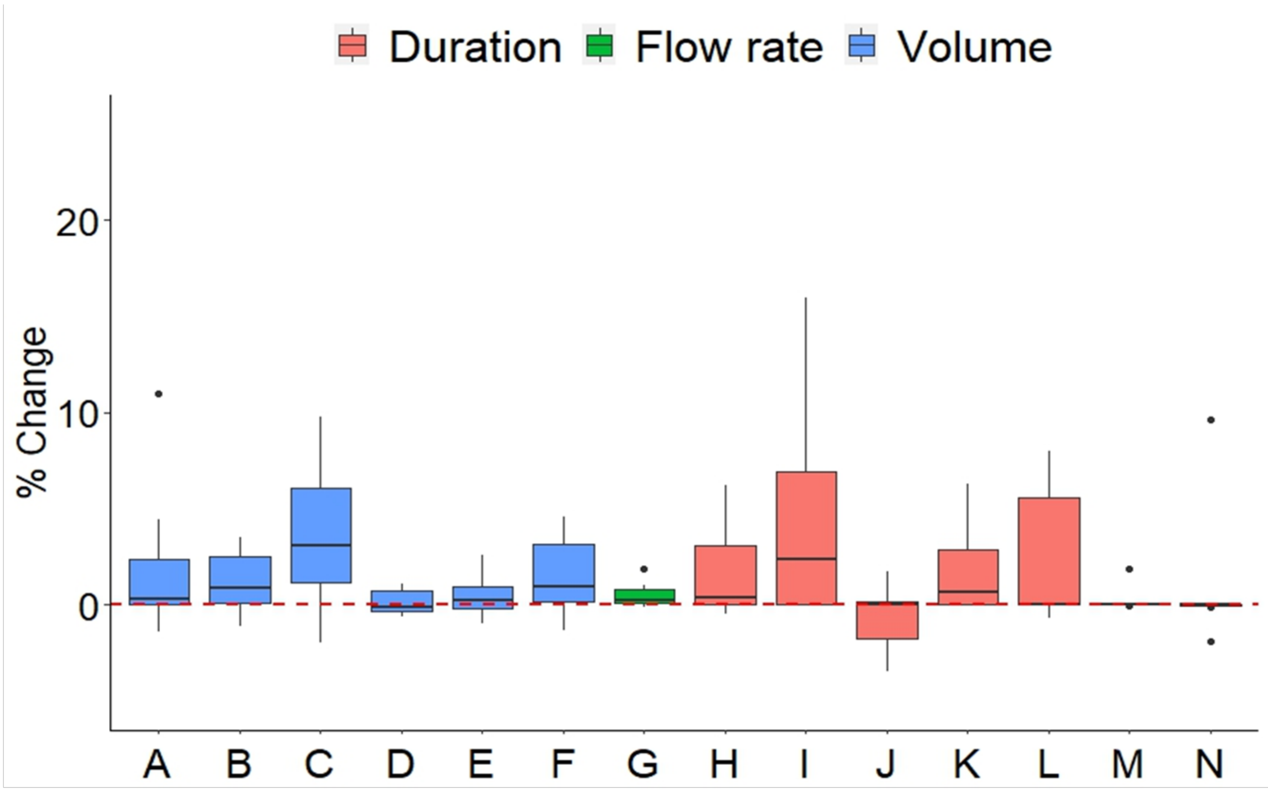
Modelling indicates that implementation of the *policy* will result in changes to some of the key hydrological features of the floodplain. The change in each of the 8 breakout zones with the *policy* implemented, expressed as percentage change from without the *policy* implemented, is provided in Table 5 and represented in Figure 15 with the unit change of the metrics provided in Table 6. Results are broken down into the key hydrological features of magnitude, duration and event frequency and discussed below. These interpretations are limited to the modelled outcomes for the end of system breakouts but provide indicative modelled outcomes for a variety of areas on the Namoi Valley floodplain.

Results presented are modelled long-term (over the period 1895 to 2020) changes to the hydrology of the floodplain that would occur under the *policy*.

Summary of hydrological change across the Valley

In general, there are only minor hydrological changes predicted across the Namoi valley after the implementation of the *policy* (Figure 15). Overall, there is only an average of 1.4% change across all metrics and breakout zones. The breakout zones which are predicted to have the greatest change are Bugilbone (G), Merah North (F) Wee Waa (E) and Glencoe (D).

The metrics which are predicted to change the most is the median of annual volumes (flood years only) (6.1%), total autumn flow volumes (3.6%), total of autumn days with flow (4.5%) and total summer days with flow (2.4%), with greatest percentage decrease in total winter days with flow (-2%). Smaller changes were predicted for other metrics (<3.5%).



A – Median of annual volume
B – Mean of annual volume
C – Total of autumn volume
D – Total of winter volume
E – Total of spring volume
F – Total of summer volume
G – Median of event magnitude
H – Total number of days with flow
I – Total of autumn days with flow
J – Total of winter days with flow
K – Total of spring days with flow
L – Total of summer days with flow
M – Number of events
N – Mean inter-event period

Figure 15 Box plot of percentage change in key hydrological metrics after implementing the *policy* in the Namoi 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 simulation period across the 8 breakout zones

Magnitude

Larger flood volumes reaching the floodplain environment would provide improved inundation extent and durations. The **total** and **mean annual volumes** are predicted to have small increases in six of the eight breakout zones after implementation of the *policy*. During flood years (i.e. excluding non-flood years) the *policy* is predicted to allow an average of 1.2 GL in mean annual volumes to return to the floodplain across all breakout zones. The largest percent increase in mean annual volume (3.5%, 3.3 GL) and total volume (180 GL, 3.5%) is at Bugilbone (G) (Table 5, Table 6). Bugilbone (G) is also predicted to have the greatest percentage increase in median of annual volume in flowing years indicating at least a 33.7% increase in flood volume for 50% of floods (Table 5). Two breakout zone are predicted to have minor decreases in mean annual volume (<1%) at Gunnedah (A) and Boggabri (B).

Total seasonal volumes are also predicted to increase during some seasons (mostly summer and autumn) at selected breakout zones (e.g. Glencoe (D), Wee Waa (E), Merah North (F), and Bugilbone (G)), while other breakout zones are predicted to have minimal change in seasonal volumes (Gunnedah (A), Boggabri (B), and Tarrario (C)). The total volume percentage increase was largest in autumn at Bugilbone (G) (9.8%, 75.6 GL), Merah North (F) (7.2%, 75.8 GL), Wee Waa (E) (5.7%, 1.8 GL). In addition, summer volumes at Wee Waa (E) (4.6%, 8.9 GL) and Bugilbone (G) (4.2%, 83.8 GL) should increase, with Merah North (F) and Glencoe (D) having relatively high unit increases (Table 6).

Median event magnitudes, which provide a measure of change in peak flow rates (ML/day) during flood events, are predicted to change only slightly (<1%) when averaged across all breakout zones (Table 5). The highest predicted percentage change is 1.9% (61 ML/day) at Glencoe.

Duration

Longer flow durations, measured as number of flow days would provide long inundation duration and connectivity between the river and floodplain. However, the **total number of flow days** is only predicted to increase by a relatively small amount, 1.6% (9 days) averaged across all breakout zones (Table 5). The predicted changes in 5 of the 8 breakout zones is less than 1%. The larger increases are predicted for Wee Waa (E) (6.2%, 12 flow days), Bugilbone (G) (4%, 46 flow days) and Merah North (F) (2.8%, 23 flow days) (Table 5, Table 6). Glencoe has the highest unit change (61 flow days), but this represents less than a 1% increase (Table 5).

Seasonal changes to flood durations vary with the season and breakout zone. Autumn (4.2%) and summer (2.5%) are predicted to have the greatest average percentage increase in flow days across the Namoi floodplain (Table 5). The breakout zones with the greatest increase include Wee Waa (E) (16%, 4 flow days), Bugilbone (G) (9.1%, 19 flow days) and Merah North (F) (6.2%, 6 flow days) during autumn. During summer, increases were predicted for Wee Waa (E) (8%, 7 flow days), Bugilbone (G) (7.1%, 26 flow days) and Merah North (F) (5.1%, 13 flow days) (, Table 6). Days with flow during winter decreased for 4 breakout zones, with Boggabri (B) having either no change or reduced flow days across all seasons.

All other breakout zones generally had minimal increases or decreases in flow days for all seasons.

Event based metrics

A reduced inter-event period and associated rise in number of events would result in more events reaching floodplain assets and values with shorter periods between each flood event. However, the predicted change in the **number of flood events** between 1895 and 2020 is predicted to slightly reduce across all breakout zones by -0.4% on average (Table 5). The only percentage increases were for Merah North (F) (1.9%, +2 events) and Bugilbone (G) (3.9%, +4 events). There were decreases in percentage predicted at Wee Waa (E) (-2%, -2 events), Glencoe (D) (-1.5%, -1 event) and Boggabri (B) (-1%, -1 events) with no change predicted at the other breakout zones (, Table 6).

The mean period between events (**inter-event period**) is predicted to have no change or slightly increase at all breakout zones (average 0.5% increase) (Table 5). The highest reduction in inter-event period, which means shorter periods between events is predicted for the Bugilbone (G) breakout. The periods between events for this breakout are expected to reduce by 3.9%, which is 17 days shorter than without the *policy*. However, Wee Waa (E) which experiences very few floods, separated by large periods between events is predicted to have an increase in the period between events (6.9%, 92 days more between floods) (Table 5, Table 6). Three of the 8 breakout zones are predicted to have no change in inter-event period.

Modelled outcomes for the **rise and fall** statistics of flood events vary by breakout zone and flow metric of interest (Table 5). Five of the eight breakout zones are predicted to have increases in total duration of the rising limb of flood events, with the highest percentage increase at Gunnedah (A) breakout zone (9.8%, 12 day) with minimal changes (<2%) observed for most breakout zones. A predicted decrease in the duration of the rising limb of flood events is predicted for Bugilbone (G) (-5.7%, -27 days), and to less extent Glencoe (D) and Wee Waa (E) (Table 5, Table 6).

Overall, the mean **rate of rise** across breakout zones will increase 3.3%, with the highest increase predicted for Trilby Park (H) (15.2%, 184ML/d) and the highest unit change (247 ML/d, 1.2%) predicted at Glencoe (F) (, Table 6). A small reduction in percentages are predicted for two of the breakout zones (Boggabri (B) and Tarrario (C)).

Negligible changes are predicted for the total duration of the **falling limb** of events for any of the breakout zones (Table 5). The highest unit change is at Bugilbone (G) breakout zone (27 days, 0.1%) (Table 6). The rate of fall varies across the breakout zones with increase predicted at four breakout zones, a decrease at three breakout zones and no change at one breakout zone. The highest predicted increase is at Tarriaro (C) (25.9%, 24 ML/d) with the greatest unit increases at Gunnedah (A) (207 ML/d, 5.4%) and Trilby Park (H) (109ML/d 13.6%) (, Table 6). The greatest decrease is predicted at Bugilbone (G) (-6.7%, -42 ML/d) (Table 5, Table 6).

