Australian Government

MURRAY–DARLING BASIN AUTHORITY

Environmental outcomes of the Northern Basin Review

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Environmental Outcomes of the Northern Basin Review

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Cover image: The Darling River at Bourke, May 2016. Photo by Willem Vlotman.

Accessibility

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray–Darling Basin Authority acknowledges and pays respect to the Traditional Owners, and their Nations, of the Murray–Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. The MDBA understands the need for recognition of Traditional Owner knowledge and cultural values in natural resource management associated with the Basin.

Darling River, Bourke (photo by Josh Smith)

Contents

What is this report about?

This report, *Environmental outcomes of the Northern Basin Review,* is about how different levels of water recovery will affect the ecological health of the river environment in the northern Murray–Darling Basin. This report is one of a suite of reports prepared for the Northern Basin Review.

What is in this report?

The report describes how different water recovery scenarios may maintain or restore ecologically important elements of the flow regime, such as base flows, in-channel freshes and overbank flows.

A diversity of flows are essential to support the life-cycle needs of plants and animals and achieve environmental outcomes.

What are environmental outcomes?

Environmental outcomes include improved native fish numbers and distributions, more frequent opportunities for waterbird breeding and increased numbers, and healthier streamside and floodplain vegetation.

What information is this report based on?

The findings of this report are determined by identifying flow events (indicators) that support particular plant/fish/waterbird life cycle needs, and using these in a long-term hydrological model to predict environmental outcomes and risks for different water recovery scenarios.

What is the Northern Basin Review?

The Basin Plan seeks to deliver vibrant communities, productive industries and healthy rivers. The Northern Basin Review aims to provide information to support this vision; and specifically review the current Basin Plan recovery target of 390 GL of water for the river systems of the north.

Recommendations of the review may lead to resetting the amount of water to be recovered for the northern Basin.

Is the review about more than just a volume of water?

Yes. Northern basin communities have explained that any solution to a healthy working Basin must consider more than a volume of water. Consideration of the management activities required to compliment water allocations also need to be taken into account

What else is in the review?

In addition to the environmental outcomes summarised in this report, the Northern Basin Review is also assessing social, cultural and economic impacts associated with different water recovery scenarios in the northern Basin.

Do communities have a say?

Yes, they do. There is a formal Basin Plan amendment process in 2016–17. As part of that process, people have opportunities to provide their views to the Murray–Darling Basin Authority.

OUTCOMES

Water recovery will restore some key elements of the flow regime which have been impacted by development.

The effectiveness of water recovery depends on where and what water is recovered (location and entitlement types).

Targeted water recovery can help achieve particular flow indicators, and therefore environmental outcomes, with less water.

The number of flow indicators achieved improves with increasing water recovery (from 16 out of the 43 indicators up to 24 flow indicators).

24 flow indicators were achieved by the 415 GL recovery scenario. 16 flow indicators were achieved by the 278 GL scenario (which represents current water recovery levels).

Long term model outputs are insightful when making planning decisions but are only one line of evidence being used by the MDBA. Operational management decision as well as social and economic information and community views are equally important.

We recognise that other management measures (toolkit) add to water recovery to support and improve environmental outcomes. Toolkit measures will also assist with the effective and efficient delivery of environmental water, making sure we make the most of water that has been recovered.

RISKS

Water recovery alone cannot restore all elements of the flow regime that are important to the river system's ecology.

Regardless of the water recovery scenario modelled, at least 19 of the 43 flow indicators were not met (under the 415 GL scenario). The highest number of indicators not met was 27 out of the 43 flow indicators (278 GL scenario).

This means that a level of risk remains for supporting sustainable ecology in the northern basin into the future.

The results indicate that the risks are likely to be present across many aspects of the northern basin ecology are spread unevenly across the northern basin landscape.

These risks are associated with impacts to native fish species and populations, the ability of nesting waterbirds to achieve large-scale breeding events, and the health and resilience of floodplain wetland vegetation.

The outcomes described in this report can only be delivered if supported by effective operational management.

TOOLKIT MEASURES

There are a range of complementary measures not based around a volume of water that will help achieve better environmental outcomes in the Northern Basin. Collectively these measures provide the operational flexibility essential to protect, coordinate and boost environmental outcomes for particular flow events as they pass through the system.

- Protection of environmental flows is critical to meeting environmental outcomes and the community is demanding attention on this aspect of water reform.
- The Basin Plan is about making the most of every drop of water—that is, ensuring all water can be effectively used for agriculture and the watering of environmental assets. To this end, measures that assist in effectively delivering flow are also critical. These include: market based mechanisms, and improved ability to manage and coordinate flows.
- Environmental outcomes are linked to more than water. Outcomes can be boosted through other means. River health can also be supported through other measures such as addressing impediments to higher flows (which are very important for the environment); investment in infrastructure such as fishways; and measures to reduce the effects of cold water pollution. Investments such as these will also provide some economic offset for a number of communities across the North.

The Authority has recognised and will consider the need for toolkit measures as part of their decision, water recovery advice and SDL recommendation.

Brewarrina fishway on the Barwon River 2015

About this report

This report summarises the findings for one key component of the Northern Basin Review. The report describes how different modelled water recovery scenarios may affect the flow regime of northern basin rivers, and in turn, how this may affect environmental outcomes. The report also describes what additional measures (referred to as toolkit measures) may be useful in securing and strengthening these environmental outcomes.

The report should be read in conjunction with other reports from the review that address the social, cultural and economic impacts associated with the water recovery scenarios. The decision on whether or not to amend the current legislated sustainable diversion limit for the northern basin is based on finding a balance between social, cultural and economic impacts using a triple bottom line assessment.

The findings presented here are the culmination of the environmental science element of the Northern Basin Review undertaken by the Murray-Darling Basin Authority. This report describes the assessment of how well different water recovery scenarios in the northern Murray–Darling Basin may potentially maintain or restore elements of the rivers' flow regime (i.e. base flows, in-channel freshes and overbank flows). How effectively elements of the flow regime are maintained or restored link to positive environmental outcomes, such as improved native fish numbers and distributions, more frequent opportunities for waterbird breeding and increased numbers, and healthier streamside and floodplain vegetation.

The environmental science element of the Northern Basin Review commenced with a range of scientific reviews and field studies that were undertaken on northern basin fish, birds and plants, in order to build upon the existing knowledge base. This work was focused on the Barwon–Darling and Condamine–Balonne catchments and was used primarily to describe updated environmental water requirements for the Barwon–Darling, Lower Balonne and Narran Lakes catchments through description of a set of ecologically important flow indicators. The environmental science information was also used to support the environmental water requirements of the other northern basin catchments, although the 2012 reports and flow indicators for these catchments were not updated. A map showing the locations of these catchments (in context with the southern basin) is shown in Figure 1.

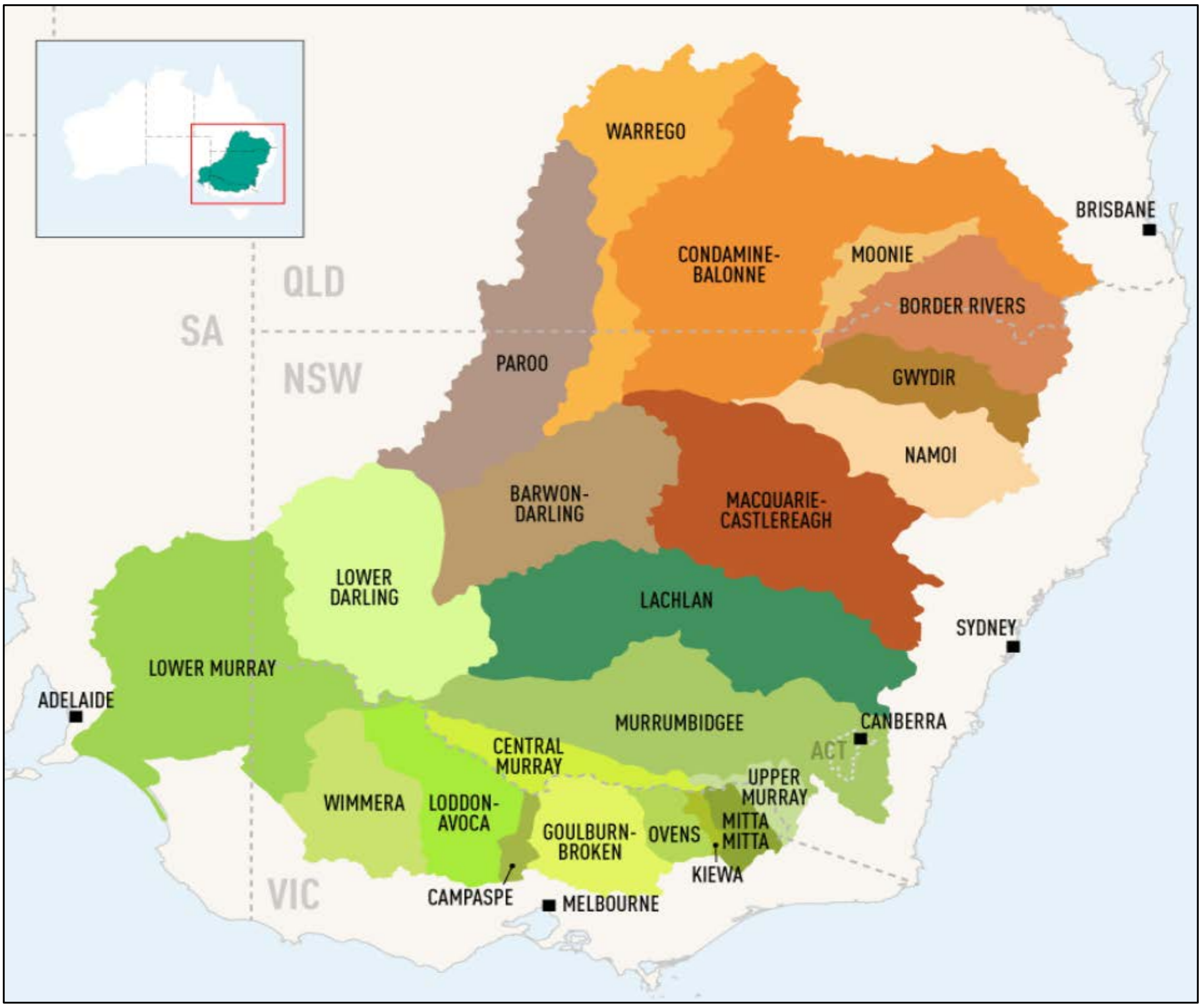


Figure 1: The catchments of the Murray–Darling Basin, spanning the southern (Murray) basin and the northern (Darling) basin.

Using a hydrologic modelling framework (see CSIRO 2008; Yang 2010; and MDBA in prep.b), we then assessed how effectively each water recovery scenario could meet the environmental water requirements (as described by 43 different flow indicators) and therefore the expected environmental outcomes of the northern basin catchments. We recognise that hydrologic models provide important planning insights, but are necessarily an approximation of the true complexity of the system (see environmental complexity, assumptions and uncertainty section). Models also do not tell us how to manage the system on an event by event real time basis. Thus, although model results are an important tool that the Authority uses in coming to a decision on recommending Sustainable Diversion Limits, they are not the only line of evidence. Management actions required to effectively manage and deliver environmental water are also considered. In addition to the environmental assessment, the outcomes of economic and social studies and community views are also included, with equal importance, in the Authority's decision making process.

The **Results** sections of this report presents a collated description of the potential environmental outcomes for the entire northern Basin, based on the modelling outputs. This is followed by a section that reports on potential outcomes for the catchment of each of the seven umbrella environmental assets that we look at in detail.

In brief, the results show that the effectiveness of water recovery is influenced by the amount of water recovered as well as the location of water recovery and the type of water recovered (i.e entitlement type). Targeted recovery can help achieve particular flow indicators with less water, however targeting can result in trade-offs and reduced outcomes in other areas. With a combination of water recovery and targeting, some key elements of the flow regime that have been impacted by development can be restored.

The modelling results show the potential to restore between 16 and 24 of the 43 northern basin flow indicators, depending on what water recovery scenario is being considered. This represents a likely environmental improvement for some areas of the northern basin. For example, in many northern basin rivers (but not all) there would likely to be more freshes to connect habitats along the river and stimulate fish to breed and move. Some catchments would get more frequent bank-full and overbank flows that would maintain floodplain vegetation condition; provide a diversity of habitats for feeding and breeding of fish; and provide for nutrient exchange between terrestrial and aquatic systems.

However, given that the modelling results show that between 19 and 27 flow indicators cannot be achieved regardless of water recovery scenario, a level of environmental risk will remain in the northern basin. For example, in the Lower Balonne base flows and small fresh flow indicators show little improvement. These flows are particularly important for breaking up extended dry-spells, and if not achieved risk the potential for local extinction or reduced/slower recovery by many aquatic species upon return to wetter conditions. There is also little improvement in the Barwon-Darling wetland and floodplain flow indicators and the bank-full and inner floodplain watering needs of the Lower Balonne. Over the longer term this could result in vegetation stress with increasing dry-spell length likely to lead to changes in floodplain vegetation composition and condition, moving towards less water dependent species.

A full description of both the potential environmental risks and benefits expected from the various water recovery scenarios under investigation is detailed in the results section of this report.

Speaking with community groups, research scientists, and community representatives has been a critical part of the Northern Basin Review information gathering and assessment process. A critical finding in this process was that the potential environmental benefits are likely to be heavily dependent on the implementation of other non-volumetric management measures. These measures (termed toolkit measures) could mitigate some of the identified risks, as well as enhance some of the benefits. They include opportunities such as:

- **Protection of environmental flows** such as re-crediting flows that return to the river. Implementation could result in better low flows and in-channel connectivity in the Condamine–Balonne and Barwon–Darling.
- **Targeted recovery of water entitlements** in high priority areas within catchments. Implementation could result in improved Narran Lakes outcomes (through targeting of in-stream Narran River entitlements), Lower Balonne floodplain outcomes (through targeting of overland flow licenses) and Barwon–Darling outcomes (through targeting of Barwon–Darling entitlements and some benefits from well-connected tributary recovery).
- **Market-based mechanisms** such as one-off temporary trade by event, options over pumping (enduring agreements) and store and release from private storages. Implementation could result in enhanced environmental outcomes across a range of

catchments; but is less useful in places where large volumes are required (e.g. Barwon–Darling bank-full and overbank flows).

- **Improved coordination of environmental water** where release of environmental water is coordinated with other river operations to compliment natural events. Implementation could result in improved frequencies of in-channel freshes in the Barwon–Darling.
- **Constraints management** such as strategies to remove impediments to higher flows in some catchments, such as the Gwydir. This could results in significant environmental outcomes, often related to floodplain and wetland processes.
- **Infrastructure** investment such as the implementation of fishways to improve fish passage at barriers, which would significantly enhance the native fish outcomes that can be achieved with environmental water. Other examples include screening of intake pipes at major irrigation offtakes.
- **Mitigation of cold water pollution** caused by release of water from lower depths of dams. Implementation of mitigation measures at large dams (for example, the thermal curtain that was installed at Burrendong Dam in 2014) could result in enhanced water quality outcomes, especially for fish.

The possible implementation of many of these toolkit measures is the responsibility (potentially jointly) of the Commonwealth and state governments, and Commonwealth and state environmental water holders. Risks including third party impacts, relevant state and Commonwealth legislation, and the financial costs associated with the development and implementation of these measures must be taken into consideration. The Authority will consider and include the need for toolkit measures as part of their decision and water recovery advice and SDL recommendation.

How will the environmental outcomes information be used?

The Northern Basin Review assesses the likely social, economic and environmental outcomes for nine water recovery scenarios (including current Basin Plan settings). The scenarios include recovery volumes that are above and below the volume that is currently legislated in the Basin Plan.

The Murray–Darling Basin Authority will use a triple bottom line framework to recommend a final water recovery scenario that best balances social, economic and environmental outcomes. The triple bottom line framework facilitates decisions that are consistent and transparent, by applying and documenting social, economic and environmental information at each step of the decision-making process.

The findings and analysis contained within in this report will work directly with the triple bottom line framework to enable the Authority to transparently demonstrate key environmental considerations; and logically and clearly set out the objectives and measures of economic, environmental and social criteria (see Appendix A for a full list of key documents).

The framework also enables an assessment of other important considerations beyond the information base, including the practicality of water recovery and equity between States and catchments.

About the Northern Basin Review

The development of sustainable diversion limits for the northern part of the Murray–Darling Basin required more information than was available at the time that the Basin Plan was released. Hence the Northern Basin Review was implemented to improve the information available and refine the limits, to balance water for the environment, agriculture and the community.

The Murray–Darling Basin is a working basin and its future depends on securing the health of the natural environment, so that adequate amounts of good quality water are available to water users and for environmental requirements. Recognising the modern pressures on water resources in the Basin, especially in a time of drought, the Australian Government passed the Water Act 2007 (Cwlth), with bipartisan support in the Australian Parliament. As a requirement of the Water Act, the MDBA was required to develop the Basin Plan, with the primary objective of determining a sustainable diversion limit in the Basin.

Implemented in 2012, the Basin Plan is a framework that guides governments, regional authorities and communities to sustainably manage and use the waters of the basin. The Basin Plan seeks to balance the water needs of communities, industries and the environment in order to achieve a healthy working basin into the future. The Basin Plan defined sustainable diversion limits (SDLs) for water extraction for each catchment and aquifer in the Basin, as well as an overall limit for the Basin as a whole. The sustainable diversion limits are like a new 'cap' on water use. They regulate the amount of water that can be used for consumptive purposes in the Basin.

At the time of finalising the Basin Plan it was decided that there would be a review into specific aspects of the Basin Plan in the northern Basin, acknowledging that the information base used for determining water recovery in the northern Basin was not as well developed as that used for the southern Basin. The Northern Basin Review was implemented to improve the information used to develop sustainable diversion limits in the north. The Northern Basin Review includes research and investigations in social and economic analysis, hydrological modelling, and environmental science, supported by stakeholder engagement. The review is re-applying the established and the peer reviewed 'Environmentally Sustainable Level of Take' method with updated environmental information specific to the northern basin, and will lead to either the resetting of the sustainable diversion limits for the northern basin, or a recommendation for no change to the currently legislated arrangements.

If a new sustainable diversion limit is recommended by the Murray-Darling Basin Authority, (including the volume of the northern-shared reduction and the Condamine–Balonne local reduction), the Murray–Darling Basin Authority will follow the process for formally amending the Basin Plan, as set out in legislation. This includes inviting states and the broader community to make submissions, considering submissions and preparing a consultation report. This process takes about 12 months. The Murray–Darling Basin Authority Northern Basin Review webpage will be regularly updated to show how the community can continue to be involved as the formal amendment and consultation process takes place.

Background on water resource development and river flows

Although largely unregulated, particularly compared with the southern Murray–Darling Basin, water resource development in the northern Basin has grown rapidly over the past twenty or so years, changing the way many rivers flow.

The expansion of irrigation and intensification of agricultural practices in northern New South Wales and southern Queensland has been rapid and dramatic. Irrigated agriculture has expanded in area and spread westwards along virtually all of the major river valleys. For example the Lower Balonne floodplain has undergone significant change with the development of irrigated cotton, made possible by the development of large-scale flood harvesting schemes and on-farm water storages.

Before the Basin Plan, under the water sharing arrangements in 2009, estimated long-term average flows in some areas of the Condamine–Balonne and Barwon–Darling catchments were around one-third to a half of what they would have been without development. Taking two thirds to a half of the water out of the river system has significant consequences for how rivers flow and the condition of the surrounding floodplain environments. This is particularly true for downstream areas.

The further downstream that a community, a farm or an environmental site is, the greater the impact is of water management decisions and actions taken by upstream landholders and water managers. In recent years, the largest reduction in flows impacting communities, economies and the environment are seen in the lower parts of the Condamine–Balonne and Barwon–Darling catchments (Table 1, Figure 2 and Figure 3).

The currently legislated Basin Plan aims to reduce total water extraction across the north, meaning more water will be left in the rivers so they are better placed to provide values for all river users in the long term. The amount of water available for consumptive use (i.e. not environmental water) is termed sustainable diversion limit (SDL). The current SDL for the northern Basin is 390 GL.

Table 1: Comparison of long-term average flows: modelled without development, baseline (2009) and Basin Plan (390 GL water recovery); at selected river gauge stations in the Condamine–Balonne and Barwon–Darling catchments.

Flow metric	Culgoa River at Brenda	Narran River at Wilby Wilby	Darling River at Bourke	Darling River at Wilcannia
Without development long-term average flow	620 GL/year	159 GL/year	3,812 GL/year	2,819 GL/year
Baseline (2009) long-term average flow	224 GL/year (36% of without development	75 GL/year (47% of without development	2,152 GL/year (56% of without development	1,528 GL/year (54% of without development
Basin Plan (390 GL recovery) long -term average flow	295 GL/year (48% of without development	93 GL/year (58% of without development	2,362 GL/year (62% of without development	1,711 GL/year (61% of without development

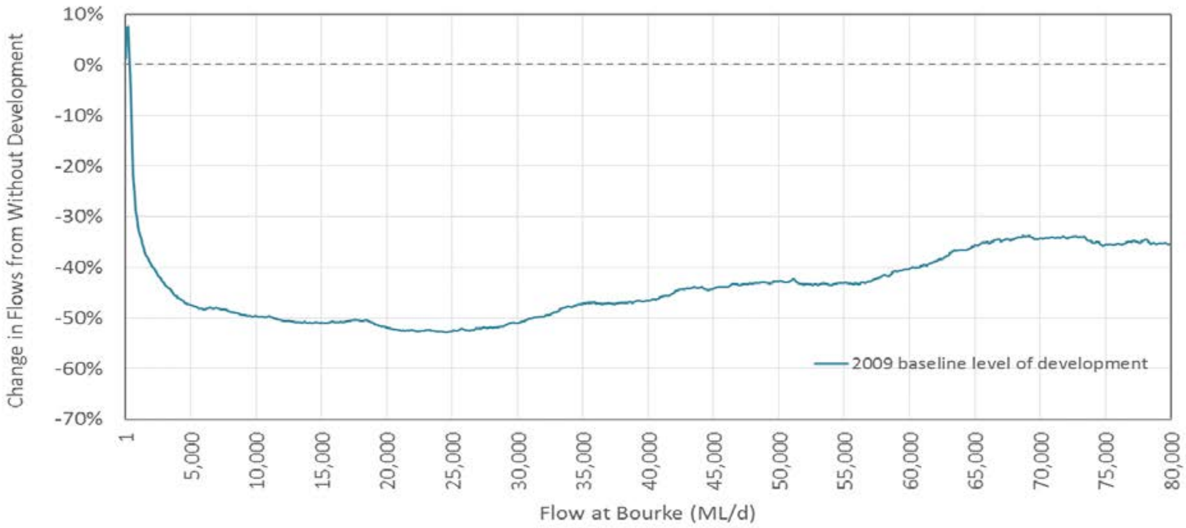


Figure 2: Percentage change in daily time-step modelled flows in the Darling River (at Bourke gauge) from without development condition (dotted line) to 2009 baseline levels of development (blue line).

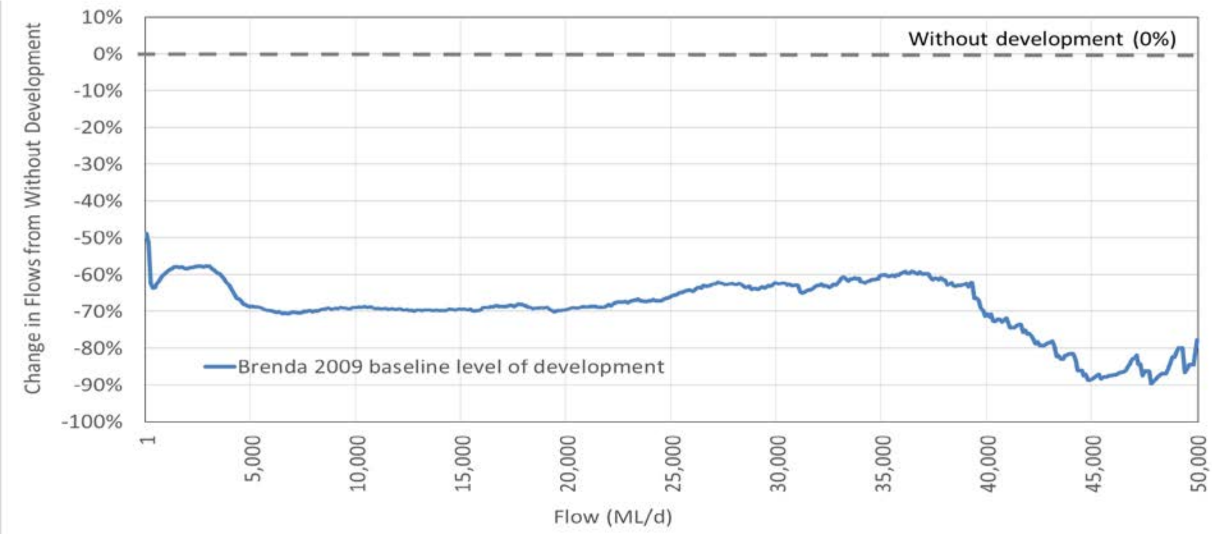


Figure 3: Percentage change in daily time-step modelled flows in the Culgoa River (at Brenda gauge) from without development condition (dotted line) to 2009 baseline levels of development (blue line).

What types of river flow are important?

The quantity and quality of the river and floodplain environment is controlled by the way rivers flow. River channel flows and overbank flows are flows of different sizes that water different parts of the landscape (Figure 4). Hydrological connectivity is a key concept used in this report. Hydrological connectivity is about where and how often water flows, including along rivers and between the river and its floodplain (Figure 5), and flows that create and support vital habitats.

- **River channel connectivity (longitudinal)** — a range of flows in the river channel help support its connectivity both upstream and downstream. Flow sizes can include base flows and small and large freshes. These flows are important for maintaining, and providing access to a variety of in-stream habitats for a range of native aquatic species (e.g. fish, frogs, turtles, invertebrates). They also boost in-stream production and nutrient transfer. Larger in-channel freshes are important for fish movement and breeding, as they can trigger spawning in some species, and drown out in-stream barriers to provide fish with opportunities to move large distances.

- **Wetland / floodplain connectivity (lateral)** — a range of overbank flow sizes provide hydrological connections between the river and its floodplains and wetlands. Overbank flows are important for: supporting flood-dependent native vegetation; providing a diversity aquatic habitats (e.g. temporary wetlands) for foraging, breeding, and re-colonisation by fish, frogs, turtles and invertebrates; groundwater recharge and grassland productivity; and providing for nutrient exchange between terrestrial and aquatic systems. Large overbank flows can also promote processes such as large-scale recruitment of vegetation on the floodplain.
- **Vital habitat (drought refuges)** — these are habitats such as waterholes that provide a refuge for native water-dependent biota during dry periods and drought. These habitats are supported by a range of flow sizes, but are particularly reliant on base/low flows to keep waterholes healthy, waiting until larger flows to reconnect them to the broader river reach.
- **Vital habitat and populations (waterbirds)** — provide for a diversity of important feeding, breeding and nursery sites for waterbirds and conditions conducive to large-scale bird breeding. These habitats are supported by regular small overbank flows to maintain the condition of vegetation used as breeding habitat, and by occasional larger overbank flows that support successful large scale waterbird breeding events.

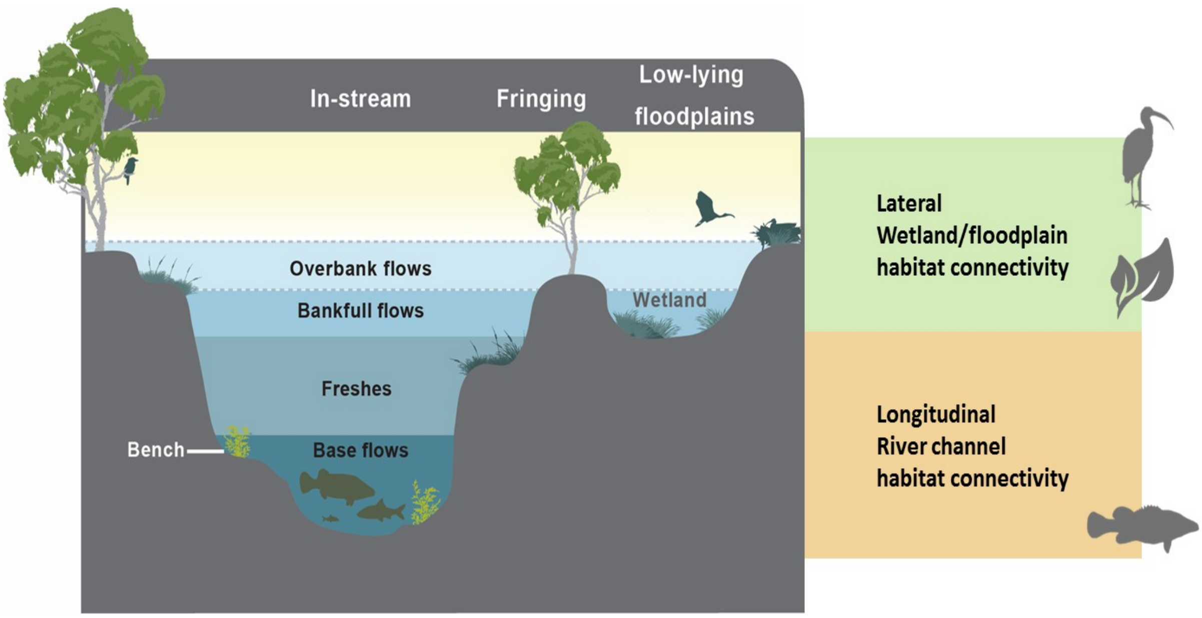


Figure 4. The range of flow sizes that connect different areas of the landscape

Figure 5: Conceptual diagram of longitudinal (river channel) and lateral (wetland/floodplain) connectivity in a river system

The environmental outcomes assessment process

What are umbrella environmental assets and flow indicators?

Northern basin catchments are ecologically complex, often data poor, and as such need to be represented by a smaller area within the catchment, called an umbrella environmental asset. The seven umbrella environmental assets are generally located at or near the bottom of the system (e.g. large terminal wetlands, lowland floodplain complexes) and below major areas of water extraction (e.g. dams and irrigation districts); and it is assumed that the water that reaches these asset areas will have flowed through and provided environmental benefits to areas upstream.