Table 5 Percentage change in ecologically relevant flow metrics after implementation of the *policy*. Values are averaged over the simulation period. EC = Event created, i.e. there was no event before implementation of the *policy*. Only flows >1 ML/d 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.

Hydrological feature	Flow metric	(A) Gunnedah	(B) Boggabri	(C) Tarriaro	(D) Glencoe	(E) Wee Waa	(F) Merah North	(G) Bugilbone	(H) Trilby Park	Average
Magnitude	Mean of annual volume (flood years only)	-1.1%	0.0%	0.2%	1.6%	3.1%	2.3%	3.5	0.1%	1.2%
	Median of annual volume (flood years only)	-0.1%	0.4%	0.1%	4.4%	0.3%	11.0%	33.7%	-1.4%	6.1%
	Ratio of median to mean annual volume	1.0%	0.4%	-0.2%	2.8%	-2.7%	8.5%	29.2	-1.5%	4.6%
	Total autumn volumes	-2.0%	0.3%	1.5%	4.6%	5.7%	7.2%	9.8%	1.6%	3.6%
	Total winter volumes	-0.3%	-0.4%	-0.4%	1.1%	0.8%	-0.2%	0.7%	-0.6%	0.1%
	Total spring volumes	0.4%	0.1%	-0.1%	0.9%	-0.4%	2.6%	1.2%	-1.0%	0.5%
	Total summer volumes	-1.3%	0.1%	0.2%	1.4%	4.6%	2.8%	4.2%	0.5%	1.6%
	Median event magnitude	0.1%	0.0%	0.1%	1.9%	-0.1%	0.7%	1.0%	0.4%	0.5%
Duration, frequency and timing	Total flow days	0.0%	-1.1%	-0.5%	0.6%	6.2%	2.8%	4.0%	0.1%	1.6%
	Number of events	0.0%	-1.2%	0.0%	-1.5%	-2%	1.9%	3.9%	0.0%	-0.4%
	Total autumn days with flow	0.0%	-2.2%	0.0%	4.3%	16.0%	6.2%	9.1%	0.5%	4.5%
	Total winter days with flow	0.0%	-1.4%	-1.7%	-3.5%	1.7%	0.7%	-1.9%	0.0%	-0.6%
	Total spring days with flow	2.1%	-1.9%	0.0%	6.3%	0.0%	1.3%	5.2%	0.0%	1.9%
	Total summer days with flow	-0.7%	0.0%	0.0%	0.0%	8.0%	5.1%	7.1%	0.0%	2.4%
	Mean inter-event period*	0.0%	1.2%	0.0%	1.6%	6.9%	-1.9	-3.9%	0.0%	0.5%
	Total duration of rises	9.8%	1.4%	1.8%	-0.8%	-1.0%	1.5	-5.7%	1.2%	0.9%
	Mean rate of rise	1.3%	-2.6%	-4.8%	1.2%	4.7%	0.5	9.0%	15.2%	3.3%
	Total duration of falls	0.0%	0.0%	0.0%	0.0%	0.0%	0.0	0.1%	0.0%	0.0%
	Mean rate of fall	5.4%	-0.6%	25.9%	0.0%	3.4%	-5.2	-6.7%	13.6%	4.5%

Table 6 Unit change in ecologically relevant flow metrics after implementation of the *policy*. Only flows >1 ML/d were considered flowing days.

Hydrological feature	Flow metric	(A) Gunnedah	(B) Boggabri	(C) Tarriaro	(D) Glencoe	(E) Wee Waa	(F) Merah North	(G) Bugilbone	(H) Trilby Park	Average
Magnitude	Mean of annual volume (flood years only) (ML)	-1,342	-4	91	3,209	576	3,361	3,334	162	1,173
	Median of annual volume (flood years only) (ML)	-27	9	13	868	19	5,554	14,564	-1,137	2,483
	Total autumn volumes (ML)	-8,622	1,063	3,308	37,771	1,816	75,841	75,579	7,592	24,294
	Total winter volumes (ML)	-233	-2,025	-1,429	27,159	867	-5,396	12,871	-6,980	3,104
	Total spring volumes (ML)	1,564	107	-100	12,437	-130	31,052	7,435	-2,576	6,224
	Total summer volumes (ML)	-15,520	660	1,045	49,424	8,957	80,254	83,815	6,665	26,912
	Median event magnitude (ML/d)	6	0	3	61	-1	39	35	5	19
Duration, frequency and timing	Total flow days	0	-7	-2	2	12	23	46	1	9
	Number of events	0	-1	0	-1	-2	2	4	0	0
	Total autumn days with flow	0	-2	0	2	4	8	19	1	4
	Total winter days with flow	0	-3	-2	-4	1	2	-8	0	-2
	Total spring days with flow	1	-2	0	3	0	2	9	0	2
	Total summer days with flow	-1	0	0	0	7	13	26	0	6
	Mean inter-event period (days)*	0	6	0	10	92	-8	-17	0	10
	Total duration of rises (days)	12	4	4	-1	-1	5	-27	5	0
	Mean rate of rise (ML/d)	55	-23	-39	247	43	19	134	184	77
	Total duration of falls (days)	-12	-4	-4	1	1	-5	27	-5	0
	Mean rate of fall (ML/d)	206	-4	24	1	17	-34	-42	109	35

4.3.3 Case study of hydrological changes

This section presents an analysis of the modelled hydrological changes for a 10 year period with a number of consecutive floods (1970-1979). The analysis includes an assessment of total annual volumes, peak magnitude, and flow duration changes for:

- the 10 year period,
- a year with one single large event (1971), and
- a year with multiple events of different sizes (1977)

This information is provided to highlight changes over a decade time-span (Figure 16) and within individual flow events (Figure 17). The two breakout zones with the highest predicted change over all metrics (Table 5 and Table 6) were selected to highlight the potential hydrological changes. These were the Bugilbone (G) and Merah North (F) breakout zones.

There are only small changes in total annual volume predicted for both breakout zones (Figure 16) with an overall increase of 19.1 GL (2% increase) over the 10-year period at the Bugilbone (G) breakout zone and 8.1 GL (0.5% increase) at the Merah North (F) breakout zone. In most years there are only small increases predicted with the relative improvements increasing in years with subsequent floods. For example, in the Bugilbone (G) breakout zone there was a flood volume increase of 1.4% or 3GL in 1976, 4.0% or 10 GL in 1977 and 7.3% or 2 GL in 1978 (Figure 16). This reflects the account management rules proposed within the *policy*, where years immediately following a drier year (no floods) have larger entitlement volumes (due to carry over provisions) compared to years with subsequent events where carry over is less likely to occur.

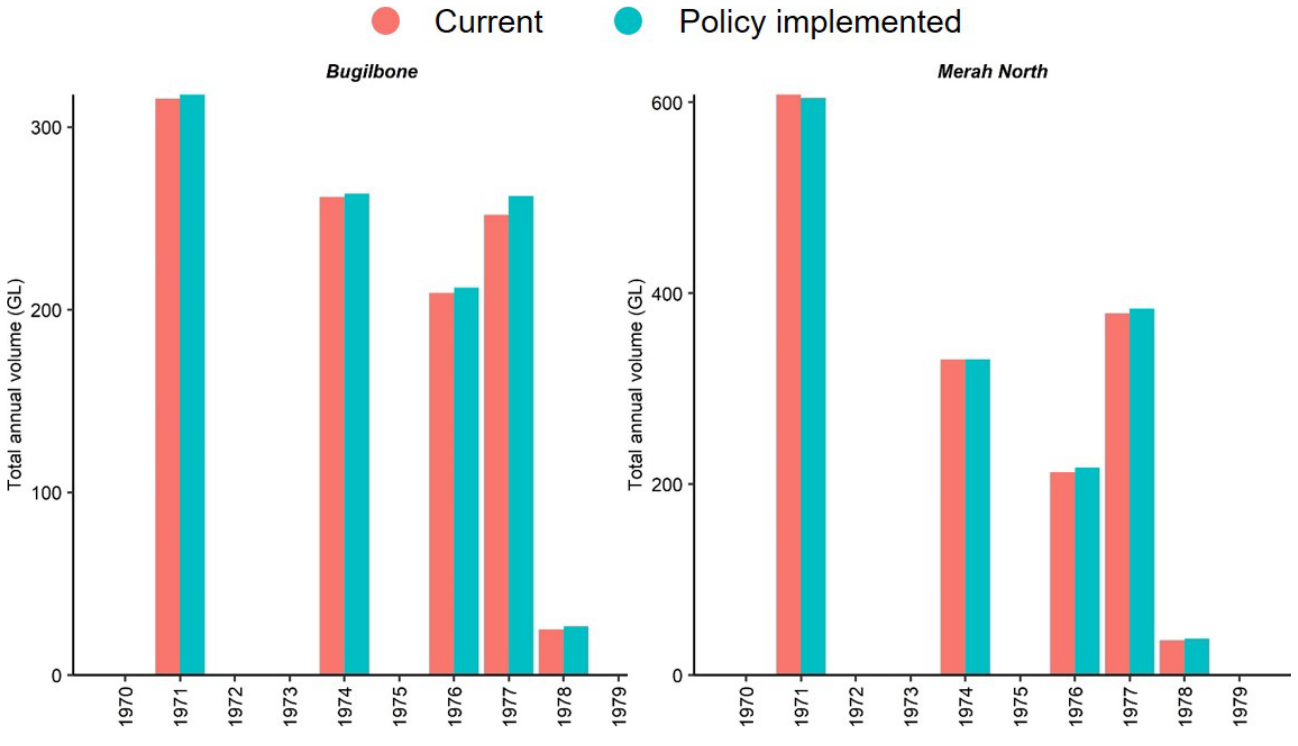


Figure 16. Modelled total annual volumes (GL/year) 1970-1979 and floodplain breakout volume (GL/d) for two the breakout zones with most predicted change to hydrology (Bugilbone (G) and Merah North (F)). Data represents the volumes remaining after FPH diversions have been applied.

Modelled hydrographs of floodplain discharge with and without the *policy* during flood events in 1976 and 1977 identifies relatively small changes to the hydrology of individual flood events (Figure 17). During the events in 1976, the maximum change in peak discharge rates would have increased by 346 ML/day at Bugilbone (G) and 1,950 ML/day at Merah North (F). The total increase in event volume would have been 3 GL for the Bugilbone breakout and 4.7 GL for the Merah North breakout zone. In contrast, the discharge duration of the events in 1976 were modelled to remain unchanged for Bugilbone (G) (40 days with flow) and reduced by one day in the Merah North (F) breakout zone.

During the 1977 flood events, the modelled change in peak discharge rate during an event was an increase of 1,481 ML/day at Bugilbone (G) and 1,665 ML/day at the Merah North (F) breakout zone. Total volume across multiple events in this year for Bugilbone (G) and Merah North (F) would have increased by 10 GL and 4.9 GL respectively. Surprisingly, the days with flow was predicted to reduce by 5 days (-7.5%) in the Bugilbone (G) breakout and 3 days (-6.5%) in the Merah North (F) breakout zone. This suggests that whilst lower volumes would have been diverted during this period, the duration of some events may be reduced based on a change in harvesting practice with the *policy*.

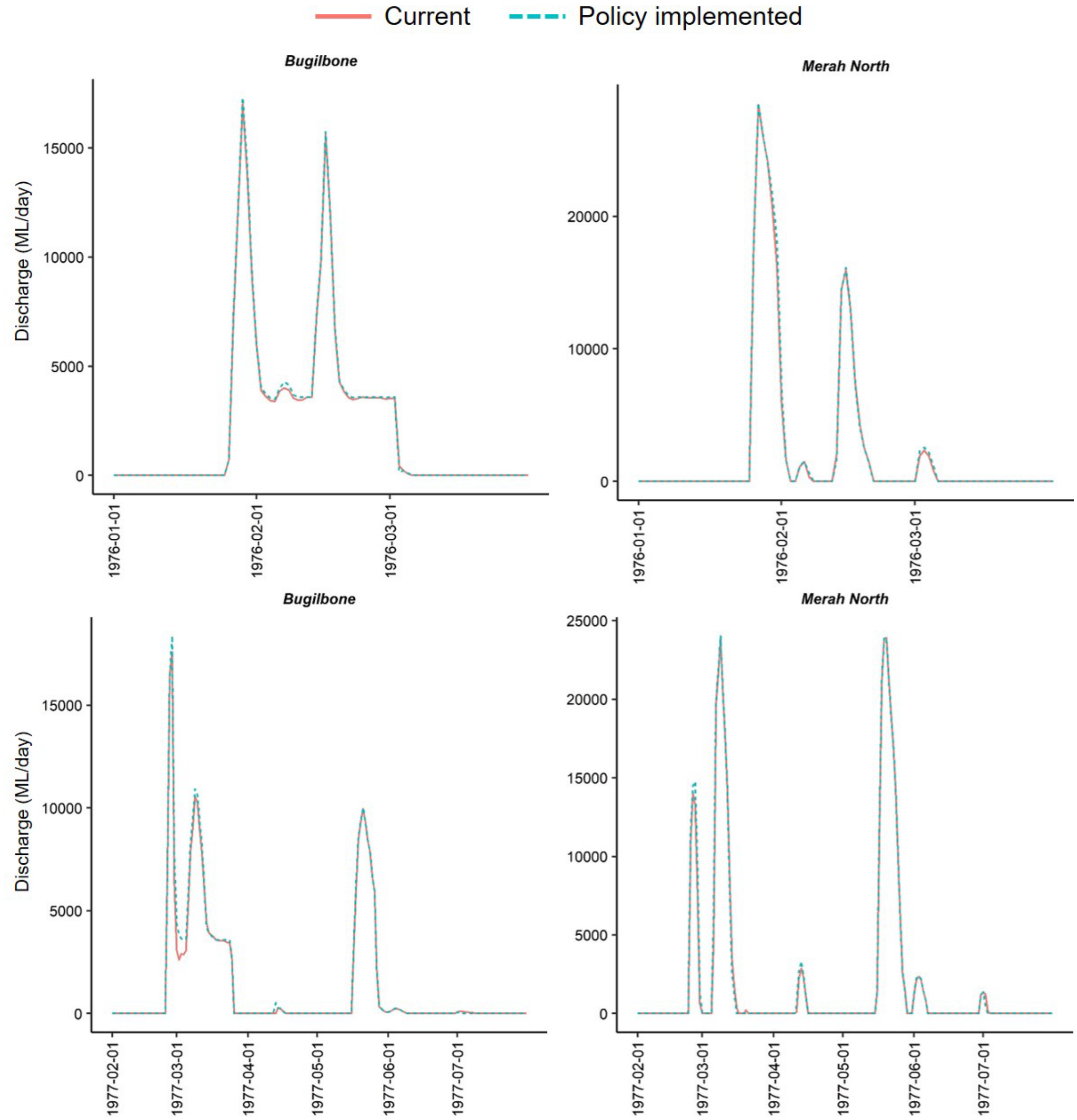


Figure 17. Modelled floodplain discharge (ML/day) during 1976 and 1977 at two breakout zones with the highest predicted change to hydrology after implementation of the *policy* (Bugilbone (G) and Merah North (F)). Data represents the discharge (flow) remaining after FPH diversions applied.

5 Predicted ecological outcomes

The results presented in this chapter are based on long-term (1895 to 2020) simulated hydrological changes where the *policy* is implemented across the entire record. In reality, the *NSW Floodplain Harvesting policy* is a proposed future water resource management measure. The predictions reported herein are therefore only indicative of potential outcomes under implementation of the *policy*.

5.1 Assessment approach

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

In addition, known EFRs (provided in Appendix C) increase the capacity to predict whether improved environmental outcomes can be expected under different hydrological scenarios. While duration EFRs were available for most assets or values, this assessment has used **changes to the number of flow days** on the floodplain as a measure of change to flood durations in important seasons (i.e. timing EFRs) for an asset or value. The reasons for substituting a specific EFR duration for this measure are explained in *Assumptions and limitations* (Section 5.2) below.

For the majority of environmental values, EFRs 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 EFR 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 are supported under the *policy* is important. For example, an EFR for seedling germination in a tree species may be met, but the EFR for maintaining the condition of mature trees of the same species is not met, or vice versa. In many cases the specific EFR had an upper and lower bound (for example, 3 to 5 years in 10 required for reproduction in short-moderate lived floodplain specialists). The lowest measure, usually the lower bound (e.g. 3 years in 10), was used to test the EFR outcomes. Whilst the upper bound is a more conservative estimate, this approach provides a minimum requirement to achieve the documented EFR.

Each EFR was tested under the two model scenarios; with the *policy* implemented (*Plan Limit Compliance Scenario*) and without (*Current Conditions Scenario*) (EFR values are listed in Appendix C). This involved first identifying all flood events, including the event duration, in the modelled flow data[7]. 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 or less of <1 ML/day flows) were considered one flood event due to the short inter-flow period. The month of, season of, days between, and years between events were then generated from the spell length data[7]. These metrics were then tested against the specific frequency and timing EFRs assigned to environmental assets and values identified on the valley

[7] 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.

floodplain. This method allowed a simple quantification of how often each EFR was met under the modelled long-term record for both scenarios. The results were also interpreted as a % change in EFRs 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 EFRs used in this assessment are provided in Appendix C. Considerable time and effort by various authors has been put into developing many of the EFRs used in this assessment. The scientific information which supports each EFR can be sourced from the associated reference in Appendix C. Key outcomes are summarised for native fish, native vegetation, and waterbirds in this Chapter.

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 EFRs 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 flow requirements and hydrological metrics.

It is assumed that if a documented EFR 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 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 EFR may not actually 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) and or the level of take (lawful/unlawful). The assumption is that volumes of water returned to the floodplain are able to pass through un-hindered. In reality, ongoing monitoring is required to ensure that flood works do not inhibit 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 (e.g. 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 EFRs

Most, if not all, documented floodplain duration EFRs 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 EFR. For example, the Namoi Long term Watering Plan Part B (DPIE-EES, 2020b) suggests a >14,000 ML/day event at the Namoi River at Goangra (419026) flow gauge for 2 days will achieve a large overbank flow event and inundation for 1 month. 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 >1 ML/day) is actually much longer than represented by the river system models 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 C).

Where a duration EFR 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 EFRs) 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 EFR. Instead, it is a test to identify if there is a change in the number of flow days during the required timing (season/month) of known EFRs.

5.3 Changes to monthly flow durations

As reported above, where a duration EFR could not be tested, the substitute was to calculate the total flow days (>1 ML/day) for each month[8]. The data were interpreted as a % change in the number of flow days per month, after implementing the *policy*. Figure 18 represents the summary statistics (median, 25th and 75th percentiles) across all eight breakout zones. Percent change results are in Table 7.