The seven umbrella environmental assets, and the catchment they are located in, are the:

- Barwon–Darling river system (Barwon–Darling)
- Lower Balonne River floodplain system (Condamine–Balonne)
- Narran Lakes (Condamine–Balonne)
- Gwydir Wetlands (Gwydir)
- Lower Border Rivers (Border Rivers)
- Lower Namoi River (Namoi)
- Macquarie Marshes (Macquarie–Castlereagh).

In each umbrella environmental asset, a set of flow indicators were described. Flow indicators are flow events that seek to support a particular environmental outcome (e.g. waterbird breeding in Narran Lakes; large scale movement opportunities for native fish in the Darling River; etc.). The flow indicators, working as a set, are also expected to support a wider range of ecological processes.

Flow indicators are described in terms of:

- an amount of water (e.g. a flow rate, 5 ML/d; or a total volume, 50 ML)
- at a particular river gauging station (e.g. Brenda gauge - see Figure 2 for a full list of gauges and geographic location)
- for a specific minimum duration (e.g. for a minimum of 20 days)
- a specific timing (e.g. between January and May)
- a frequency target range.

The **frequency target range** represents how often the flow indicator should be occurring. The frequency target range is based on the environmental outcomes it is trying to achieve (e.g. 40–50% of years with an event). Target ranges are typically based on specific pieces of evidence, such as the life-cycle needs of fish, waterbirds and floodplain plants, or the likely persistence times of refuge waterholes. The range is generally specified as a frequency point where there is a high likelihood that the ecological outcome being target will occur (termed low uncertainty); and a frequency point where beyond which is a low likelihood that the outcome being targeted will occur (termed high uncertainty). These flow indicators are linked to specific ecological requirements such as native fish movement and spawning; waterbird breeding; and watering of riverbank and floodplain vegetation (measured at specific locations as shown in Figure 2).

Some indicators are nested, which means that larger flows can also achieve smaller flow indicators. All flow indicators are categorised into different flow types, such as base flows, small freshes, large freshes and floodplain and wetland flows. They work together to achieve stated broader environmental targets for the catchment, and are outlined in detail in the relevant Environmental Water Requirements reports.

Figure 6: Locations of the gauging stations used to describe flow indicators across the northern Basin

How MDBA uses flow indicators to assess environmental outcomes

Each flow indicator is tested, against a range of different water recovery scenarios, to see if it occurs as often as required (i.e. is the target frequency range met, or not met). Some water recovery scenarios target more water for the environment (meaning that generally, more flow indicator targets are met); while other water recovery scenarios leave more water for other uses (generally meaning less flow indicator targets are met). This testing is done using hydrological models. The hydrological models are computer models that we use as planning tools. They have over 100 years of historical flow data and climatic conditions, spanning 1895–2009, as well information about how rivers are managed (state water resource plans). The models are a representation of the real world that include a number of assumptions about how the system operates, including deliverability considerations (MDBA in prep.a).

To put the frequency results of the flow indicators into context, we also work out how often the flow indicators would have happened under '**baseline'** and '**without development'** using different model settings. The flow indicator targets generally sit in between these two points. Importantly, water recovery is not trying to restore without development conditions.

Baseline applies to 2009 levels of development (representing the relevant regime of water harvesting, regulation and operating rules) over the historical flow record to understand the implications of this level of development over the longer term. This typically shows that small and medium flows happen less often and dry spells are much more frequent and longer with development, compared to 'without development' (Figure 7).

Without development is a modelled estimation of what the flow record would have been if there was no water harvesting across the entire flow record. This typically shows small and medium flows happening much more often and that dry spells were shorter than those under the 2009 baseline levels of development (Figure 7).

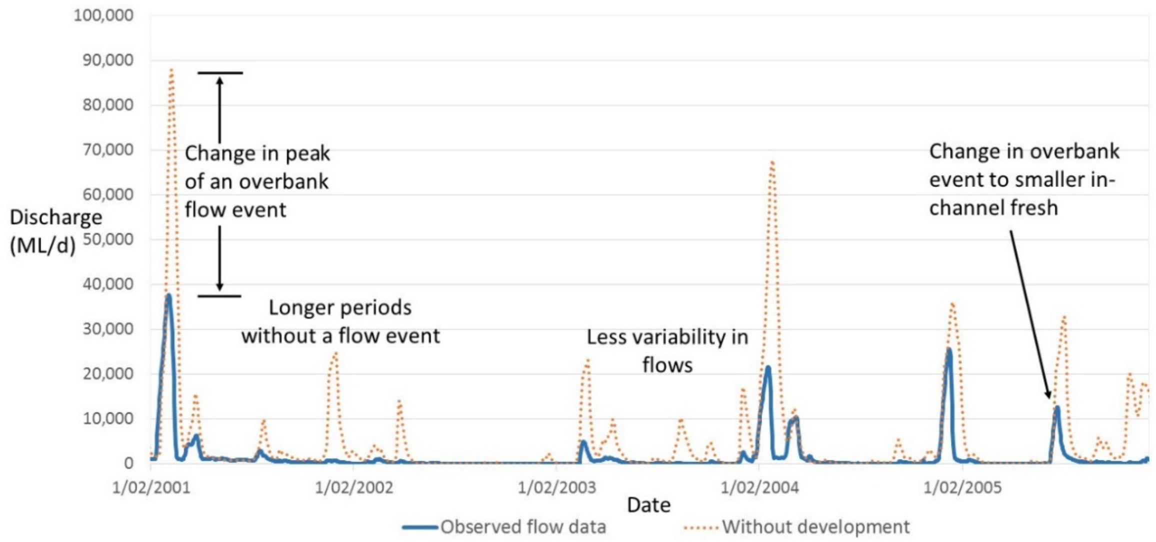


Figure 7: Historical flows at Bourke on the Darling River. Observed flows and estimated without development flows highlight changes to the flow regime arising from water resource development.

When each scenario is assessed, the following outcomes are possible:

- the flow indicator target ranges are achieved (the frequency under a particular scenario meets the target range)
- the flow indicator frequency is improved from baseline (the target range has not been met under a particular scenario, but improvement in frequency has been achieved).

For information and results on the individual flow indicators, and whether or not they met the frequency targets, see Appendix C. The time between flow indicator events occurring (e.g. the maximum time period between events across the 114-year model period) is also assessed using *spells analysis*. For additional detail on these assessment methods see Appendix B. Raw data on spells analysis is at Appendix E

How many flow indicators meet the target range for a particular umbrella environmental asset, under a particular water recovery scenario, gives us an indication of what sort of ecological outcomes could be expected under a particular water recovery scenario for the entire catchment. Depending on what flow indicators are met, environmental outcomes that can maintain the ecosystem processes and build resilience across species populations and communities could include:

- more base-flows or small freshes reducing the length of no-flow periods and increasing the likelihood that a network of refuge waterholes will persist through dry times in order to support plants and animals
- more large freshes providing opportunities for fish to move up and down the river channel over large distances, and for some species a strong stimulus to breed
- more bankfull or overbank flows providing opportunities for successful waterbird breeding, boost to plant condition and growth, and for fish to access the floodplain as important nursery and feeding habitat.

This information is then used to determine what water recovery scenarios best meet the environmental needs of the northern Basin.

What water recovery scenarios are being looked at?

Nine water scenarios are being looked at, which vary by how much water is recovered from the northern Basin catchments, and/or by modelling assumptions, such as how and where the water is recovered.

The Northern Basin Review assesses the likely social, economic and environmental outcomes for nine water recovery scenarios, which are above and below the volume that is currently legislated in the Basin Plan.

The development of water recovery scenarios evolved as initial assessments raised new issues to consider. The first step defined a set of scenarios that differed in terms of volume recovery but had the same hydrological modelling assumptions.

The second step in the development of scenarios added three new scenarios that tested different modelling assumptions. These included: the influence of targeting where water is recovered from and the mix of entitlement types; the ability for river operators to call on regulated flows to top-up unregulated flows (flow coordination); and how water recovery is shared between New South Wales and Queensland to maintain equity between the states and entitlement holders.

The third step took learnings from the first seven scenarios and developed two additional refined scenarios. These sought to improve environmental outcomes while limiting social and economic impacts. The evolution and general differences between the scenarios is described in Table 2, Table 3 and Table 4.

The environmental outcomes of these nine scenarios are assessed in this report. The scenarios differ in terms of not only how much water is to be recovered, but also differences in modelling assumptions, such as how and where the water is recovered (Figure 8, Table 5). Detailed information on the scenarios and the modelling framework is available in the Northern Basin Review hydrologic modelling report (MDBA in prep.a).

Table 2: Step 1 in development of recovery scenarios and a brief description of each

Scenario name	Scenario description	Why?
278 GL — water recovery at December 2015	Represents the amount of water that had been recovered by the Commonwealth in the northern Basin as at December 2015, based on current planning assumptions and an estimate of 10 GL of expected future infrastructure-related recovery.	To understand what outcomes are possible with water that has already been recovered under the Basin Plan.
320 GL A — water recovery less than Basin Plan	Represents water recovery at December 2015 (278 GL) supplemented with a further 42 GL recovered from the Condamine–Balonne, Border Rivers and Namoi catchments.	To understand what outcomes are possible with some continued water recovery in certain catchments that have not met many of the outcomes.
390 GL A — fully implemented Basin Plan	Represents the fully implemented Basin Plan as currently legislated.	This scenario is the primary comparison scenario for the Northern Basin Review.
415 GL — water recovery more than Basin Plan	Represents a similar water recovery approach to the fully implemented Basin Plan, but with a 25 GL increase to the volume of water recovered.	To understand what additional environmental outcomes might be possible with more water recovery.

Table 3: Step 2 in the development of recovery scenarios and a brief description of each

Scenario name	Scenario description	Why?
320 GL B — default water recovery less than Basin Plan (pro rata)	Represents a 320 GL recovery volume that is based primarily on achieving an equitable recovery strategy.	To test the performance of different recovery strategies (i.e. looking at how outcomes are influenced by where and how much water is recovered for each catchment)
350 GL — targeted recovery	Represents Basin Plan recovery strategy, but includes a highly targeted recovery strategy in the Condamine–Balonne. In particular targeting in-channel water recovery in the Narran River over overland flow licenses.	To understand if outcomes can be improved if water recovery is targeted for particular areas, volumes and entitlement types.
390 GL B — current river operations	Represents the Basin Plan 390 GL scenario described above, but with an altered strategy for managing/delivering environmental flows to the Barwon–Darling. Under this option, there is no coordination of catchment flows — instead, the catchments worked individually to deliver low flows downstream to maintain connectivity with the Barwon–Darling, as per the Barwon–Darling Water Sharing Plan rules.	To determine the level to which environmental outcomes in the Barwon–Darling are dependent on the assumed management strategy for environmental water. The management strategy in this scenario is largely consistent with current knowledge and operating practices, and therefore assumes there will be minimal future advances in operating capacity.

Table 4: Step 3 in development of recovery scenarios and a brief description of each

Scenario name	Scenario description	Why?
320 GL C — refined	Another variation of a 320 GL scenario. This option was designed based on the results from previous scenarios. There is an adjustment to the pattern of catchment water recovery to achieve outcomes in an efficient way.	To test if the Basin Plan (390 GL) scenario environmental outcomes can be achieved by combining less water recovery with a refined recovery pattern.
345 GL — refined	This option was designed based on the results from previous scenarios. There is an adjustment to the pattern of catchment water recovery to achieve outcomes in an efficient way.	To test if the Basin Plan (390 GL) scenario environmental outcomes can be achieved by combining less water recovery with a refined recovery pattern.

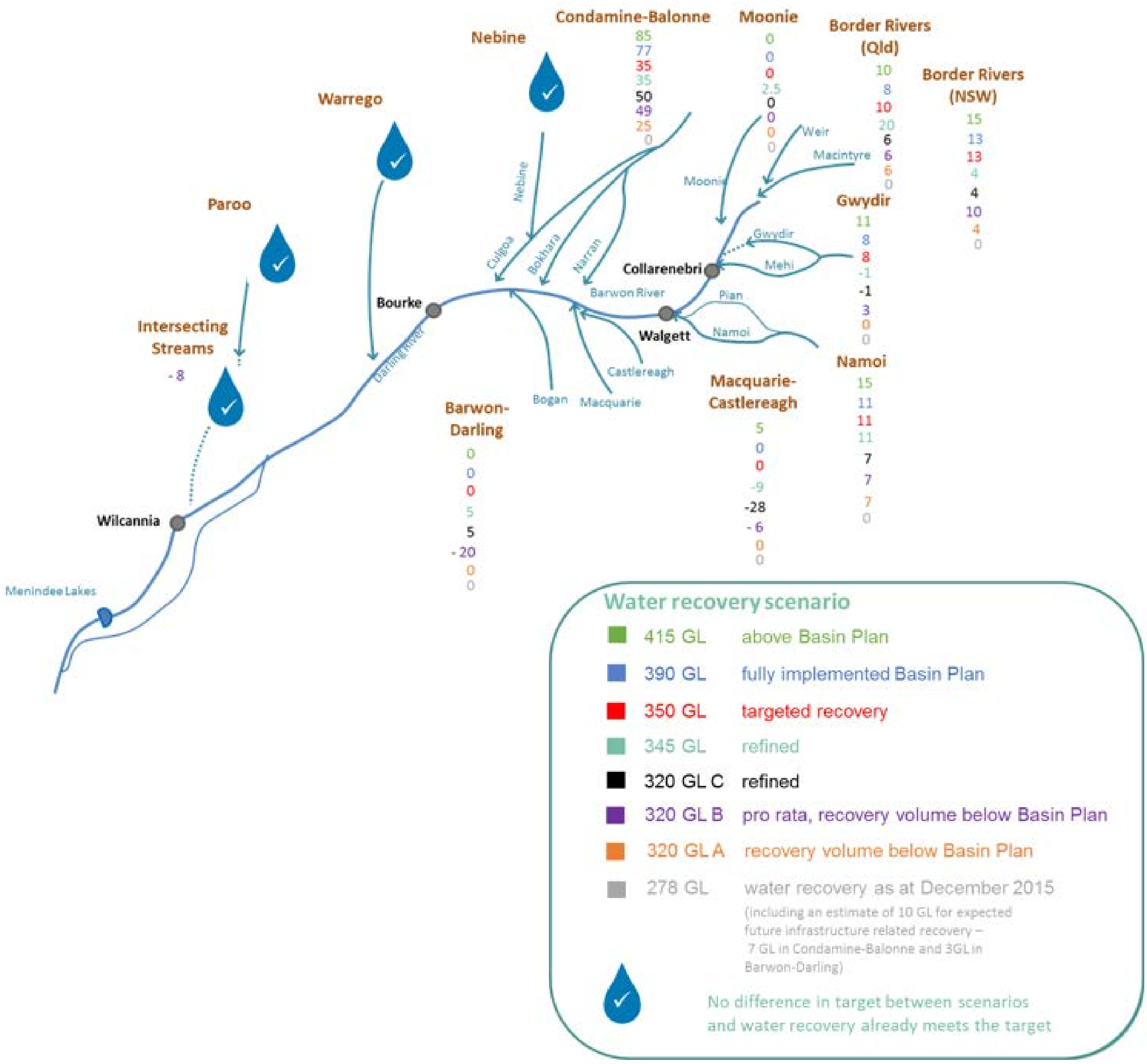


Figure 8: Additional water that would remain to be recovered for each of the water recovery scenarios (GL based on taking into account water that has already been recovered as at December 2015).