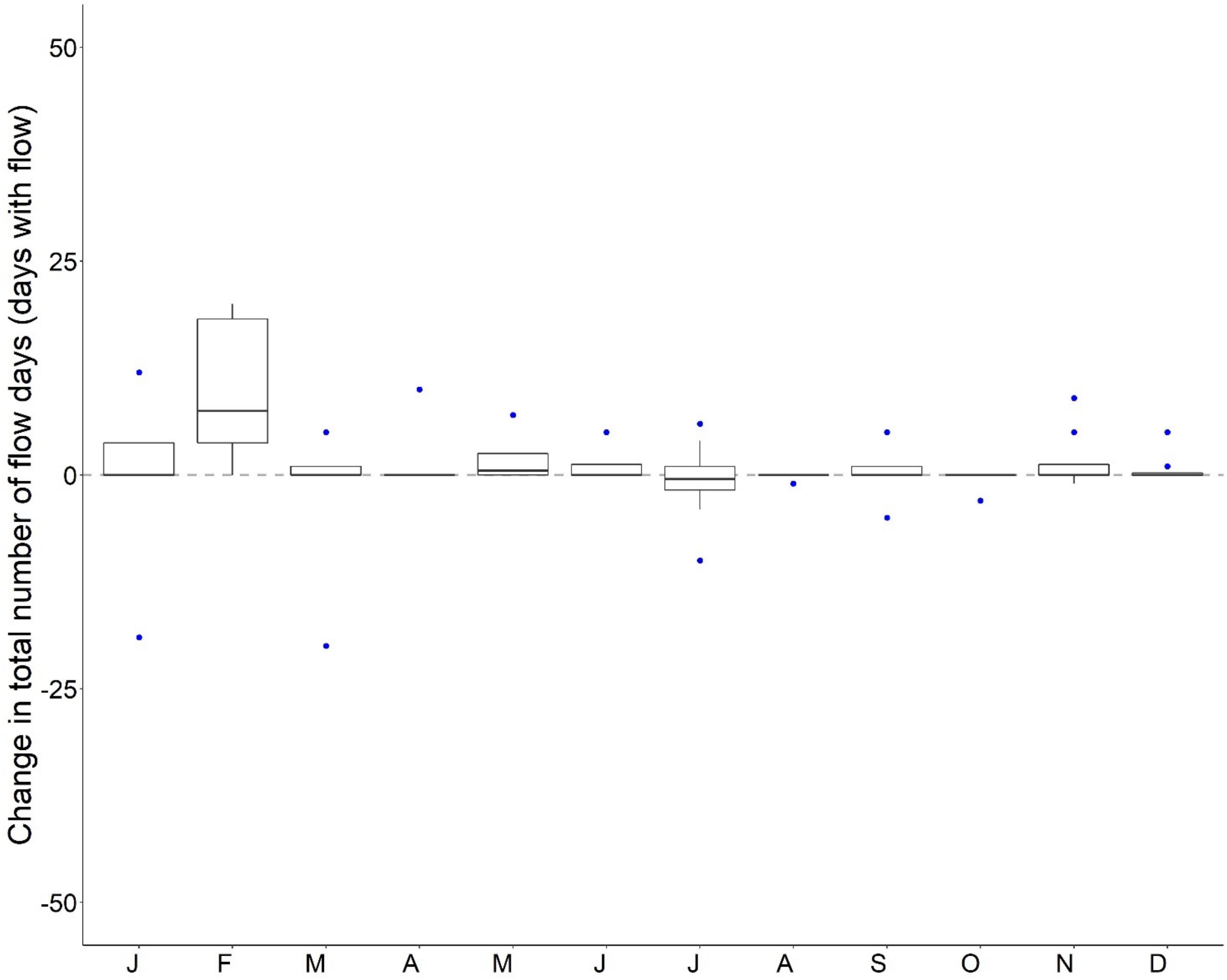


Figure 18 Box plot of change in total number of flow days in each month after implementing the *policy* in the Namoi Valley. Values are averaged over the simulation period across all eight breakout zones. Number of flow days is based on modelled flow >1 ML/day. Boxes show the medians (bold line inside box), 25th and 75th percentiles (bottom and top of box), minimum and maximum (bottom and top whiskers) and outliers (points) for the 8 breakout zones

[8] 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.

Table 7 Percentage change 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. EC = Event created i.e. there was no event before implementation of the *policy.* Only flows > 1 ML/day were considered flow days.

Hydrol feature	Breakout zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Duration	A Gunnedah	0	0	0	0	0	0	0	0	5.6	0	-3.6	0
	B Boggabri	0	6.17	0	0	4.2	0	-0.7	0	-11.9	0	0	0
	C Tarriaro	0	0	0	0	0	0	-1.2	0	0	0	0	0
	D Glencoe	0	0	8.3	0	0	35.7	-6.6	0	0	0	0	0
	E Wee Waa	2.9	20	0	0	0	0	0	0	0	0	0	0
	F Merah North	17.1	4.9	14.3	0	2.1	0	4.1	-3.3	2.1	0	7.9	19.2
	G Bugilbone	8.9	9.7	2.6	41.7	7.6	0	-6.8	0	10.2	-4.8	14.1	1.8
	H Trilby Park	0	0	0	0	0	0	2.3	0	0	0	0	0

The median number of flow days across all zones is predicted to increase predominately in the summer and autumn months with most monthly changes driven by Bugilbone (G), Merah North (F) and Wee Waa (E) (Table 7, Figure 18). However, one breakout zone (Tarriaro (C)) is predicted to have a 35% increase (5 flow days) in June. The largest increases in the number of flow days are predicted for February with four breakout zones predicted to have increases in flow days with an average increase of 4.75 flow days across all breakout zones. The largest monthly increase is predicted at Bugilbone (G) with 41.7 % (10 flow days) in April and the largest increase in flow days was 18 flow days (9.7%) predicted at Bugilbone (G) in February (Table 5).

July, August, and October are predicted to have lowest percentage change with all three months recording a small decrease in percentage change averaged across all breakout zones. Gunnedah (A), Boggabri (B), Tarriaro (C), and Trilby Park (H) are predicted to have no change or minimal changes in durations within each month (Table 5).

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

5.4 Native fish

5.4.1 Metrics

Fourteen different fish species were either predicted or recorded across the 8 breakout zones using the available data. 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). We did not consider outcomes for the river specialist guild as the estimates of return flows to downstream rivers are not clear. In addition, not all breakout zones had predicted or recorded observations of a native fish species from each fish guild (Table 2). Therefore, the assessment only considered the outcomes for each fish guild if it occurred in the breakout zone. The fish guilds, species and relevant breakout zones are summarised below:

- flow dependent specialists, such as Silver Perch, Spangled Perch and Golden Perch. Species from this guild were recorded and/or predicted to occur in all breakout zones.
- 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, C, D, E, F and G.
- short-moderate lived floodplain specialists such as Olive Perchlet and Flathead Galaxias are predicted and/or recorded in breakout zones A, B, C, D, F, G, and H.

Figure 19 The spangled perch, a flow dependent species which inhabits floodplain and riverine environments, and would be impacted by changes to floodplain harvesting practices [Photo: Gunther Schmida]

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

- egg development – flood durations required to achieve successful egg development. These durations refer to a flow peak of a set number of days (5–14 depending on guild). Modelled flow at the breakout nodes represent peak flow periods allowing this duration EFR to be tested using the hydrological models

- maintenance – the frequency, duration and timing (seasonality) needed to maintain native fish
- reproduction – the flood frequency required to provide sufficient reproduction opportunities
- recruitment – the timing (seasonality) of flood events required for effective recruitment
- spawning, habitat and food – native fish often require flood events during specific seasons due to seasonality preferences for spawning. This also relates to the timing of flood events for spawning habitat, food resources and refugia for recruits.

Specific EFRs 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. The majority of native fish EFRs were sourced from the *Fish and Flows in the Northern Basin* (NSW Department of Primary Industries 2015, 2019) and the *Long Term Water Plan EWRs* (DPIE-EES, 2020a).

In total, 10 EFR metrics and 23 tests were undertaken for native fish.

5.4.2 General hydrological impacts

Impacts of implementing the *policy* vary across the breakout zones, with some areas seeing small to moderate improvements and others having small negative outcomes. Overall, the small valley-level predicted improvements would only provide limited localised benefits for native fish in the 3 breakout zones with the greatest change (Glencoe (D), Merah North (F), and Bugilbone (G)).

The most notable change after implementing the *policy* is the increase in annual flood volumes, primarily in the 3 zones (Table 5). The **number of flood events** and the **inter-event period** are not expected to improve, which are both are critical for improving fish outcomes. Small increased **total summer volumes** and increased **total spring and summer flow durations** (Table 5) should provide some benefits for all fish guilds.

5.4.3 Impacts on fish guild-specific EFRs

There are limited changes in the number of EFRs achieved for the majority of metrics important for native fish (Table 8, Figure 20). Of the 23 EFR tests, 10 are predicted to improve by 5 to 10%. Another 10 EFRs are either not predicted to change, or only change by 1% on average across the floodplain. Flow dependent specialists like **Spangled Perch** are likely to benefit the most from the implementation of the *policy*, however these improvements are relatively small.

However, these changes vary drastically across the floodplain. For example, achievement of the duration required for egg development in flow dependent specialists like **Golden Perch** increases by 5% on average but did not change in one zone and increased by 23% in another (Table 8). Only one EFR metric had reduced frequencies:

- the timing of flows important for spawning in small-moderate floodplain specialists (-2%).

Breakout zone specific outcomes for native fish EFRs are summarised in Section 6.

Table 8 Percentage change in frequency of achieving EFRs for native fish in the Namoi 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 EFR available; *n* = number of breakout zones assessed.

Hydro feature	EFR metric	S-M FP specialists (*n* = 7)	Generalists (*n* = 7)	Flow dependent specialists (*n* = 8)
Duration	Egg development	+1% (-4, +10)	+5% (0, +23)	+5% (0, +23)
Frequency	Maintenance	+1% (0, +7)	+1% (0, +4)	+1% (0, +5)
	Maintenance (interflow)	+1% (0, +6)	+1% (0, +4)	+2% (0, +6)
	Reproduction	0% (0, 0)	N/A	0% (0, 0)
	Reproduction (interflow)	+1% (0, +6)	0% (0, 0)	N/A
Timing	Maintenance	N/A	+5% (0, +14)	+5% (0, +14)
	Recruitment	+5% (0, +33)	+3% (0, +20)	+10% (0, +57)
	Spawning	-2% (-12, 0)	N/A	+6% (0, +22)
	Spawning habitat	+5% (0, +15)	+5% (0, +14)	N/A
	Food, refugia	+6% (0, +19)	N/A	N/A