This graphic does not show the ninth scenario tested (the 390 GL B current river operations), which has the same additional water to be recovered as the 390 GL A fully implemented Basin Plan, but differs in its deliverability assumptions.

Table 5: Water recovery volumes (GL) for the water recovery scenarios investigated as part of the Northern Basin Review.

Gigalitres proposed to be recovered under the different scenarios	278 GL Current recovery	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A & B Basin Plan	415 GL
QLD Paroo	0	0	0	0	0	0	0	0
QLD Warrego	8	8	8	8	8	8	8	8
QLD Nebine	1	1	1	1	1	1	1	1
QLD Moonie	2	2	2	2	4	2	2	2
QLD Condamine–Balonne	65*	90	115	115	100	100	142	150
QLD Queensland Border Rivers	15	21	21	21	35	25	23	25
Queensland total (GL)	**91**	**122**	**147**	**147**	**148**	**136**	**176**	**186**
NSW Intersecting Streams	8	8	0	8	8	8	8	8
NSW Gwydir	48	48	51	47	47	56	56	59
NSW Border Rivers	3	7	13	7	7	16	16	18
NSW Namoi	13	20	20	20	24	24	24	28
NSW Macquarie–Castlereagh	83	83	77	55	74	83	83	88
Barwon–Darling	31*	31	12	36	36	28	28	28
NSW total (GL)	**187**	**198**	**173**	**173**	**196**	**214**	**214**	**229**
Whole of north total (GL)	**278**	**320**	**320**	**321**	**345**	**350**	**390**	**415**

**** Includes an estimate of 10 GL from future infrastructure related recovery (3 GL in the Barwon–Darling and 7 GL in the Condamine–Balonne***

Note: This table does not show the ninth scenario tested (the 390 GL B current river operations), which has the same water recovery as the 390 GL A fully implemented Basin Plan.

Results: Whole of north

The modelling framework shows that water recovery would be effective at restoring some elements of the flow regime (meeting between 16 and 24 out of 43 flow indicators targets) depending on the scenario applied. This is likely to lead to improvement in ecological resilience, maintenance of key environmental processes or simply arrest declining environmental health in some areas.

However, many flow indicators targets are not achieved (between 19 and 27 out of 43 indicators). This means that regardless of water recovery scenario, a level of ecological risk remains for supporting a sustainable environment across the northern Basin.

These results highlight the importance of the implementation of additional (toolkit) measures (e.g. targeted recovery, protection of flows events, fishways etc). Such measures would serve to both secure and strengthen the potential environmental objectives outlined below, as well as potentially minimise the scale of environmental risk where flow indicators are not met.

Across the seven catchments of the northern Basin, the modelling results show that between 16 and 24 out of 43 flow indicators would achieve the target frequency range, depending on water recovery scenario (Figure 9). Based on this assessment, the 415 GL scenario presents the lowest environmental risk (achieving 24 flow indicators), while the 278 GL scenario presents the highest level of risk (achieving 16 flow indicators) (see Table 6). However the environmental risk, as described by the flow indicators and the model results, is not evenly distributed across the catchments, as shown in Figure 10.

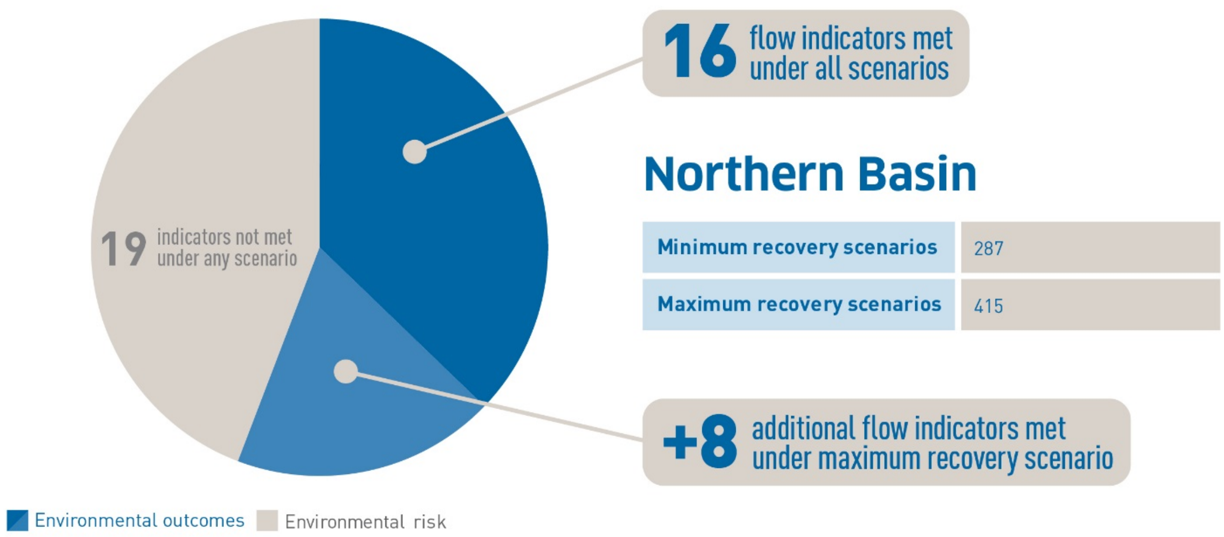


Figure 9: Minimum and maximum number of northern Basin flow indicators that can be met (and the correlating scenarios), and the number of flow indicators not able to be met under any scenario.

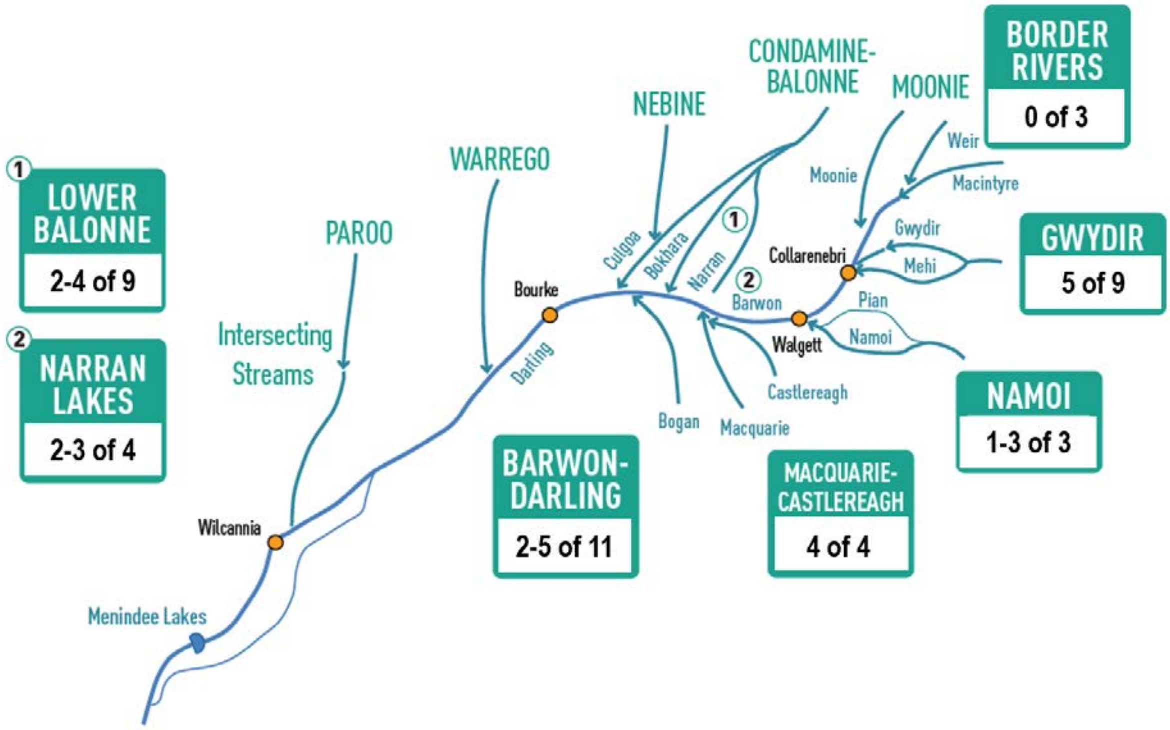


Figure 10: Range of flow indicators that meet the target frequency range for all modelled water recovery scenarios. How many flow indicators that are met changes depending on the specific scenario being assessed.

The general pattern is the more water that is recovered (volume), the more flow indicators that are achieved (target frequency range). The effectiveness of water recovery also depends on where and what types of water are recovered (locations and entitlement types). Targeted recovery can help achieve particular flow indicators with less water.

Table 6: Number of flow indicators met against total number of flow indicators for each northern Basin catchment and modelled scenarios (individual results available at Appendix D).

Water recovery scenarios	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
Lower Balonne	2/9	2/9	2/9	3/9	2/9	2/9	3/9	3/9	4/9
Narran Lakes	2/4	2/4	3/4	3/4	2/4	3/4	2/4	2/4	3/4
Barwon–Darling	2/11	4/11	4/11	4/11	4/11	4/11	4/11	2/11	5/11
Border Rivers	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
Gwydir	5/9	5/9	5/9	5/9	5/9	5/9	5/9	6/9	5/9
Namoi	1/3	3/3	3/3	3/3	3/3	3/3	3/3	3/3	3/3
Macquarie	4/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4
TOTAL	**16/43**	**20/43**	**21/43**	**22/43**	**20/43**	**21/43**	**21/43**	**20/43**	**24/43**

Whole of north environmental outcomes

The modelling framework results show that water recovery is effective at restoring specific flows in some of the northern basin catchments. At the minimum recovery volume scenario of 278 GL, and all scenarios, the following outcomes can be expected:

- Riparian, inner, mid and outer floodplain connectivity in the Macquarie Marshes is restored to a frequency that will likely result in healthy and resilient vegetation communities.
- Mid and outer floodplain connectivity in the Gwydir Wetlands is restored to a frequency that will likely result in healthy and resilient vegetation communities.
- Short duration small freshes in the Barwon–Darling (measured at Wilcannia) are restored to a frequency that will likely increase nutrient transport, which will benefit the river system's food web, which in turn is considered important for native fish and other aquatic biota. Further, flow frequencies that would support the vegetation communities on the outer floodplain were also restored.
- Flows that support floodplain habitat in parts of the Narran Lakes are restored to a frequency that will likely result in long-term improvement in the health of vegetation in the northern lakes, which in turn supports waterbird breeding opportunities.
- Large-scale river channel connectivity flows in the Culgoa River is restored to a frequency that will likely provide sufficient opportunities for aquatic biota (such as native fish) to move, feed and breed.

The Macquarie–Castlereagh is the only catchment to achieve all indicators (which are focused on the Macquarie Marshes), regardless of scenario. The Namoi also achieves all of its flow indicators, in all scenarios except the 278 GL.

These environmental outcomes are dependent upon, and could be further strengthened, through the implementation of additional (toolkit) measures, such as coordination of flow events, targeting of water entitlements, etc (discussed later in this report).

From this point forward, the discussion of environmental outcomes excludes the 390 GL B current river operations. This is because it has distinctly different assumptions compared to the other scenarios, and hence is discussed separately in a later section of this report. Individual flow indicator results for the 390 GL B current river operations are also shown in in Appendix C.

Whole of north environmental risks

The most indicators met across the northern Basin are by the 415 GL scenario, which achieves 24 indicators out of the 43; leaving 19 flow indicators that do not meet the target frequency range. Consequently, regardless of scenario, a number of environmental risks will remain across the northern Basin:

- In the Lower Balonne, base flows and small fresh flow indicators show little improvement under all scenarios. These flows are particularly important for breaking up extended dry spells. They are associated with significant environmental outcomes (maintenance of refuge waterholes) and pose substantial ecological risk if not achieved (potential for local extinction or reduced/slower recovery upon return to wetter conditions).

- No water recovery scenario can achieve the target frequency range for riparian and inner floodplain connectivity flows in the Culgoa River, nor the Barwon–Darling. This is critical for connecting the river channel with the floodplain. Over the longer term this could result in vegetation stress with increasing dry spell length likely to lead to changes in floodplain vegetation composition and condition, moving towards less water dependent species. This may also lead to loss of habitat for native fish and birds.
- For the internationally recognised Narran Lakes Ramsar site, the flow indicator that provides large-scale habitat opportunism for waterbirds is not met under any scenario. Waterbirds will remain at risk of having less than two opportunities in their life cycle to breed, which is the minimum requirement to maintain stable populations, even under the assumption that breeding often takes place in other areas.
- For the Border Rivers, the three river channel connectivity flow indicators, that are nested, are not met under any scenario. This risks insufficient hydrological connectivity between habitats along the river and opportunities for fish and other native animals to move, feed and breed at critical times.

It may be possible to reduce the severity of these risks though additional (toolkit) measures (discussed in detail later in this report).

Differences between scenarios

The model results shows that the 415 GL scenario achieves the highest amount of flow indicators (24), and for the options considered, is the lowest risk scenario for the northern Basin's river and floodplain ecosystem functions and ecology (notwithstanding the whole of north risks identified above would remain). Current water recovery (represented by the 278 GL scenario) achieves the least number of flow indicators (16) and represents the highest risk scenario (notwithstanding, there are a range of environmental benefits that would be achieved, as described earlier). Between these two ends of a spectrum, there is a range of flow indicators that can be met under some scenarios, but not others, as discussed below.

The fully implemented Basin Plan (represented by the 390 GL scenario) achieve 21 flow indicators. The 350 GL scenario also achieves 21 indicators, which shows that targeting water recovery by location and entitlement type can help achieve particular flow indicators with a lower volume of water. In the 350 GL scenario, water harvesting entitlements in the Narran River are targeted over floodplain harvesting entitlements in order to maximise in-channel Narran River flows to reach and fill Narran Lakes. This results in meeting two extra Narran flow indicators (Narran River large fresh and northern floodplain habitat in the Narran Lakes). The trade-off is that by targeting water recovery in the Narran River, less is recovered in the Culgoa River, which results in the Culgoa large fresh indicator no longer being met by the 350 GL scenario (which is met by the 390 GL scenario).

A number of learnings from earlier scenarios were applied to the two refined scenarios of 345 GL and 320 GL C. Learnings included the relative effectiveness of targeted water recovery to improve the achievement of particular flow indicators; and system connectivity (focusing on those upstream tributaries that have stronger hydrological connections to the Barwon–Darling and therefore have a greater potential flow contribution to help improve Barwon–Darling outcomes).

The first refined scenario attempted (345 GL) met 20 out of 43 flow indicators, which is a similar result to the 320 GL scenario. The second attempt at a refined scenario (320 GL C), results in more flow indicators being achieved with a lesser volume: 22 out of 43 indicators, second only to the 415 GL scenario. Of course these lessons can be applied to all recovery volumes.

Relative improvement in river channel and floodplain/wetland flow frequencies

As described above, the modelling results indicate that many flow indicators across the northern Basin would not reach their frequency target ranges, regardless of scenario. However, many water recovery scenarios do increase how often certain flow indicators occur (compared with the baseline condition), even if the target range is not achieved. This improvement in flow frequency is important and has been assumed to result in some reduction in the risk (from baseline) to the indicator's specific environmental target (e.g. waterbird breeding, fish spawning opportunities) and is used to support the assessment of the scenarios.

The aggregated flow indicator frequency results for the river channel connectivity and wetland/floodplain connectivity groups are shown in Figure 11 and Figure 12. These aggregated results take into account the achievement of flow indicators and any progress made toward reaching individual flow indicator target frequencies (the aggregation method is described in Appendix B). The aggregated results may mask significant improvement, or lack of improvement in individual indicators, and should be read in the context of understanding the individual improvements in frequency for each flow indicator (e.g. non-aggregated) as shown in Appendix C.

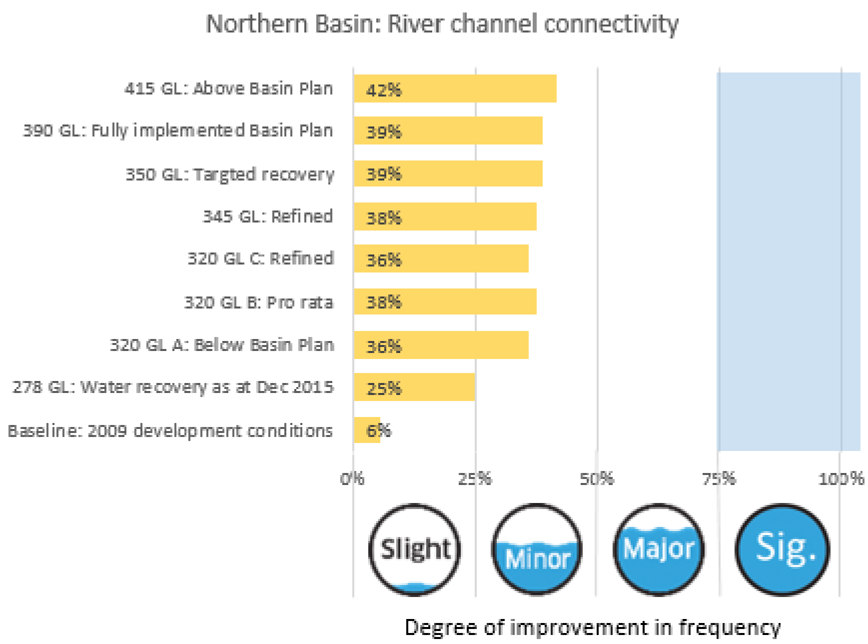


Figure 11: Aggregated frequency results for all 19 northern Basin river channel connectivity flow indicators (aggregated target range is 75% onwards shown as the blue bar). 0% indicates no improvement for any flow indicators.

River channel connectivity shows a marked improvement in frequency beyond current recovery (as shown by the 278 GL scenario); though there is less difference between scenarios beyond that. The greatest level of improvement is by the 415 GL scenario (42% compared to 25% from the 289 GL scenario). All scenarios are categorised as resulting in ‘minor’ improvement in the frequency of flow indicators (between 25 and 50%).

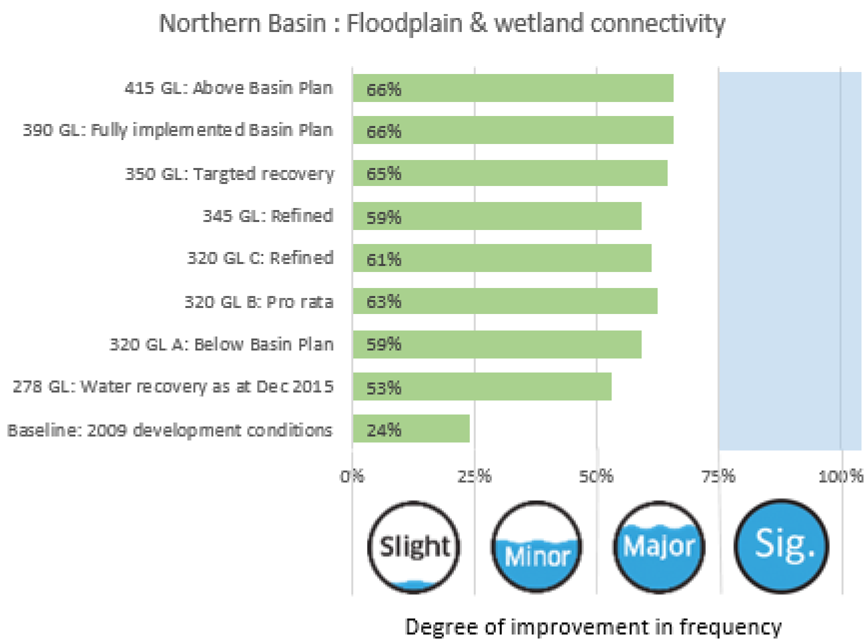


Figure 12: Aggregated frequency results for all 24 northern Basin floodplain and wetland connectivity flow indicators (aggregated target range is 75% onwards shown as the blue bar). 0% indicates no improvement for any flow indicators.

Floodplain and wetland connectivity also shows improvement in frequency beyond current recovery (as shown by the 278 GL scenario). The greatest level of improvement in frequency for wetland/floodplain connectivity is by the 415 GL and 390 GL A scenarios (66%); with the lowest level of improvement by the 278 GL scenario (53%). All scenarios are categorised as having ‘major’ improvement in the frequency of flow indicators (between 50 and 75%).

The importance of additional measures

The results shown above (and below for individual catchments) are outcomes from a modelling framework and are necessarily based on a series of assumptions and calculations. It is likely that the environmental outcomes discussed are dependent on, and could be further strengthened by, the implementation of other flow and non-flow related measures.

These additional measures (referred to as toolkit measures in the Northern Basin Review) are largely considered to be complementary (in addition) to the role of water recovery, to further enhance environmental outcomes from an improved long-term flow regime, rather than being a substitute for water recovery.

The relative utility and significance of a range of additional measures is currently being explored and includes:

- protection of environmental water (noting that it was assumed in the Basin Plan that the states would have this in place)
- targeting of flow entitlement for water recovery
- market-based mechanisms (e.g. temporary trade)
- improved coordination of the delivery of environmental water
- constraints management
- infrastructure (e.g. fishways, cold water pollution controls, irrigation offtake screening)
- other natural resource management activities which could provide environmental benefits specified in the Basin Plan.

Generally, smaller flows are more likely to be enhanced (either through frequency, volume, or both) through the application of additional measures that give increased operational flexibility. For example, improvements to the low flow part of the flow regime may be achievable through a combination of measures such as varying low flow rules to protect low flow events under certain circumstances, temporary trade, and use of private storages. However, additional measures to contribute to the frequency and volume aspects of very large flow events (such as those that connect the river channel to the outer floodplain) are far less likely to be effective or logistically feasible in the north due to the highly variable nature of the system and the flat landscape.

Importantly, any variation in access and/or operating rules would need to be part of a co-operative approach between stakeholders, state jurisdictions and the Australian Government. Decisions regarding the types of entitlements that are acquired and how environmental water is used would need to be discussed with environmental water holders.

As the modelled recovery scenarios are not able to meet the full set of flow indicators across the northern Basin, additional measures will play an important part in the protection of the ecology and ecosystems process of the northern Basin. Such measures may require agreement between multiple jurisdictions, changes to legislation, and available funding. Toolkit measures that may be effective in restoring particular flow elements are identified in the sections below in individual catchment results, and again with more information later in the report.

Results: Barwon–Darling Catchment

About the Barwon–Darling

The natural geomorphology of the Barwon–Darling River includes deep channels, deep pool areas, suspended-load depositional ‘benches’, higher floodplain ‘benches’, braided channels, terminal wetland complexes, gravel beds and riffle zones (NSW DPI 2007). The river provides a multitude of vital habitats that play a critical role in the life cycles of a variety of species. The lowland Darling River also provides a wide range of habitats for fish and invertebrates, including pools, riffles, backwaters and billabongs, in-stream woody habitats and aquatic plants (NSW DPI 2007). The NSW Fisheries Scientific Committee found that the fish community has a diverse assemblage of native species, including 15 native fish species and a large number of native invertebrate species (NSW DPI 2012).

When inundated, lakes and wetlands along the Darling River system provide habitat for large numbers of waterbirds, including migratory birds (DEWHA 2010). Kingsford et al. (1997) identified Poopelloe Lake, Talyawalka Creek and Pelican Lake within the Talyawalka–

Teryaweynya system and the Darling River floodplain near Louth as areas known or predicted to support 20,000 or more waterbirds. While not recognised as an important colonial waterbird breeding site, the Talyawalka–Teryaweynya system provides waterbird habitat for roosting, nesting and foraging (Brandis and Bino 2016). The Directory of Important Wetlands in Australia (DEWHA 2010) reports that Talyawalka–Teryaweynya system is relatively unaltered and representative of black box (*Eucalyptus largiflorens*) dominated, semi-arid, inland floodplain wetland systems. This system includes numerous channels and lakes and is nationally important and listed in the Australian Wetlands Database system.

The Darling River at Louth, May 2016

How much water recovery is being looked at?

The baseline diversion limit for the Barwon–Darling (excluding interceptions) is 198 GL. Current Basin Plan legislation has a local water recovery target of 6 GL in the Barwon–Darling. This is a 3% reduction in the total Barwon–Darling consumptive pool. Current Basin Plan legislation has a shared water recovery target of 143 GL across catchments of the north to meet the needs of the Barwon–Darling system. This includes a small contribution from the Barwon–Darling itself.

There has been local and shared water recovery in the Barwon–Darling with an estimate of 32 GL recovered as at December 2015 (including 3 GL from expected infrastructure recovery). The Northern Basin Review looked at a range of water recovery scenarios, from no further water recovery in the Barwon–Darling, to a potential return of 20 GL to the consumptive pool.

In general, in-situ recovery provides for the most efficient outcomes in the Barwon–Darling. However, a large proportion of flow in the Barwon–Darling originates from the upstream tributaries. For example, for the scenarios investigated, around 43% of water recovered in the upstream catchments makes it down to the Barwon–Darling as inflows. The shared recovery volume acknowledges the importance of these upstream catchments to improving environmental outcomes in the Barwon–Darling.

Barwon–Darling flow indicators

There are eleven flow indicators identified for the Barwon–Darling (Table 7). The flow indicators target outcomes throughout the broader Barwon–Darling river system. While river channel freshes are specified at specific locations they will provide benefits to other water-dependent ecosystems along the system. The differences in the indicators relate to the size, duration and seasonal timing of the flow events with each indicator aiming to achieve a different environmental outcome. Mapping of floodplain inundation also indicates the high level of floodplain connectivity that larger overbank flow events provide for the whole river system. The indicators are nested, which means that larger flows can achieve more than one indicator.

There are seven river channel indicators identified for the Darling River:

- Three small in-channel freshes to provide regular opportunities for in-stream biota to access habitats (including habitats associated with snags and in-channel benches), and facilitate some breeding of fish and other aquatic species.
- Four large freshes to provide aquatic biota with opportunities for large-scale movement, enhanced access to a diversity of habitats (e.g. snags and in-channel benches), and increasing nutrient transport through the inundation of benches that can provide benefits to aquatic food webs.

There are four wetland/floodplain flow indicators identified for the Darling River:

- Riparian, inner, mid and outer floodplain overbank indicators to connect different parts of the floodplain and reach key flood-dependent vegetation to maintain their character and condition. Overbank flows are important for nutrient exchange between the river and its floodplain and for supporting food webs.

Table 7: Barwon–Darling flow indicators (size of flow, duration, timing and how often)

Why?		Where in the landscape?	Stream gauge	Size of flow	Duration (days)	Timing	How often?
Wetland/floodplain • Water wetlands, lagoons, anabranches and floodplain woodlands • Provide habitat for waterbirds • Maintain important wetland vegetation • Increase food resources – exchange nutrients between river channels and floodplain • Inundate fringing vegetation, especially river cooba and red gum • Floodplain productivity (grasslands)	BD08	Bank-full flow - Inundate fringing vegetation and wetlands	Bourke	30,000 ML/d	24	Any time of year	to occur on average every 2 to 3 years
	BD09	Low-lying or inner floodplain	Bourke	45,000 ML/d	22	Any time of year	to occur on average every 3.5 to 4 years
	BD10	Mid floodplain	Bourke	65,000 ML/d	24	Any time of year	to occur on average every 6 to 8 years
	BD11	Higher or outer floodplain	Wilcannia	> 30,000 ML/d	Annual flow volume of 2,350 GL when flows are above 30,000ML/d	Any time of year	7-10% (years with at least 1 event)
River channel • Movement between habitats • Successful fish breeding • Inundate benches and snags (habitat diversity) • Primary production supporting the food web • Connectivity through the river system • Maintenance of waterhole habitat (drought refuges) • Breaks up extended dry spells	BD01	Small fresh – connect habitats	Bourke	6,000 ML/d	14	Any time of year	80 to 90%
	BD02	Small fresh (longer duration) – connect habitats	Louth	6,000 ML/d	20	b/w Aug. & May	70%
	BD03	Small fresh (shorter duration) – productivity	Wilcannia	6,000 ML/d	2 x 7	Any time of year	45 to 60%
	BD04	Large fresh – fish movement	Bourke	10,000 ML/d	14	b/w Aug. & May	60 to 80%
	BD05	2 Large freshes in a year – fish movement and breeding cue	Bourke	10,000 ML/d	2 x 20	b/w Aug. & May	25 to 35%
	BD06	Large fresh (longer duration) – fish movement and breeding cue	Louth	21,000 ML/d	20	b/w Aug. & May	40%
	BD07	Large fresh (shorter duration) – productivity	Wilcannia	20,000 ML/d	7	Any time of year	45 to 60%

What are the Barwon–Darling environmental results?

The model results indicate that the water recovery scenarios would achieve between 2 and 5 of the 11 individual Barwon–Darling river channel and wetland/floodplain flow indicator targets (Figure 13). Based on this binary assessment, the 415 GL scenario meets the most number of indicators (5 in total) and presents the lowest risk scenario; while the 278 GL scenario meets only 2 flow indicators, and presents the highest risk scenario.