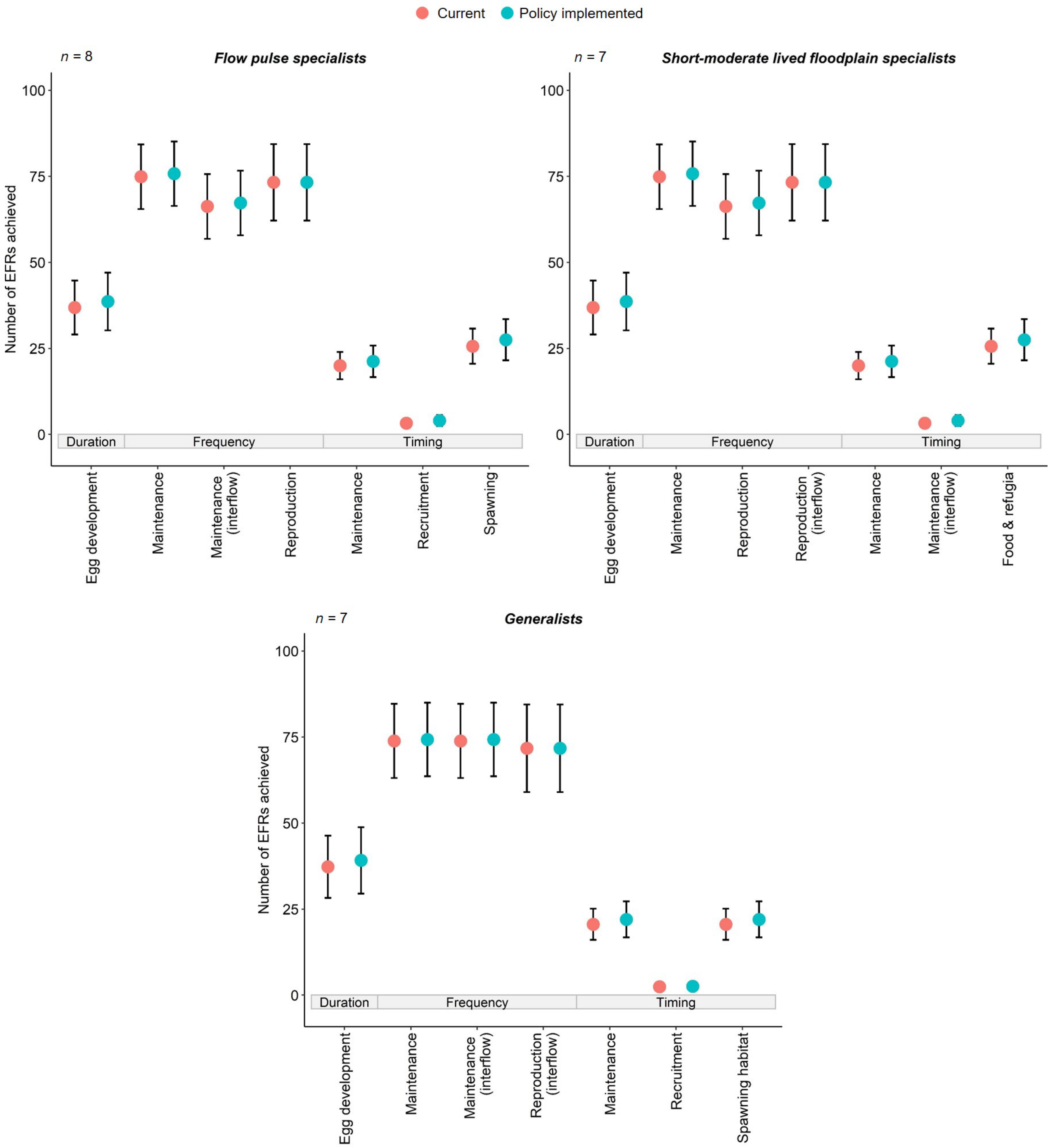


Figure 20 Average number of EFRs achieved for native fish with (*policy* implemented) and without (Current) the *policy* implemented in the Namoi Valley over the 125 year simulation period and across the relevant breakout zones. The grey horizontal rectangles identify the hydrological feature (duration, frequency, timing) and the x axis labels are the EFR metric. Error bars represent the standard error; *n* = number of breakout assessed.

5.5 Native vegetation

5.5.1 Metrics

The key water-dependent native vegetation values used in this assessment are key species in the plant community types (PCTs) from Table 2. Six vegetation species were selected for this assessment. They represent key umbrella species for a range of other vegetation values and have detailed EFR information documented. Although other species are predicted, known or recorded on the floodplain (e.g. poplar box), EFR 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 which was found in 3 breakout zones (zones D, G and H),
- coolabah (woodland and wetland) found in 4 breakout zones (zones B, D, G and H),
- lignum shrubland in 6 breakout zones (zones A and D-H),
- river red gum (forest and woodland) which was found in all 8 breakout zones (zones A-H),
- river cooba found in all 8 breakout zones, and
- water couch (non-woody wetland) present in 6 breakout zones (zones B-G).

Figure 21 Coolibah on the floodplain. This species is an important component of plant communities on the Namoi Valley Floodplain [Photo: Sharon Bowen]

This assessment tested native vegetation EFRs based on two key hydrological features – **frequency and timing of flood 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 EFR was not assessed. Specific values for each EFR metric vary for each native vegetation species (detailed in Appendix C). Most EFR values were sourced from (Roberts & Marston, 2011; DPIE-EES, 2020a).

As flood duration is a critical EFR metric for native vegetation, we substituted with **total flow days in key months/seasons** as an indicator of outcomes for duration EFRs[9]. The full list of key months/seasons is in 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.

5.5.2 General hydrological impacts

The impacts of implementing the *policy* on native vegetation vary by species and location on the floodplain. Some areas are predicted to receive small to moderate improvements and others, small negative outcomes (Table 5, Figure 22). Overall, the small predicted improvements at a valley scale would only provide limited localised benefits for vegetation in the 3 breakout zones with the greatest change (Glencoe (D), Merah North (F), and Bugilbone (G)).

Predicted small increases in the **total number, duration** and **volume of flow events** across the floodplain are likely to provide limited improvements in key native vegetation species, providing some opportunities for seed dispersal, seedling establishment and maintenance of mature vegetation. Increases in spring and summer volumes and flow durations are particularly important, as many species require flood events over the warmer months to enable seedling establishment and to avoid desiccation. Summer particularly is a critical period for maintenance, regeneration and reproduction for most vegetation values including river red gum, lignum, coolabah and water couch. There is predicted to be minimal changes predicted for breakout zones for spring, however small increases in summer are predicted for Glencoe (D), Merah North (F), and Bugilbone (G) and to less extent Wee Waa (E)(Table 5, Table 6).

5.5.3 Impacts on native vegetation specific EFRs

Modelling indicates that implementation of the *policy* in the Namoi Valley will result in a small average increase in the achievement of most the native vegetation EFRs tested (Table 9, Figure 22), showing no reduction in the rate of achievement (all average % changes positive or zero).

The average percentage change for achieving EFRs ranged between 1-8% (Table 9) depending on the floodplain breakout (Table 11). The greatest predicted change for the timing required for the best outcomes for lignum seedling dispersal (Table 9). However, there were also some reductions in

[9] The reason for this substitution is set out in Section 5.3. In short, duration of flood water on the floodplain is not modelled.

specific EFR metrics (e.g. river red gum seedling dispersal) (Table 9). The relative increase in EFR achievement was largest for the Wee Waa (E) (17%), Merah North (F) (5%), and Trilby Park (H) (5%) breakouts (Table 11). There is <2% improvements predicted for the other 5 breakout zones.

The improved frequency of achieving the lignum EFR metric is driven by the seedling establishment and dispersal metric in Wee Waa (150%) (Table 11). However, as Wee Waa is not a major breakout within the Namoi Valley, this percentage increase only represents a small magnitude of change (increase of three 1 in 18-month flood events), with the *policy* from two 1 in 18-month events without the *policy*. Taking the magnitude of change into account, Merah North (F), Bugilbone (G) and Trilby Park (H) is expected to have most change for the vegetation assets identified in their breakout zones, with lignum and river red gum likely to benefit the most. Gunnedah (A), Boggabri (B), Tarriaro (C) and Glencoe (D) are not predicted to have any increases in achieving vegetation EFRs (Table 11).

Whilst relatively small, any improvement for native vegetation will likely have flow on benefits for other environmental values on the floodplain, including waterbirds and native fish. 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.

Table 9 Percentage change in frequency of achieving EFRs for native vegetation in the Namoi Valley floodplain after implementing the *policy*. Values represent average (minimum and maximum) predicted outcomes, averaged over the simulation period across the relevant breakout zones identified in Section 5.5.1. *n* represents the sample size or the number of breakouts in which a value was present. N/A = no EFR available; *n* = number of breakout zones assessed

Hydro feature	EFR metric	Lignum (n = 6)	Coolabah (*n* = 4)	River cooba (*n* = 8)	River red gum (*n* = 8)	Black box (*n* = 3)	Water couch (*n* = 7)
Frequency	Maintenance	Large +1% (0, +4)	Wetland +2% (0, +5)	+1% (0, +4)	Forest +2% (-1, +7)	+1% (0, +3)	+2% (0, +9)
		Small 2% (-1, +7)	Woodland +0% (0, 0)		Woodland +2% (0, +6)		
	Seedling establishment	+30% (0, +150)	+2% (0, +7)	N/A	+2% (0, +9)	+2% (0, +7)	N/A
Timing	Maintenance	N/A	N/A	N/A	+5% (0, +14)	N/A	+5% (0, +17)
	Seedling establishment	+6 (0, +14)	+3% (0, +11)	N/A	-1% (-8, +6)	4% (0, +11%)	N/A
	Seedling maintenance	N/A	N/A	N/A	+5% (0, +14)	N/A	N/A
	Seedling dispersal	+8% (-3, +40)	N/A	N/A	N/A	N/A	N/A

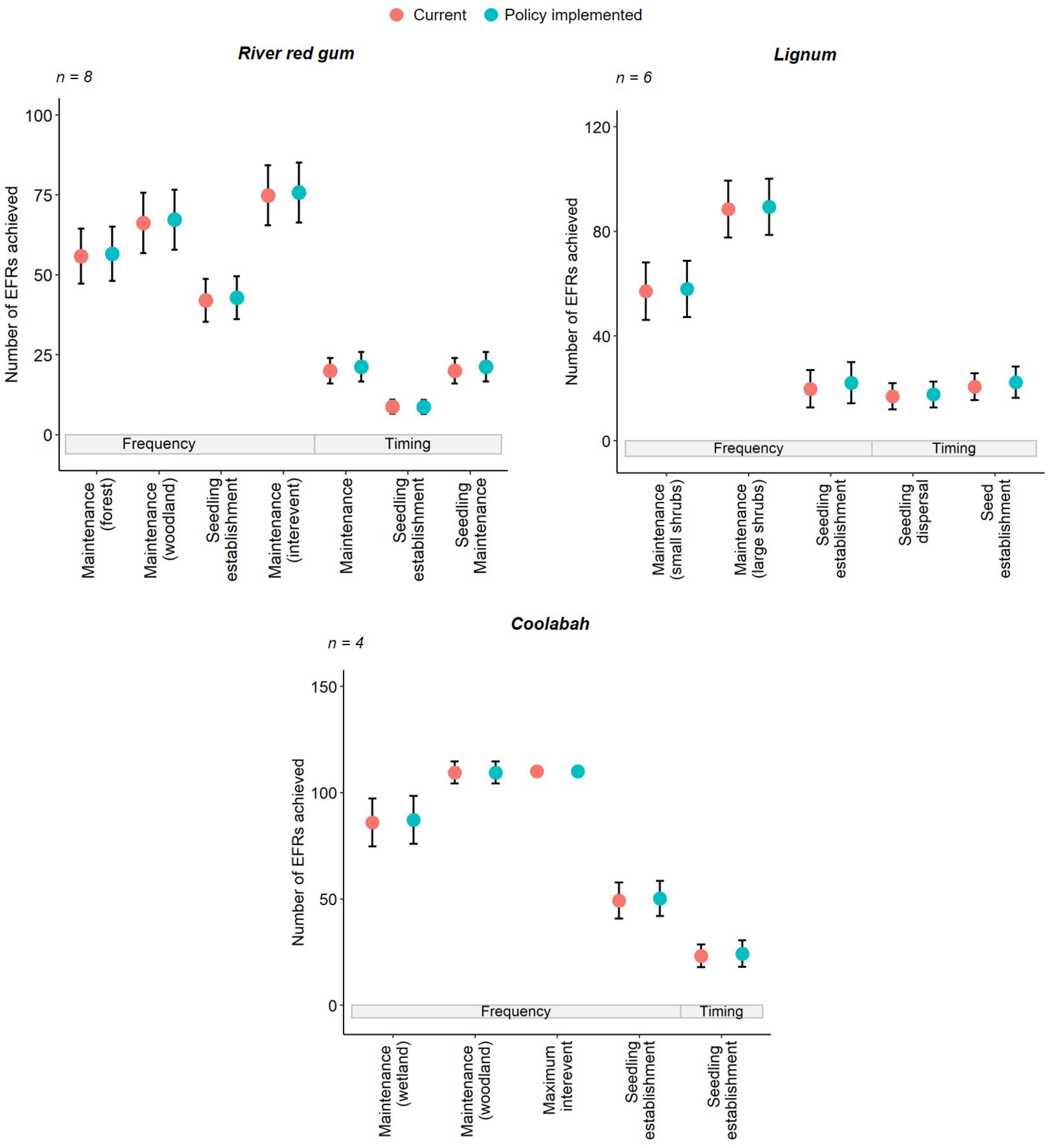


Figure 22 Average number of EFRs achieved for native vegetation (lignum, coolabah, and river red gum) with (*policy* implemented) and without (Current) the *policy* implemented in the Namoi Valley over the simulation period and across the 8 breakout zones. The grey horizontal rectangles represent the hydrological feature whilst the x axis labels are the EFR metric. Error bars represent the standard error

5.6 Waterbirds

There were 38 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. Although colonial waterbirds have been recorded within the valley, there are no known nesting sites. The waterbird assessment has therefore been focussed on non-colonial waterbird outcomes within the Namoi valley.