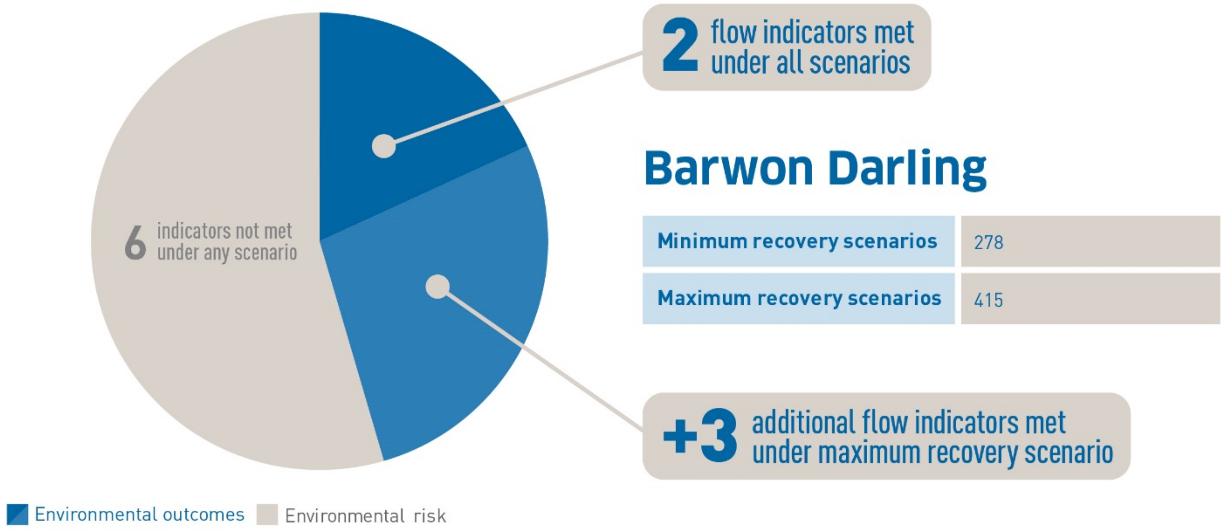


Figure 13: Minimum and maximum number of Barwon–Darling flow indicators that can be met (and the correlating scenarios), and the number of flow indicators not able to be met under any scenario.

No water recovery scenario reaches the aggregated target range of either the river channel connectivity or wetland/floodplain connectivity indicator group. The water recovery scenarios generally have a greater influence on increasing the frequency of river channel connectivity flows (minor to major improvements, see Figure 14) as opposed to frequency increases in wetland and floodplain connectivity flows (slight improvement, see Figure 15). The results indicate that there is no difference between scenarios in their effectiveness at restoring floodplain and wetland connectivity flows. In fact, the water recovery range investigated does not provide any ability to reconnect the river with its wetlands or floodplain.

The scenarios meet between 1 and 4 of the 7 river channel flow indicator targets. Under all scenarios, only the 6,000 ML/d Wilcannia small river channel flow meets the target range. No scenario is able to meet the small river channel flow indicator at Louth; nor the two large river channel flows at Bourke; nor the large river channel flow at Louth.

The scenarios meet only 1 of the 4 wetland/floodplain flow indicators. This flow indicator is also met by the baseline condition and is the outer floodplain flow measured at Wilcannia (total volume of 2,350 GL). The target ranges for the three other indicators are not achieved by any water recovery scenario.

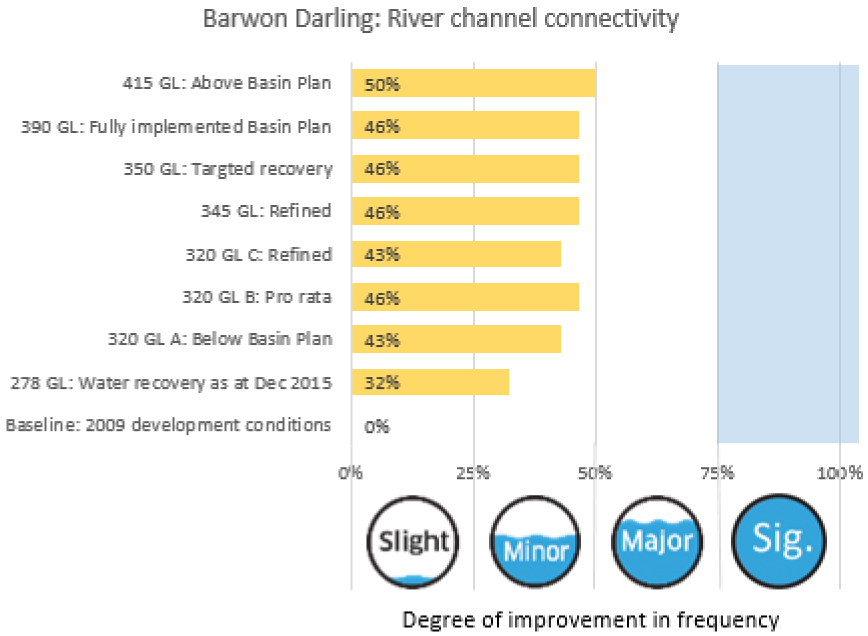


Figure 14: Darling River aggregated river channel flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

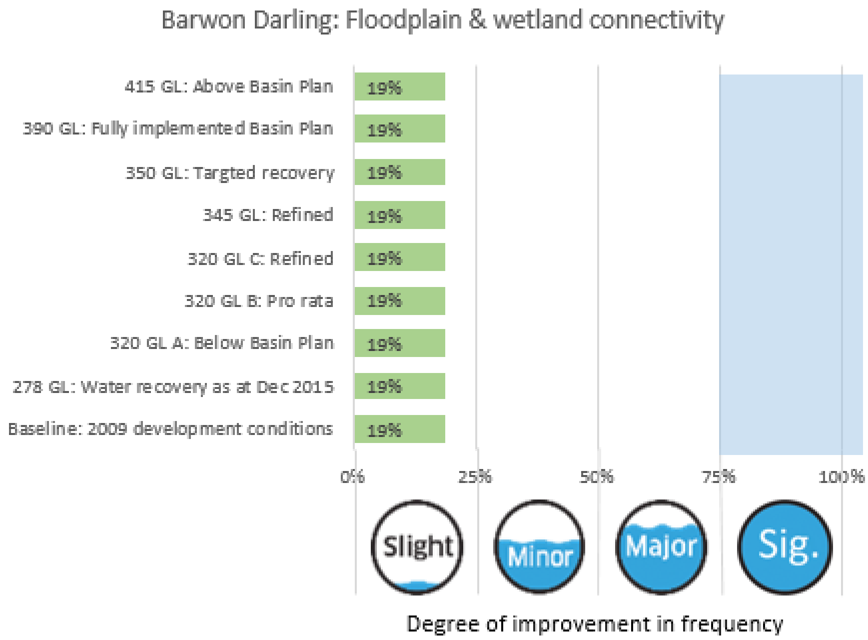


Figure 15: Darling River aggregated floodplain and wetland connectivity flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

Based on the scenarios investigated, the results show that environmental outcomes in the Barwon–Darling are most heavily influenced by recovery in the Barwon–Darling itself. However, also important is the contributing recovery upstream especially in the catchments providing the largest volumes of inflow (Macquarie, Namoi, Border Rivers, and Condamine–Balonne). While current recovery is 32 GL, further improvement in environmental outcomes is likely to be achieved through either increased local recovery or larger volumes recovered in the upstream connected catchments. However, environmental outcomes are likely to be constrained to river channel connectivity processes due to the large volumetric requirements of the floodplain and wetland connectivity indicators and the flow regulation impact of large public storages in some of the upstream catchments.

River channel connectivity outcomes

The frequency of small freshes (river channel connectivity) in the Barwon–Darling is improved across all scenarios; though only slightly for the Louth indicator (see Appendix C). The improvement in the Bourke and Wilcannia small fresh indicators generally reaches the target zone (one exception exists for the 278 GL scenario, but is not considered significant). These results indicate that, regardless of scenario, there will be increased movement opportunities for fish and improved access to in-channel habitats along the Barwon–Darling. Further, the increased frequency of inundation of benches, will improve the frequency of carbon and nutrient release into the river, which fuels aquatic food webs (most significant under the 415 GL scenario). This improves food availability for fish and other aquatic biota and can improve recruitment success. The lack of significant improvement in the Louth indicator, under all scenarios, is likely to result in an insufficient number of spawning and recruitment opportunities for both the flow dependent (e.g. golden perch) and in-channel specialist native fish functional groups (e.g. Murray cod).This could lead to reduced population size, health and/or resilience for these fish species.

There were mixed results for large fresh flows in the Barwon–Darling. The indicators that have shorter duration requirements (such as the 10,000 ML/d for 14 days at Bourke, and the 20,000 ML/d for 7 days at Wilcannia) are either met, or close to being met, across all scenarios. Once the duration extends (e.g. 2 x 20 days at Bourke; and 20 days at Louth), the rate of improvement in event frequency drops markedly). This is most apparent for the 20 day Louth indicator which does not move from baseline frequency regardless of the recovery scenario applied.

The ecological outcome of this result under all scenarios (except perhaps the 278 GL scenario) is likely to be sufficient opportunities for regular fish passage between Walgett and Menindee. This is important for those species that undertake large-scale migrations such as golden perch and silver perch. Benches and snags will also be inundated more regularly (than under the baseline scenario), which will provide increased access to a diversity of aquatic habitat. Combined, the opportunity to move, spawn and access habitat is likely to improve mixing and genetic diversity of fish populations and enhance conditions for breeding, especially for flow-dependent specialist fish. There is little difference between the levels of improvement among the recovery scenarios; though the 415 GL scenario does meet the target range.

However, the lower levels of improvement for the second Bourke indicator (2 x 20 days) and large-scale river channel Louth indicator (20 days), implies reduced recruitment of native fish larvae and juveniles under prolonged dry conditions. Species such as golden perch may not receive sufficiently regular cues for migration and breeding, which may result in a reduction in the population size over time. There is no distinct difference between scenarios in the mitigation of this risk.

The Wilcannia indicator is either met, or within 1–3% of the target range, across all scenarios. Regardless of scenario, the ecological outcome is likely to be sufficiently regular access to off-channel wetlands, which is important for many fish (such as olive perchlet and Darling River hardyhead). Access to the wetlands provides a boom in food supply and access to ideal spawning and nursery habitats. Further, regular inundation of benches and wetlands will also be suitably frequent which in turn promotes nutrient spiralling that fuels food webs. The river channel ecological outcomes outlined above are at highest risk under the 278 GL and the 320 GL B scenarios.

The risks associated with river channel connectivity outlined above may be mitigated by the implementation of additional measures. Opportunities include fishways to allow fish passage on lower flows (rather than relying on weir drown-out); flow coordination from upstream tributaries that could assist in providing more frequent flows up to around 10,000 ML/d at Bourke; and consistent protection of environmental flows.

Floodplain and wetland connectivity outcomes

Floodplain and wetland connectivity in the Barwon–Darling is targeted through riparian, inner, mid and outer floodplain flows indicators. Across all four indicators, improvement in frequency beyond the baseline condition across all recovery scenarios is little to nil, and the system will be under significant risk. These risks are best mitigated under the 415 GL, 390 GL A and 350 GL scenarios (though the risks still remain significant). The ecological consequence under all scenarios is that under prolonged dry periods, the flooding requirements to sustain vigorous river red gum forests (such as areas around the Talyawalka Anabranch) and lignum, and to re-fill wetlands near the channel may not be achieved. Further, without the ideal flow frequency (such as in prolonged low flows), increases in riverbank collapse and erosion problems may also occur as a result of decreased riparian vegetation cover.

Under prolonged dry periods, the flooding requirements to sustain vigorous growth for black box are not likely to be achieved. Further, given the target range was based on close to the critical interval of river red gum woodlands and lignum, these species/communities would also be at considerable risk under all scenarios during prolonged dry periods. It is acknowledged that these two species may remain alive if inundation occurs at a lower frequency, though their condition is likely to be poor, and more frequent subsequent wetting may be required to improve their health and vigour.

It should be noted that the outer floodplain flow, while not showing any improvement beyond baseline, is still within target range. As a result, the filling of lakes in the Talyawalka–Teryaweynya system, as well as inundating wetlands and vegetation communities on the outer Darling floodplain, is likely to be frequent enough to sustain many of the vegetation communities in those areas, regardless of scenario. The communities/species targeted by the frequency of this indicator include black box, lignum, and grasslands. Further, when inundated, the system's lakes provide foraging habitat for large numbers of waterbirds, and also mass exchange of nutrients, sediment and recruitment and dispersal opportunities for a range of native aquatic animal and plant species.

The water recovery scenarios that were investigated are not capable of shifting the near-channel and inner-mid floodplain flow frequencies in any significant fashion, and despite their volumetric and targeting strategies, their outcomes are not particularly different.

Under all scenarios there will remain a significant to major risk that the following ecological targets will not be achieved:

- support of recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles, invertebrates)
- support of habitat requirements of waterbirds
- sustaining the current extent of native vegetation of the riparian, wetland and floodplain communities in a healthy, dynamic and resilient condition
- support of hydrological connectivity between habitats, along the river (longitudinal) and between the river and its floodplain (lateral) as a surrogate for many other ecological processes.

It should be noted that the 415 GL scenario has the greatest capacity to mitigate risk associated with in-channel processes, while 278 GL has the least capacity.

Additional measures

A range of additional measures should be investigated in order to increase the likelihood of reaching the ecological targets. River channel connectivity flow could be supported through a mix of infrastructure (e.g. fishways), flow coordination from upstream tributaries and protection of environmental flows. Wetland and floodplain connectivity is considered highly important for many ecological processes by providing regular exchange between the river and its floodplain. However, no toolkit measures have been identified to date that can increase the frequency of overbank flow events in the Barwon–Darling to mitigate this risk (these are large volume events). For example, works and measures to artificially inundate wetlands and floodplains are not practiced in the northern Basin due to the flat landscape.

Toolkit measures that may have a partial contribution towards helping pass larger unregulated flows include a mix of protection of environmental water and targeting overbank flow entitlements. Temporary trade and use of private storages is not considered feasible in the Barwon–Darling as initial hydrological modelling has shown that such opportunities are rare and the volumes required are prohibitively large.

Results: Border Rivers Catchment

About the Border Rivers

Under the NSW Fisheries Management Act, the Border Rivers region contains part of a declared endangered aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River (NSW Scientific Committee 2004). This valley contains lowland riverine environments with meandering channels and a variety of aquatic habitats — including deep channels and pools, wetlands, gravel beds and floodplains that support the endangered ecological community. The floodplain between Goondiwindi and Mungindi contains a large number of anabranches and billabongs (CSIRO 2007). When flooded, these areas provide large amounts of dissolved organic carbon to the riverine ecosystem, which is essential to aquatic ecosystem functioning (CSIRO 2007). The lowland sections of the Border Rivers are also recognised for their ability to support significant populations of native fish. The region provides habitat for many native fish species, including the EPBC-listed Murray cod, and NSW listed silver perch, purple spotted gudgeon, and endangered populations of freshwater catfish and olive perchlet. The importance of this area is elevated because of the Basin-wide decline of native fish populations, as shown by the Sustainable Rivers Audit (Davies et al. 2008).

The anabranches and billabongs of the Macintyre River floodplain are important geomorphological assets. These wetlands are important breeding habitat for protected waterbirds including brolgas, black-necked storks and magpie geese. The Border Rivers system also provides a wide range of aquatic habitats. It supports river red gum, coolibah and river oak, with weeping bottlebrush a common understorey plant along the network of rivers (McCosker 1999).

Macintyre River, 2013

How much water recovery is being looked at?

The baseline diversion limit (excluding interceptions) is 242.1 GL for the Queensland Border Rivers and 207.6 GL for the New South Wales Border Rivers. Current Basin Plan legislation has a local water recovery target of 8 GL in the Queensland Border Rivers and 7 GL for the NSW Border Rivers. This represents a 3% reduction in the Border Rivers total consumptive pool. Current Basin Plan legislation also has a shared water recovery target of 143 GL across catchments of the north to meet the needs of the Barwon–Darling system. The shared recovery volume acknowledges the importance of upstream catchments to improving flow components and environmental outcomes in the Barwon–Darling. An estimate of 15 GL (Queensland) and 3 GL (New South Wales) has been recovered as at December 2015.