5.6.1 Metrics

This assessment focussed on key components of the NSW Long-Term Water Plan environmental water requirements (LTWP EWRs) to **maintain habitat and provide breeding opportunities for colonial-nesting waterbirds** only. Metrics assessed for waterbird outcomes were **frequency of floods, inter-event period between floods, flow duration,** and **timing of floods**. Metrics used in this report were adapted from the NSW Long-Term Water Plans specific for the Namoi valley (DPIE-EES, 2020a). They do not represent comprehensive tests of the LTWP EFRs (as described in section 7.2) but are an assessment of specific components to identify if important overbank frequency, timing or duration metrics are expected to change with the *policy* implemented.

Below are summaries of the **metrics used in this report** for **non-colonial waterbird outcomes**.

Frequency

- Selected metric 1: 1, 3, 4 and 5 years in 10
- Selected metric 2: Maximum inter-event period of 4, 5, and 10

Timing

- Selected metric 1: Frequency of floods occurring between September and April
- Selected metric 2: Frequency of floods occurring between September and February
- Selected metric 3: Frequency of floods occurring between August and February

Duration

- Selected metric 1: Duration, or days with flow of 1 days or more
- Selected metric 2: Duration, or days with flow of 2 days or more
- Selected metric 3: Duration, or days with flow of 5 days or more
- Selected metric 4: Duration, or days with flow of 10 days or more

Not all species were recorded in all breakout zones. However, achievement of the waterbird EFR metrics was assessed at the non-colonial group level rather than a species-specific level. Outcomes for non-colonial waterbirds were assessed for all 8 breakout zones.

This assessment assumes that meeting a desired EFR metric 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 EFR 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, Kingsford & Thompson, 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 key hydrological features across the Namoi floodplain (Table 5, Table 6, and Figure 15).

The main change predicted would be an increase in mean and median **annual flood volumes**, primarily in the Glencoe (D), Merah North (F), and Bugilbone (G) breakout zones. Improvements to autumn and summer flood events are expected for these breakout zones. The rest of the floodplain is predicted to have minimal changes to flood volumes. The **frequency of flood events,** however, is not expected to change significantly with the implementation of the *policy*, providing no benefit or further detriment to waterbirds in the Namoi. The number of flow days is also unlikely to change substantially, with only an increase of 1.6% days with flow on average across the entire Namoi floodplain.

In general, implementation of the *policy* will only provide minimal improvements to flood volumes and flow durations, with the frequency of floods remaining unchanged. This may be a constraint to achieving improved waterbird outcomes in the Namoi.

5.6.3 Impacts on waterbird specific EFRs

The outcomes for waterbirds varies across the 8 breakout zones, but on average, implementing the *policy* is not predicted to provide substantial changes for non-colonial waterbirds (Table 10). The average achievement across the 8 zones only increased by 5% or more for 5 of 14 EFR tests. These improvements were driven by predicted improvements in 3 breakout zones. These are the Bugilbone (G), Merah North (F) and Wee Waa (E) breakouts. However, the relatively large percentage change improvements for some EFRs (presented in Table 10) do not necessarily translate to large unit based changes (Figure 23).

For example, the frequency of achieving the **3 in 10 year flood frequency** in the Wee Waa (E) breakout increased by 140%, more than twice the value without the *policy*. In reality, this was a predicted increase from 5 to 12 periods where the criteria were met. Surprisingly, this differs to the pure hydrological assessment that detected very little change in flood frequency within this breakout zone. Regardless, the improvement over 125 years is relatively small when compared to other breakout zones, e.g. Bugilbone (G), which achieved the 3 in 10 year criteria 58, and 57 times with and without the *policy* implemented, respectively.

The achievement of appropriate **flood timing** and **minimum flow durations** are only predicted to improve by small amounts, driven purely by changes in the Merah North (F) and Bugilbone (G) breakout zones. Achievement of timing and duration based metrics for all other 6 breakout zones are not predicted to change. Breakout zone specific outcomes for waterbird EFRs are summarised in Chapter 6.

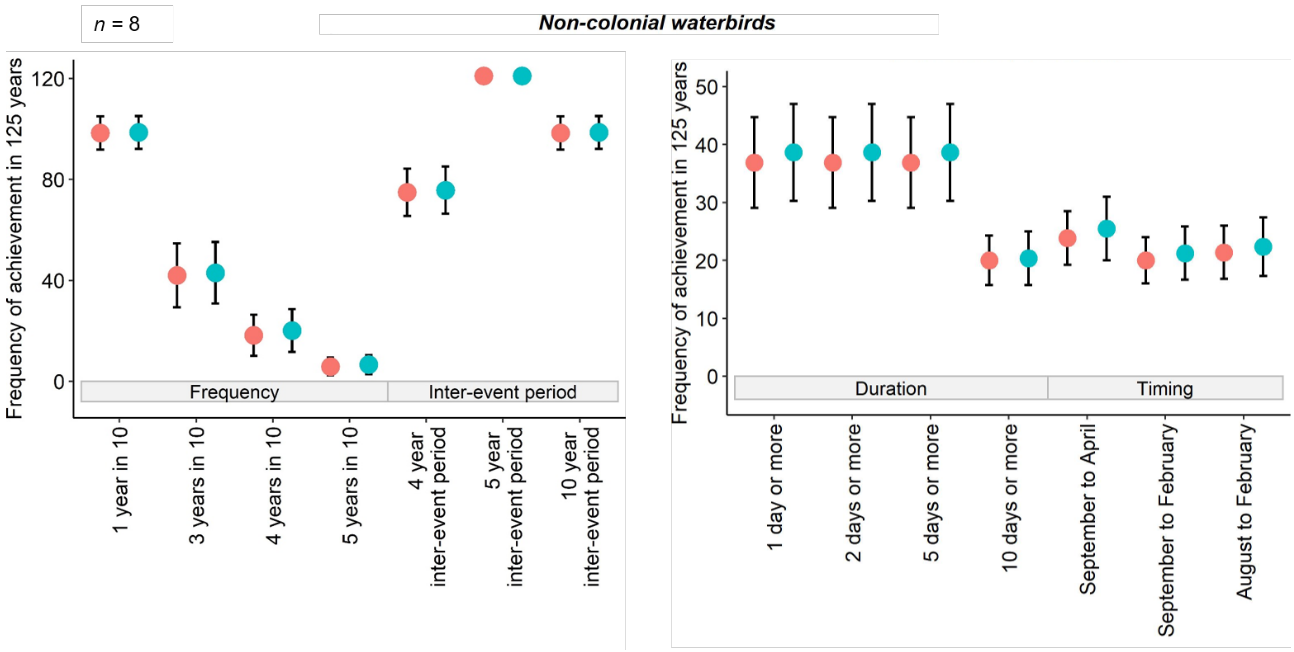


Figure 23. Average achievement of EFRs for non-colonial waterbirds with (*policy* implemented) and without (Current) the *policy* implemented in the Namoi Valley over the 125 year simulation period and across the 8 breakout zones. The grey horizontal rectangles represent the hydrological feature whilst the x axis labels are the tested metric. Error bars represent the standard error

Table 10 Percentage change in achievement of waterbird flow requirements for non-colonial nesting waterbirds in the Namoi Valley floodplain after implementing the *policy*. Values represent average (minimum and maximum) predicted outcomes, averaged over the simulation period across all 8 breakout zones. Event created ([EC]) indicates that one breakout zone only met the metric with the *policy* implemented.

Hydrological feature	Waterbird requirement	EFR detail	Non-colonial nesting waterbirds (*n* = 8)
Duration	Breeding, maintenance and habitat condition/extent	1-day minimum flow duration	+2% (0, +11)
		2-day minimum flow duration	+2% (0, +11)
		5 day minimum flow duration	+2% (0, +11)
		10-day minimum flow duration	+1% (-4, +10)
Frequency	Breeding, maintenance and habitat condition/extent	1 year in 10	-3% (-25, 0)
		3 years in 10	+19% (-6, +140)
		4 years in 10	+24% (-8, EC)
		5 years in 10	+18% (0, +100)
Inter-event period	Breeding, maintenance and habitat condition/extent	4 years max	-2% (-22, +5)*
		5 years max	0% (0, 0)
		10 years max	-3% (0, -25)*
Timing	Breeding, maintenance and habitat condition/extent	September - April	+5% (0, +14)
		September - February	+5% (0, +14)
		August - February	+4% (0, +13)

6 Breakout zone specific changes to EFRs

The average percentage change in the achievement of all tested EFRs for a given asset (or group of values) was calculated for native fish, waterbirds and native vegetation for each of the 8 breakout zones (Table 11). Summarised outcomes for these 3 key value categories at each breakout zone provide an assessment of breakout zone specific outcomes on the Namoi Valley floodplain. The average percentage change represents a high-level summary of the predicted increase or decrease in the number of EFRs met after implementation of the *policy*. For the majority of environmental assets and values, implementing the *policy* resulted in modelled improvements in only 3 breakout zones, with some breakout zones predicted to see greater improvements than others.

In total, 10 **native fish** EFRs were tested for each fish guild (Table 8). Minor to moderate increases in EFR achievement are predicted for the Merah North, Wee Waa and Bugilbone breakout zones. The best outcomes are predicted for flow pulse specialists in these zones Little to no changes are predicted for the other 5 zones.

Up to 6 different EFRs were assessed for **native vegetation**. On average, minor to moderate increases in EFR achievement are predicted for the Merah North (F), Wee Waa (E)and Trilby Park (H) breakout zones. These improvements are primarily for River red gum and lignum. There is <2% improvements predicted for the other 5 breakout zones.

For non-colonial **waterbirds**, 14 different EFRs were tested (Table 10). The average change in the number of EFRs predicted to be met increased for 5 of the 8 zones. The largest predicted improvement was +17% for the Wee Waa (E) breakout zone, however this breakout represents <2% of floodplain volumes in the Namoi. The more significant improvements are relevant to the Merah North (F) and Bugilbone (G) breakouts which are expected to have an average increase in EFR achievement of 9% and 4%, respectively. Although the average achievement of waterbird EFRs is predicted to improve at some breakout zones, there are some EFRs that are predicted to decrease in breakout zones. For example, the inter-event frequency of 10 years between a flood was met less often in the Wee Waa (E) breakout under the *policy* scenario.

Overall, implementation of the *policy* is likely to have small positive outcomes for two significant breakouts (Merah North (F) and Bugilbone (G)), and moderate improvements in a less significant breakout (Wee Waa (E)). Little to no change is predicted for the other 5 breakout zones when average changes in EFR achievement for all environmental asset categories are considered. This suggests that a greater focus on improving floodplain flows in these areas 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 11 Percentage change in the number of EFRs met for a given environmental value after implementation of the *policy* for the 8 breakout zones of the Namoi Valley Floodplain. Values represent average, minimum and maximum predicted outcomes, averaged across EFR 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 EFR was not assessed for that value.

Asset/value category	Environmental asset	(A) Gunnedah	(B) Boggabri	(C) Tarriaro	(D) Glencoe	(E) Wee Waa	(F) Merah North	(G) Bugilbone	(H) Trilby Park	Average
Native fish	Short-moderate lived floodplain specialists	0% (0, 0)	+1% (-12, +8)	0% (0, 0)	0% (0, 0)	Not present	+7% (-4, +33)	+4% (0, +16)	+2% (0, +7)	**+2%**
	Generalists	0% (0, 0)	0% (0, +1)	0% (0, 0)	0% (0, 0)	+8% (0, +23)	+8% (0, +20)	+4% (0, +11)	Not present	**+3%**
	Flow pulse specialists	0% (0, 0)	1% (0, +3)	0% (0, 0)	0% (0, 0)	+10% (0, +23)	+9% (0, +22)	+12% (0, +57)	+2% (0, +6)	**+4%**
	Average of all native fish guilds	0	+1%	0	0	+9%	+8%	+7%	+2%	**+3%**
Waterbirds	Non-colonial nesting waterbirds	0 (0, 0)	+4% (0, +14)	0 (0, 0)	0 (0, 0)	+17% (-25, +140)	+9% (-4, +43)	+4% (0, +14)	+8% (0, +83)	**5%**
Native vegetation	Lignum	0% (0, 0)	Not present	Not present	0% (0, 0)	+42% (0, +150)	+8% (0, +20)	+2% (-3%, +11)	+4% (0, +7)	**+10%**
	River cooba (only 1 EFR tested)	0%	0%	0%	0%	+4%	0%	0%	+3%	**1%**
	River red gum	0% (0, 0)	0% (-8, +3)	0% (0, 0)	0% (0, 0)	+7% (0, +13)	+5% (0, +14)	+2% (-6, +10)	+3% (0, +7)	**+2%**
	Coolabah	Not present	+1% (0, +2%)	Not present	0% (0, 0)	Not present	Not present	+2% (0, +11)	+2% (0, +7)	**+1%**
	Water Cooch	Not present	+1% (0, +2)	0% (0, 0)	0% (0, 0)	+13% (+9, +17)	+6% (+2, +11)	0% (0, 0)	Not present	**+3%**
	Black Box	Not present	Not present	Not present	0% (0, 0	Not present	Not present	+4% (0, +11)	+3% (0, +7)	**+2%**
	Average of all native vegetation	0	+1%	0	0	+17%	+5%	+2%	+5%	**+3%**

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

These data are based on available literature and spatial datasets.

Table 12 Legend for Table 18

Used in	Legend / acronyms
Specific asset descriptions	V = Vulnerable, E = Endangered, C = CAMBA, J = JAMBA, K = ROKAMBA. [1]NSW listed threatened species, [2]listed on the EPBC Act, [3]listed in the 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 (SRA), WSP water sharing plan

Table 13 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 (PCT 53), water couch marsh grassland wetland (PCT 204), sedgeland fen wetland (PCT 361), riparian sedgeland rushland wetland (PCT 400), tall rushland, reedland or sedgeland (RVC 69), wetlands and marshes (RVC 70), tall rushlands, reedlands or sedgeland (RVC 95) • Floodplain wetlands: river cooba swamp wetland (PCT 241), lignum shrubland wetland (PCT 247), Eurah shrubland (PCT 115)
Ecological asset type – other floodplain ecosystems	FMP	• Flood-dependent forest/woodland wetland: river red gum riparian open forest/tall woodland wetland (PCT 78), river oak, rough-barked apple, red gum, box, riparian (PCT 84), black tea-tree, river oak, wilga, riparian (PCT 112) and red gum, rough-barked apple +/- tea tree (PCT 399), river red gum tall to very tall open forest/woodland wetland (PCT 36), • Flood-dependent woodland: coolabah – river cooba – lignum woodland (PCT 39), black box (PCT 37), coolabah (PCT 40), poplar box-coolibah (PCT 87), carbeen +/- coolabah (PCT 628)
Endangered Ecological Communities	FMP	• sedgeland fens wetlands EEC
Vegetation	HEVAE, FMP, LTWP	• river red gum forest & woodland, lignum, river oak riparian forest & woodland, black box, coolabah, river cooba, cumbungi, common reed, non-woody wetland vegetation
Important lagoons and wetlands (FMP, WSP listed)	FMP, HEVAE, LTWP, WRP	• Lake Goran, Nicholson's Lagoon, Barwon Nature Reserve, Baraneal Lagoons, Bungle Gully, Camp Pool, Coolahbah Swamp, Eulah Lagoon, Glen Arvon Lagoon, Gurleigh Lagoon, Krui Swamp, Lacharba Lagoons, Reedy Lagoon, Warrian Lagoon, Wee Waa Lagoon, Wirebrush Lagoon, Woodlands Billabong, Yarral Lagoon, Un-named Lagoons (x3)
Water birds	LTWP, BioNet, HEVAE, SKM, WRP	• Ducks: Australian wood duck, Australian shoveler, blue-billed duck (V)[1], freckled duck (V)[1], grey teal, hardhead, hoary-headed grebe, small grebe, Pacific black duck, Australasian grebe, pink-eared duck, wondering whistling-duck • Herbivores: magpie goose (V)[1], black swan, dusky moorhen, eurasian coot, plumed whistling duck

		• Large waders: black-necked stork (E)[1], brolga (V)[1], royal spoonbill, yellow-billed spoonbill, glossy ibis, Australian white ibis, straw-necked ibis, cattle egret, unidentified egret • Piscivores: Australian bittern (E)[1,2], Australasian darter, intermediate egret, eastern egret, little egret, white-faced heron, little pied cormorant, great cormorant, little black cormorant, nankeen night heron, Australian pelican, pied cormorant, eastern great egret (J), white-necked heron • Shorebirds: Black-tailed godwit (V)[1], Australian reed-warbler, azure kingfisher, sacred kingfisher. banded lapwing, ,Lewin's rail, marsh sandpiper (CJK), latham's snipe (JK), masked lapwing, sharp-tailed sandpiper (CJK), common greenshank (CJK), pacific golden plover (CJK), spur-winged plover, Caspian tern (J), black-fronted dotterel, black-winged stilt, red-necked avocet, tern, whiskered tern
Fish	LTWP, CEWO, SRA Fish dataset, HEVAE	• Short-moderate lived floodplain specialists: Southern purple-spotted gudgeon (E)[3], olive perchlet – Western population (E)[3], flathead galaxias (E)[3] • Flow pulse specialists: golden perch, spangled perch, silver perch (V)[2] • In-channel specialist: eel-tailed catfish – MDB population (E)[3], Murray cod (V)[2], northern river blackfish • Generalists: Australian smelt, carp gudgeon, mountain galaxias, Murray-Darling rainbowfish, bony herring, un-specked hardyhead, Darling River hardyhead
Reptiles and amphibians	LTWP, FMP, HEVAE	• Flow dependent frogs: salmon-striped frogs, spotted grass frog, broad-palmed frog, Eastern sign-bearing froglet, Fletcher's frog, common eastern froglet, desert tree frog • Other frogs: Booroolong frog (E)[2], green and golden bell frog (V)[2], Sloane's froglet (E)[2], Southern bell frog (V)[2], yellow-spotted tree frog (E) • Broad shelled turtle, eastern long-neck turtle, Murray River turtle • Other: Eastern water skink, red-bellied black snake
Other threatened biota	WRP	• River snail (E)[3]
Groundwater recharge	FMP	• Likely areas of groundwater recharge present on the floodplain
Functions	LTWP, SKM	• Nutrient, carbon and primary production

Appendix BDatasets used to refine environmental assets and values in the Namoi Valley

Table 14 Datasets used to refine assets and values and their source

Dataset	Year	Source / Reference		Details
Namoi cross section breakouts	2021	DPIE Water	DPIE Water modelling team (2021)	Identifies key breakout points where the river system models will have representative flow data for base case and implementation
Upper Namoi Floodplain Management Plan Management Zones	2019	DPIE EES	NSW Office of Environment and Heritage, Floodplain Management Plans NSW Office of Environment and Heritage (2019) 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 These are Zones: AD - major flood discharge zone; AID - major flood discharge areas with ill-defined floodways; B - secondary flood paths and flood storage; C - flood fringe and flood-protected developed areas; CU – urban areas managed by local councils; D - environmentally or culturally sensitive special protection areas
Lower Namoi Floodplain Management Plan Management Zones	2020	DPIE EES	NSW Office of Environment and Heritage, Floodplain Management Plans NSW Office of Environment and Heritage (2019) 59-61 Goulburn Street Sydney 2000	FMP Management Zones. Based on hydraulic, ecological, cultural and socio-economic criteria. Five zones are included in the FMP These are Zones: A - major flood discharge areas and defined floodways; B - flood storage and discharge areas for design floods; C - flood fringe areas and existing developed areas; CU – urban areas managed by local councils, D - environmentally or culturally sensitive special protection areas
Upper Namoi Floodplain Management Plan (2019) Ecological Assets and flood	2018	DPIE EES	NSW Office of Environment and Heritage, (2015) BRG-Namoi Regional Native Vegetation Mapping. EcoLogical Australia (2008) Vegetation Mapping for the Namoi and Border Rivers-Gwydir Catchment CMA's	Mapped distribution of flood dependent plant community types (PCT) and important lagoons, billabongs, watercourses and wetlands in the Upper Namoi