The Northern Basin Review is looking at a range of water recovery scenarios. These range from no further water recovery in the Border Rivers, up to 20 GL in QLD and 15 GL in NSW of additional recovery.

Border Rivers flow indicators

The three flow indicators identified for the Border Rivers are shown in Table 8 below. These are based on previous information compiled for the valley, with no new information developed as part of the science component of the Northern Basin Review. The flow indicators aim to:

- Connect habitats along the river and stimulate fish to breed and move. Freshes help provide more habitat for fish and other aquatic animals, by inundating different habitat types and parts of the river channel. These flows increase river channel connectivity, allowing movement of fish up and down the catchment as well as transport of sediment, nutrients and carbon.

Table 8: Border Rivers flow indicators (size of flow, duration, timing and how often)

Why?	Where in the landscape?	Stream gauge	Size of flow	Duration (days)	Timing	How often? (percentage of years)
River channel • Movement between habitats • Successful fish breeding • Inundate benches and snags (habitat diversity) • Primary production supporting the food web • Connectivity through the river system	Fresh	Barwon River at Mungindi	4,000 ML/d	5 days	Oct-Dec	23-31
	Fresh	Barwon River at Mungindi	4,000 ML/d	5 days	Oct-March	44-59
	Fresh	Barwon River at Mungindi	Two events of 4,000 ML/d	11 days	Jul-Jun	25-34

What are the Border Rivers environmental results?

The model results indicate that the water recovery scenarios would not achieve any of the three Border Rivers river channel connectivity flow indicator targets (Figure 16).

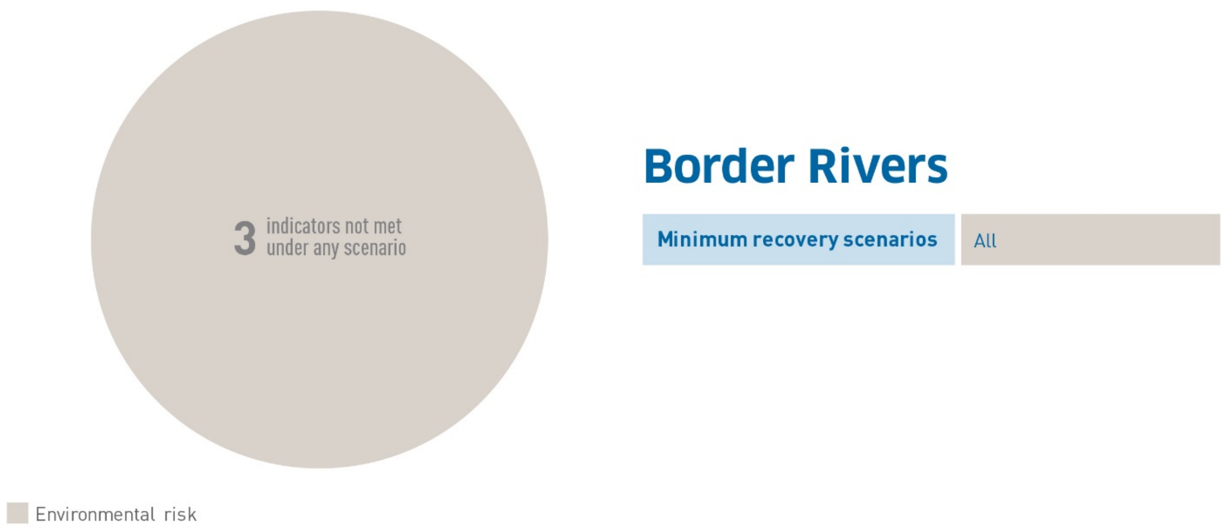


Figure 16: Minimum and maximum number of Border Rivers flow indicators that can be met (and the correlating scenarios), and the number of flow indicators not able to be met under any scenario.

All scenarios, except the 278 GL current recovery, show an improvement from the baseline condition. The 415 GL, 390 GL A, 350 GL, 345 GL and 320 GL A scenarios result in a minor improvement, with the 415 GL and 390 GL A achieving the highest increase in aggregate frequency (Figure 17). The 320 GL C and 320 GL B result in only slight improvement.

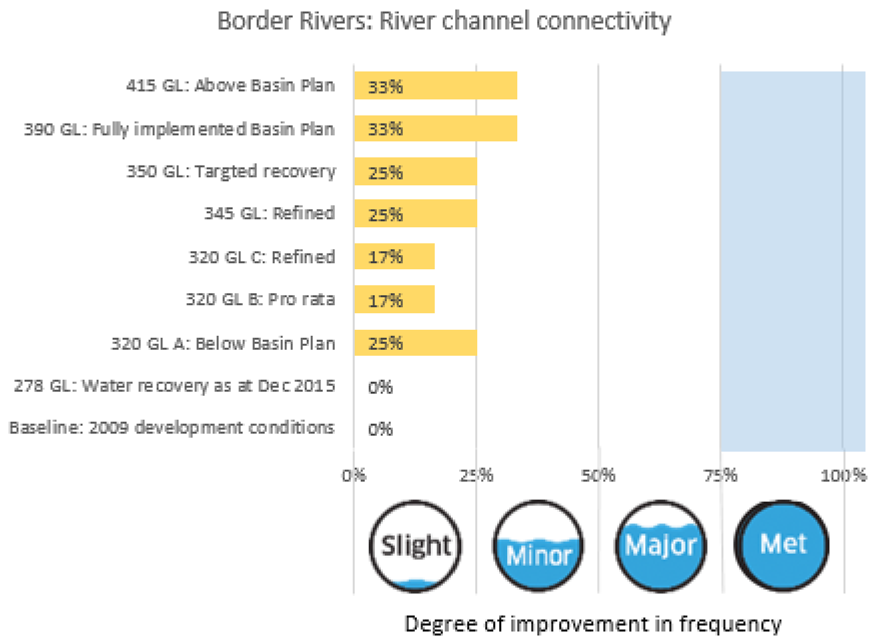


Figure 17: Border Rivers aggregated river channel flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

Based on the scenarios investigated, the results show an improvement in flow indicator frequency at Border Rivers once recovery volumes reach approximately 28 GL (i.e. all scenarios beyond current recovery). However to move beyond slight improvement to minor, results show that recovery volumes of 38 GL to 43 GL are required. There appears to be greater environmental outcomes when water recovery is from regulated water entitlements, as these can be delivered in a pattern that support the flow indicators. The recovery of unregulated entitlements enhances system flows, but there is little capacity to target a specific part of the flow regime.

River channel connectivity

Water recovery beyond the current effort (represented by the 278 GL scenario) is likely to provide improved flow conditions for fish breeding and recruitment in the Border Rivers. Under the 320 GL B and 320 GL C scenarios however, this is much less likely. There is slight to nil improvement for the other two in-channel indicators, which target broader spawning requirements for other native fish species and the provision of a variable flow regime, which is important for nutrient cycling and productivity. These functions remain at high risk regardless of scenario.

Overall, there is expected to be a high (under the 320 GL B and 320 GL C scenarios) to moderate (under the 415, 390 A, 350, 345 and 320 GL A scenarios) risk that the following targets will not be achieved:

- provision of a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles, invertebrates)
- provision of a flow regime which supports key ecosystem functions, particularly those related to longitudinal connectivity and transport of sediment, nutrients and carbon.

A significant volume of water is required to satisfy Border River flow indicators, however a number of additional measures to improve operational flexibility could assist, including temporary trade and protection of environmental flows. Use of private storages to enable quicker response times to flows at Mungindi and measures to mitigate cold water pollution issues may also be valuable for consideration. Opportunities for fish passage improvement, as well as flow coordination, exist between major tributaries and storages (e.g. Pindari and Glenlyon).

Results: Condamine–Balonne Catchment

About the Condamine–Balonne

The Condamine–Balonne has been split into two environmental assets for the purposes of reporting: the Lower Balonne river floodplain and the Narran Lakes.

Native fish in the Lower Balonne are an important component of the system's ecological value. Reaches of the Culgoa River have been identified as sites of high native fish biodiversity, with numerous threatened species present (MDBA 2014).

The Lower Balonne river floodplain supports large areas of native vegetation, which is periodically inundated by floods. The lateral connectivity from these flows provides for the exchange of carbon and nutrients between the watercourses and the floodplain (Thoms 2003). The floodplain coolibah–black box woodland community of the northern riverine plains (Darling Riverine Plains and the Brigalow Belt South bioregions) is listed as an endangered ecological community under the *Threatened Species Conservation Act 1995* (NSW). Additionally, there are national parks on the Culgoa River on each side of the Queensland–New South Wales border that have a high degree of naturalness. Woodlands dominated by coolibah (*Eucalyptus coolabah*) on the floodplains of the Culgoa River are the largest and least disturbed contiguous area of this vegetation type remaining in NSW (Hunter 2005).

There are two nationally important wetlands in the Lower Balonne system; the Balonne River Floodplain (downstream of St George to the first bifurcation in Qld), and the Culgoa River Floodplain (in NSW on the Culgoa River). Further, there are more than 3,400 wetlands that have been identified within the Lower Balonne river floodplain (Thoms et al. 2002), which is the largest grouping of wetlands in the Murray–Darling Basin (CSIRO 2008). These wetlands provide foraging habitat for birds, including migratory species (Brandis and Bino 2016).

The Narran Lakes also supports a number of different flood-dependent vegetation types, which are important habitats for a range of biota. The Narran Lakes contains some of the largest expanses of lignum (*Duma florulenta*) in NSW in various forms and is vital habitat for colonial waterbird breeding. The Narran Lakes is also of international significance as it is formally recognised in, or capable of supporting species listed in the Japan–Australia Migratory Bird Agreement, the China–Australia Migratory Bird Agreement and the Republic of Korea–Australia Migratory Bird Agreement. The Narran Lakes includes the Ramsar-listed Narran Lake Nature Reserve.

Narran River at Hebel Road, May 2016.

How much water recovery is being looked at?

The baseline diversion limit for the Condamine–Balonne (excluding interceptions) is 713.3 GL. Current Basin Plan legislation has a target of 100 GL of local water recovery in the Condamine–Balonne. This represents a 14% reduction in the total Condamine–Balonne consumptive pool. Current Basin Plan legislation has a shared water recovery target of 143 GL across catchments of the north to meet the needs of the Barwon–Darling system. The shared recovery volume acknowledges the importance of upstream catchments to improving flow components and environmental outcomes in the Barwon–Darling. An estimate of 65 GL has been recovered as at December 2015, which includes 7 GL from future infrastructure investment.

The Northern Basin Review is looking at a range of water recovery scenarios. These range from no further water recovery in the Condamine–Balonne (65 GL), up to 85 GL of additional contribution to the local and shared recovery (representing a total recovery range between 65 GL and 150 GL).

Lower Balonne flow indicators

The flow indicators identified for the Lower Balonne are shown in Table 9 below. There are five river channel flow indicators identified for the Lower Balonne:

- Two waterhole refuge indicators along the Culgoa and Narran rivers to maintain these waterholes as habitat. Periods of no-flow are normal but water resource development has resulted in these periods being much longer for some sections of the river system.

If too many refuge waterholes dry out, local extinction of fish populations could occur or there would be much slower re-colonisation upon the return of wetter conditions.

- Three freshes to connect habitats along the river and stimulate fish to breed and move. Freshes help provide more habitat, and different types of habitat for fish and other aquatic animals. These flows therefore support a greater diversity of species as well as more fish.

There are four wetland/floodplain flow indicators identified for the Lower Balonne:

- Four flow indicators to provide flows to connect different parts of the floodplain and reach key flood dependent vegetation to maintain its character and condition. Overbank flows are important for nutrient exchange between the river and its floodplain and for supporting both aquatic and terrestrial food webs.

Table 9: Lower Balonne individual flow indicators (size of flow, duration, timing and how often)

Why?	Where in the landscape?	Stream gauge	Size of flow	Duration (days)	Timing	How often? *Average years between events
Wetland/floodplain (Lower Balonne) • Connect different parts of the floodplain • Water wetlands and floodplain vegetation • Provide habitat waterbirds and other animals • Increase food resources – exchange nutrients between river channels and floodplain • Floodplain productivity (grasslands and benefits for grazing)	Overbank flows - Inundate fringing vegetation and wetlands	Brenda (Culgoa River)	9200 ML/d	12	Any time of year	2 to 3 years*
	Overbank flows - low-lying floodplain and wetlands	Brenda (Culgoa River)	15000 ML/d	10	Any time of year	3 to 4 years*
	Overbank flows – increasing area of floodplain and wetlands	Brenda (Culgoa River)	24500 ML/d	7	Any time of year	6 to 8 years*
	Overbank flows – large scale floodplain and wetlands	Brenda (Culgoa River)	38000 ML/d	6	Any time of year	10 to 20 years*
River channel (Lower Balonne) • Allow fish to move between habitats • Opportunities for fish to breed • Inundate benches and snags (habitat diversity) • Primary production supporting the food web • Connectivity through the river system • Maintenance of waterholes (drought refuges) • Breaks up extended dry spells	Maintain refuge waterholes	Weilmoringle (Culgoa River)	Any flow	1	Anytime of year	350 to 430 days between events
	Maintain refuge waterholes	Narran Park (Narran River)	Any flow	1	Anytime of year	350 to 470 days between events
	Small fresh – connect habitats	Brenda (Culgoa River)	1000 ML/d	7	Any time of year	80-90% of years with an event
	Large fresh – fish movement and breeding cue	Wilby Wilby (Narran River)	1700 ML/d	14	August-May	40-60% of years with an event
	Large fresh – fish movement and breeding cue	Brenda (Culgoa River)	3,500 ML/d	14	August-May	40-60% of years with an event

Narran Lakes Flow indicators

The flow indicators identified for the Narran Lakes are shown in Table 10 below. There are four wetland/floodplain flow indicators identified for the Narran Lakes:

- Four indicators to provide a range of different flow volumes to reach key parts of the Narran Lakes ecosystem, including waterbird breeding and foraging sites. These flows would also support large-scale waterbird breeding. The four indicators are of different magnitudes to water different parts of the Narran Lakes system and ensure vegetation and wetlands are maintained in character and condition.

Table 10: Narran Lakes individual flow indicators (size of flow, duration, timing and how often)

Why?	Where in the landscape?	Stream gauge	Size of flow	Duration (days)*	Timing	How often? (average years between events)
Wetland/floodplain (Narran Lakes) • Protect and restore Ramsar sites • Water wetlands and floodplain vegetation • Provide breeding and nursery sites for colonial waterbird breeding • Ensure the current extent of vegetation is maintained • Increase food resources – exchange nutrients between river channels and floodplain	Rookery habitat and in north lakes	Wilby Wilby (Narran river)	25 GL	60	Any time of year	1 to 1.3 years
	Rookery habitat in north lakes and floodplain	Wilby Wilby (Narran river)	50 GL	90	Any time of year	1.3 to 1.7 years
	Large scale waterbird breeding	Wilby Wilby (Narran river)	154 GL	90	Any time of year	Twice in 8 to 10 years
	Narran Lake and the surrounding floodplain	Wilby Wilby (Narran river)	250 GL	180	Any time of year	10 to 12 years

*the duration is the maximum period over which the flows can occur

What are the Lower Balonne environmental results?