Dataset	Year	Source / Reference		Details
dependent ecological assets			EcoLogical Australia (2008a) Namoi Wetland Assessment and Prioritisation Project. EcoLogical Australia (2009) A vegetation map for the Namoi Catchment Management Authority. EcoLogical Australia (2013) Refinement of vegetation mapping in the Namoi Catchment: Extant and pre-European. Green & Dunkerley (1992) Wetlands of the Namoi Valley: Progress Report	
Lower Namoi Floodplain Management Plan (2020) Ecological Assets and flood dependent Ecological Asseta	2019	DPIE EES	NSW Office of Environment and Heritage, (2015) BRG-Namoi Regional Native Vegetation Mapping. EcoLogical Australia (2008) Vegetation Mapping for the Namoi and Border Rivers-Gwydir Catchment CMA's. EcoLogical Australia (2008a) Namoi Wetland Assessment and Prioritisation Project. EcoLogical Australia (2009) A vegetation map for the Namoi Catchment Management Authority. EcoLogical Australia (2013) Refinement of vegetation mapping in the Namoi Catchment: Extant and pre-European. Green & Dunkerley (1992) Wetlands of the Namoi Valley: Progress Report NSW Digital Topographic Database (2012) Land and Property Information: HydroArea polygon feature class	Mapped distribution of flood dependent plant community types (PCT) and important lagoons, billabongs, watercourses and wetlands in the Lower Namoi
Upper & Lower Namoi Flood Management Plan threatened fish distributions (MaxEnt)	2019	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 Upper Namoi FMP. Species include: Eel-tailed Catfish, Flathead Galaxias, Olive Perchlet, Purple-spotted Gudgeon, Silver Perch 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: Endangered Ecological Communities MaxEnt Threatened Fish distributions Recorded and known threatened species sightings (waterbirds, fish, frogs, invertebrates, plants etc). Rankings for Diversity, Distinctiveness, Vital Habitat and Naturalness
High priority Groundwater Dependent Ecosystems	N/A	Enterprise Database	Enterprise Database extracted on 24/10/2019	Mapped high priority groundwater dependent ecosystems
Important wetlands	N/A	Enterprise Database	Enterprise Database extracted on 22/10/2019	Mapped important wetlands across Australia
BioNet	N/A	DPIE EES	NSW Wildlife Atlas BIONET	Valid Records for waterbirds. List refined to water dependent assets and values based on literature
Sustainable Rivers Audit fish data	1994-2013	DPI Fisheries	Provided to DPIE Water in 2014 by DPI Fisheries	Site based fish records from the Sustainable Rivers Audit program up until 2013
LTWP planning unit records	2020	DPIE EES	DPIE Conservation and Biodiversity (2020). Namoi Long Term Water Plan Part B: Namoi planning units. NSW Office of Environment and Heritage, Goulburn St, Sydney.	Appendix B of the LTWP lists the relevant assets and values in each planning unit.

Appendix CDetailed environmental flow requirements of key water-dependent environmental assets and values in the Namoi Valley

Table 15: Footnotes for Table 18

Footnotes
[1](Roberts & Marston, 2011), [2](DPIE-EES, 2020a), [3](Scott, 1997), [4](NSW Department of Primary Industries, 2015), [5](DPIE-EES, 2020b), [6](SKM, 2009), [7](NSW Department of Primary Industries, 2019), [8](Ballinger, Nally & Lake, 2005), [9](MDBA 2015, Fish and Flows in the Northern Basin: responses of fish to changes in flow in the Northern Murray-Darling Basin – Reach Scale Report)
N/A = No detail or unable to assess accurately, y = years, m = months, d = days, EO = flow requirement based on the expert opinion of DPE Water Ecohydrologist

Table 16 16 Details of the environmental flow requirements of key water-dependent assets and values used in this report

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
Native fish					
Short-moderate lived floodplain specialists:	Frequency	Every 2 years[7,2] Max inter-event period of 4 years[2,7]	$\leq 2^{y}$ $\leq 4^{y}$	3-5 years in 10[4,2] Max inter-event period of 2 years[2]	≥ 3 in 10^{y} $\leq 2^{y}$
	Duration	>10 days[7]	$\geq 10^{d}$	>10 days to allow egg development[2,4,7]	$\geq 10^{d}$
Olive perchlet, flathead galaxias etc	Timing	October to April for spawning habitat[2,7] Summer for increased food resources and to maintain refugia[4]	Oct-Apr Summer	September to October is the most common across species[4]	Sep-Oct
	Other	Dispersal dependent on floods and flood size[2]	N/A	Secondary event after spawning (i.e. summer) enhances recruitment[4] Gradual recession of events important for dispersal of larvae and juveniles[4] Large flow events required post spawning to connect channel and floodplain[9]	Spring event followed by Summer
Generalists:	Frequency	5 to 10 years in 10 years[2] 2 to 3 years in 10[2]	≥ 5 in 10^{y} ≥ 2 in 10^{y}	2 in 10 years in 10[7] 5 to 10 years in 10[2]	≥ 2 in 10^{y} ≥ 2 in 10^{y}
Australian smelt, Murray-Darling rainbowfish, bony herring, etc	Duration	5 days[7]	$\geq 5^{d}$	>14 days to allow egg development[2]	$\geq 14^{d}$

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
	Timing	Spring to summer[7]	Spr-Sum	October to April flows enhance spawning and provide habitat and resources for recruitment[2]	Oct-Apr
	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]	Spr-Aut with an event no more than 2 months prior
Flow pulse specialists: golden perch, spangled perch, silver perch	Frequency	2-3 years in 10[2] Maximum interflow period of 5 years[2]	≥2 in 10[y] ≤5[y]	2-5 years in 10[2] 2-3 years in 10[4] Maximum interflow period of 4 years[2]	≥2 in 10[y] ≤4[y]
	Duration	5 days [2,9]	≥5[d]	5 days [2, 7]	≥5[d]
	Timing	Aug – Feb [2,7]	Spr-Sum	Spr-Aut[4]	Spr-Aut
	Other	Velocities of 0.3 $m.s^{-1}$ required for ideal habitat[7]		Rapid recession assists with egg dispersal and to trigger spawning[4] Subsequent events enhance recruitment and dispersal outcomes[4] Temperature >17°C[2]	
Waterbirds					
Non-colonial waterbirds	Frequency	1 years in 10 3 years in 10 4 years in 10 5 years in 10[2] Maximum inter-event period of 4, 5 and 10 years[2]	≥1 in 10[y] ≥3 in 10y ≥4 in 10y ≥5 in 10y ≤4y, ≤5y, ≤10y	1 years in 10 3 years in 10 4 years in 10 5 years in 10[2] Maximum inter-event period of 4, 5 and 10 years[2]	≥1 in 10[y] ≥3 in 10y ≥4 in 10y ≥5 in 10y ≤4y, ≤5y, ≤10y
	Duration	Duration, or days with flow of 1 days or more Duration, or days with flow of 2 days or more Duration, or days with flow of 5 days or more Duration, or days with flow of 10 days or more	≥1 ≥2 ≥5 ≥10	Duration, or days with flow of 1 days or more Duration, or days with flow of 2 days or more Duration, or days with flow of 5 days or more Duration, or days with flow of 10 days or more	≥1 ≥2 ≥5 ≥10
	Timing	Small to medium floods can be anytime[2] Frequency of floods occurring between September and April[2]	N/A Sep – April	Small to medium floods can be anytime[2] Frequency of floods occurring between September and April[2,3]	N/A Sep – April

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
		Frequency of floods occurring between September and February[2] Frequency of floods occurring between August and February[2]	Sep-Feb Aug-Feb	Frequency of floods occurring between September and February[2,3] Frequency of floods occurring between August and February[2,3]	Sep-Feb Aug-Feb
Native vegetation					
Shrublands					
Lignum (shrubland wetlands) *Muehlenbeckia florulenta*	Frequency	Once in 1-3 years for large shrubs[1,8] Once in 7-10 years for smaller shrubs[1,8]	≥1 in 3^y ≥1 in 7^y	Seedlings watered once per 12 to 18 months over first three years: desirable[1]	≥1 in 1.5^y
	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[1,8] Seedling establishment before or during summer[1,8]	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					
Blackbox *Eucalyptus largiflorens*	Frequency	Once every 3-7 years[1] Maximum of 5 years between event[2]	≥1 in 7^y ≥1 in 5^y	Small inundations in the first and second year improve seedling establishment[1]	≥1 in 2^y
	Duration	Improved number of flow days	Total number of flow days	Improved number of flow days during Spring-Summer[1]	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 *Eucalyptus Coolabah*	Frequency	1 to 4 years in 10[2] The maximum inter-event period is 5 years[2]	≥1 in 10[y] ≤5[y]	Small inundations in the first and second year improve seedling establishment[1]	≥1 in 2[y]
	Duration	Improved number of flow days[2]	Total number of flow days	Improved number of flow days during Spring-Summer[1]	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[1] Seedlings vulnerable to desiccation in summer[1]	Spr-Sum
	Other	Maximum of 10 years between events[2]	≥1 in 10[y]		
River cooba *Acacia stenophylla*	Frequency	Once every 3-7 years[1]	≥1 in 7[y]	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
River red gum *Eucalyptus camaldulensis*	Frequency	Forests: every 1-3 years[1] Woodlands: every 2-4 years[1] Floodplain: 3-5 years in 10[1] Max inter-event period 4-5 years[2]	≥1 in 3[y] ≥1 in 4[y] ≥2 in 10[y] ≤5[y]	Follow up flood in 1st or 2nd year is desirable[1]	≥1 in 2[y]
	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] August – February[2]	Aug-Feb	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[1]	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[y]	Not known	N/A
	Duration	5-8 months[1]	≥5[m]	Not known	N/A

Asset	Hydro feature	Maintenance	Value used	Regeneration/Reproduction	Value used
	Timing	Start in late winter or spring with flooding over summer critical[1]	Win-Sum	Not known	N/A
	Other	Depth is critical, shallow is best[1]	N/A	Seeds short lived so if regeneration via seeds is desired annual flooding is recommended[1]	≥1[y]

Appendix DFurther 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). Discussing the intricacy of each model will not be done within 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 *NSW Floodplain Harvesting 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 the following model scenarios.

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) is available for the end of system (EOS) floodplain breakouts below each floodplain harvesting breakout zone. Modelled data covers 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, DPIE Water 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 hydrological 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 hydrological 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 hydrological models.
- The adopted approach assumes that meeting an environmental flow requirement 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 DPIE Water 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 EFRs like those in the *Long-Term Water Plans* developed for each valley by DPE EHG. 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. DPIE Water 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 LTWP 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 licenced 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[10].

Table 17 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 (from the NSW Long-term water plans)
EFR	Environmental flow requirements (compiled for this report)
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

[10] 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 18 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 (DPE Water, 2022b))
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 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 (DPE Water, 2022b))
the *policy*	Shortened term for the *NSW Floodplain Harvesting Policy*