The model results indicate that the water recovery scenarios would achieve between 2 and 4 of the 9 individual Lower Balonne river channel and wetland/floodplain flow indicator targets (Figure 18). Based on this binary assessment, the 415 GL scenario meets the most number of indicators (4 in total) and presents the lowest risk scenario; while the 278 GL, 320 GL A, 320 GL B, 345 and 350 scenarios meet only 2 flow indicators, and present the highest risk scenarios.

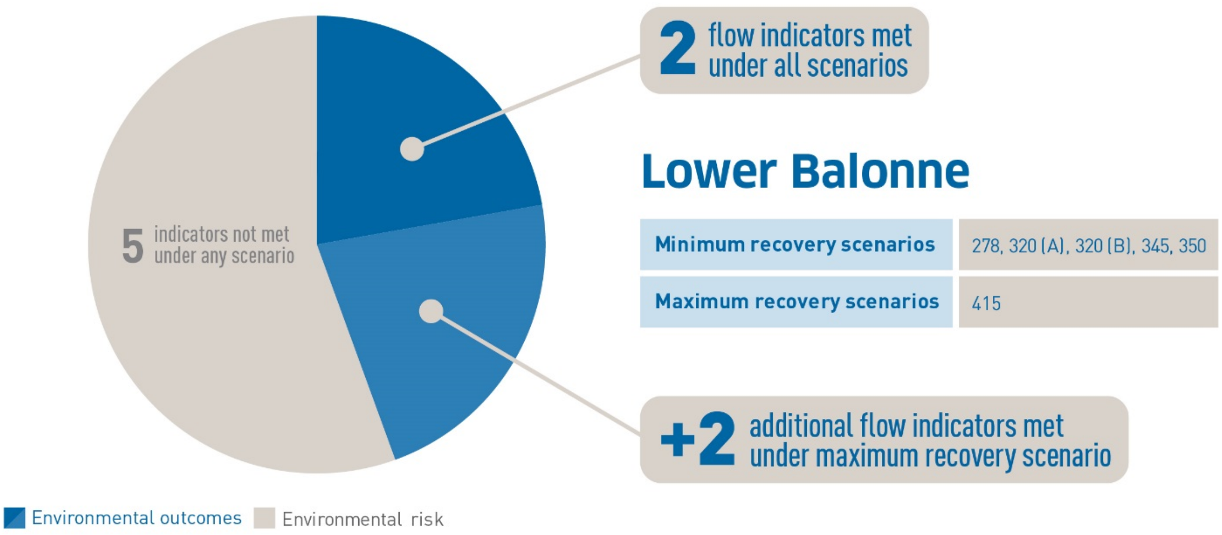


Figure 18: Minimum and maximum number of Lower Balonne flow indicators that can be met (and the correlating scenarios), and the number of flow indicators not able to be met under any scenario.

No water recovery scenario reaches the aggregated target range of either the river channel connectivity or floodplain/wetland connectivity flow indicator groups. The water recovery scenarios generally have a lesser influence on increasing the frequency of river channel connectivity flows (slight to minor improvements, see Figure 19) in contrast to frequency increases in wetland and floodplain connectivity flows (minor-major improvements, see Figure 20).

The water recovery scenarios achieve between 2 and 4 of the 9 Lower Balonne individual river channel and floodplain/wetland flow indicator targets. The scenarios meet between 1 and 2 of the 5 river channel flow indicators. Under all scenarios the 3,500 ML/d Culgoa River large river channel connectivity flow target is met. However, no scenario is able to meet the drought refuge flow indicators, nor the small scale river channel flow of 1,000 ML/d in the Culgoa River. The scenarios meet between 1 and 2 of the 4 wetland/floodplain flow indicators. No scenario is able to meet the 9,200 ML/d or 15,000 ML/d riparian and inner floodplain Culgoa River flow indicators.

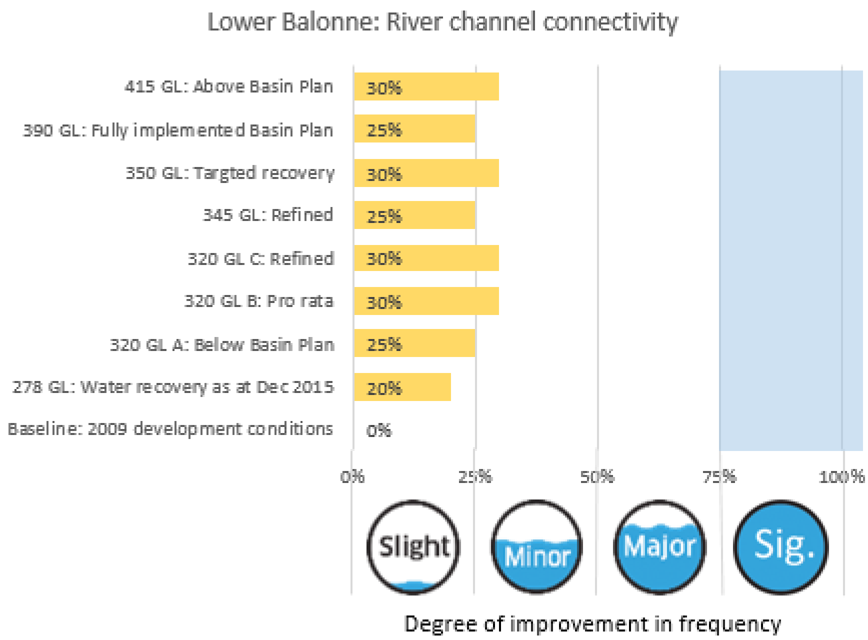


Figure 19: Lower Balonne aggregated river channel flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

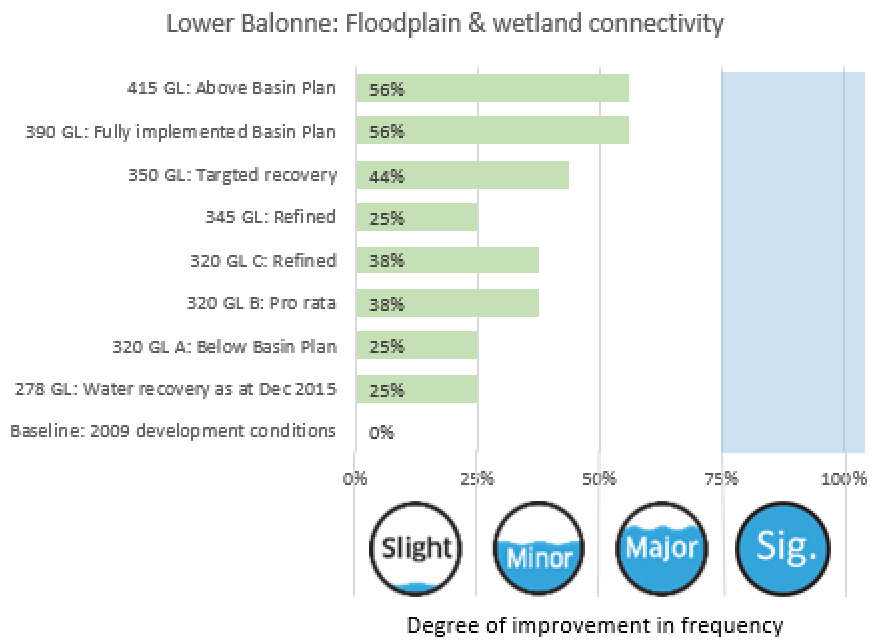


Figure 20: Lower Balonne aggregated wetland/floodplain flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

River channel connectivity outcomes

The lack of any significant improvement in the frequencies of the baseflows and small freshes across the recovery scenarios is likely to result in a high risk to native fish species, particularly during extended dry periods, due to the lack of refuge waterholes and small freshes to top them up. Ecological implications for native fish populations in the area may include slower re-colonisation upon the return of wetter conditions and reduced population numbers, distribution, genetic diversity and hence resilience. While there are differences between the scenarios with regard to baseflows and the small in-channel fresh, they are minor and not considered to be significant. Dams (such as Beardmore Dam) and large weirs (such as Jack Taylor Weir) can act as a refuge for some aquatic biota and may play an important role for aquatic biota to re-colonise parts of the river system, but they also act as barriers limiting movement throughout the system.

The frequency of the large in-channel flow indicator in the Narran River (1,700 ML/d) improves as a result of water recovery; however only the 320 B, 320 C, 350 and 415 GL scenarios reach the target range. Spells analysis shows that the 320 B, 320 C, 350, 390 and 415 GL scenarios remove the high risk critical threshold of 10 years between flow events. Further, the number of events that occur over the modelled 114-year period is highest under the 415 GL and 320 GL B scenarios (with 64 and 62 events respectively).

The frequency of large in-channel flow events in the Culgoa River also improves as a result of water recovery with all recovery scenarios achieving the target range. The 350 GL scenario results in the smallest increase in frequency (most likely because there is less recovery of low-mid channel entitlement types in the Culgoa River compared with the other scenarios); and the highest frequency increase is achieved under the 415 GL, both 390 GL scenarios, and 320 GL B scenarios.

Improvement in river channel connectivity is greatest under the 415, 350, 320 GL C and 320 GL B scenarios. These scenarios present the greatest potential to restore in-channel flows, and apply the lowest risk to flow dependent native fish species (such as golden perch, silver perch, spangled perch and Hyrtl's tandan). Improving this part of the flow regime is expected to improve the population condition and resilience of a range of aquatic species including fish, frogs and turtles. It is also expected to improve the condition of near channel vegetation, which can help increase bank stability and provide additional food resources. However, as identified above, during prolonged dry periods, the lack of baseflows and small freshes means that additional measures should be considered to enhance outcomes.

Wetland and floodplain connectivity outcomes

The riparian and inner floodplain may undergo some improvement as a result of increased flow frequencies, though no scenario can achieve the target ranges (particularly for the inner floodplain). This is a critical flow indicator as it is a mechanism for regular connection between the floodplain and in-channel systems. Under 390 and 415 GL the riparian and inner floodplain will remain at risk. However, this is the best option for improvements in frequency of inundation, which is also supported by spells analyses of maximum time between events (see Appendix E). As a result of these low frequency results vegetation (such as river red gum in the riparian zone and inner floodplain) may become poorer in condition; and habitat diversity may be reduced, including foraging habitat for migratory birds. Access to temporary, opportunistic and productive habitat would also be reduced for floodplain fish specialists and other water-dependent biota.

This is significant as some small fish species generally have a life-span less than five years and benefit from having access to off-river habitats. These habitats, with their significant diversity and aquatic productivity, form an important nursery for juveniles. The risk of losing these ecological processes is greatest under the 278 GL and 320 GL A scenarios (i.e. at recovery less than 100 GL).

Mid-floodplain processes (such as nutrient exchange and support of woodland communities, including black box and coolibah) will be reasonably well protected under all scenarios. This flow indicator can be met across many scenarios; and is possible due to the much shorter flow duration requirement (as compared to the longer requirements under the riparian and inner floodplain flow indicators). However, only under the 390 and the 415 GL scenarios can the outer floodplain flow indicator be met. This indicator supports productivity of grasslands on the outer floodplain, important for providing terrestrial animal habitat and energy sources for aquatic animals. The risk of losing these ecological processes is greatest under the 278 GL and 320 GL A scenarios.

Under all scenarios there will remain a high risk of not achieving the target of supporting recruitment opportunities, for a range of native aquatic species (e.g. fish, frogs, turtles, invertebrates), and particularly maintaining drought refuges. However, the support of recruitment opportunities is most mitigated by the 320 GL B, and the 320 GL C, 350 GL and 415 GL scenarios.

The 415 and 390 GL scenarios have the greatest capacity to mitigate risk to the following targets, though the riparian and inner floodplain will remain at risk regardless:

- supporting the habitat requirements of waterbirds and (for Narran Lakes) is conducive to successful breeding of waterbirds
- ensuring the current extent of native vegetation of the riparian, floodplain and wetland communities is sustained in a healthy, dynamic and resilient condition
- supporting key ecosystem functions, particularly those related to connectivity between the river and the floodplain.

Overall, the lowest risks for the Lower Balonne occur under the 415 GL scenario; while the 278 GL presents the highest risk.

A range of additional measures should be investigated in order to increase the likelihood of reaching the ecological targets. River channel connectivity flow could be supported through a mix of protection of environmental water, temporary trade, and use of private storages. Floodplain connectivity may be enhanced through the use of additional measures to help pass larger unregulated flows. Measures could include a mix of protection of environmental water and targeting overbank flow entitlements.

What are the Narran Lakes environmental results?

The model results indicate that the water recovery scenarios would achieve between 2 and 3 of the 4 individual Narran Lakes wetland/floodplain flow indicator targets (Figure 21). Based on this binary assessment, the 320 GL B, 320 GL C, 350 GL and 415 GL scenarios meets the most number of indicators (3 in total) and present the lowest risk scenario; while the 278 GL, 320 GL A, 320 GL B, 345 and 390 scenarios meets only 2 flow indicators, and present the highest risk scenarios.

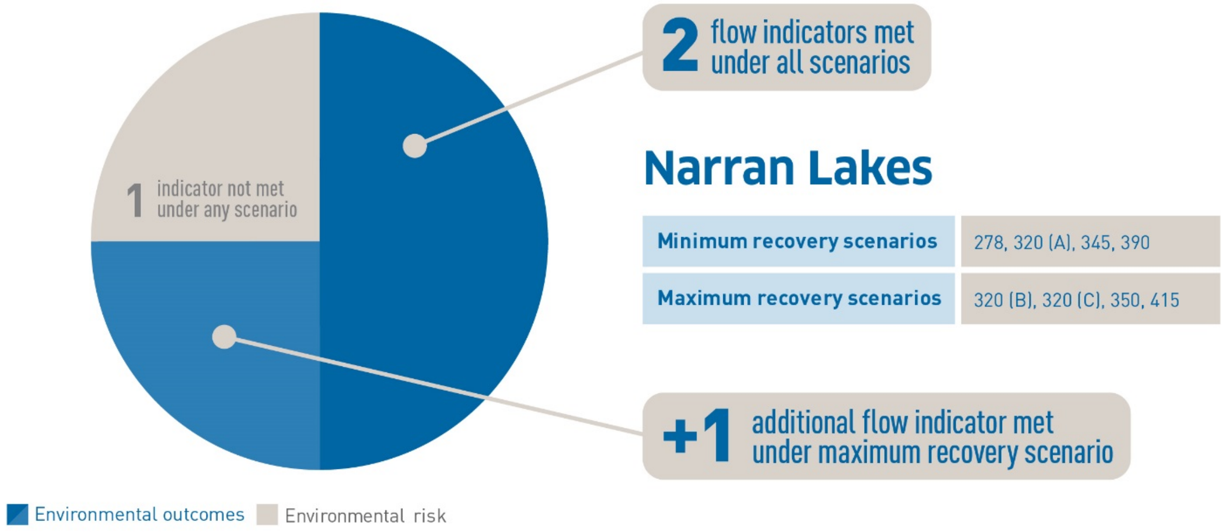


Figure 21: Minimum and maximum number of Narran Lakes flow indicators that can be met (and the correlating scenarios), and the number of flow indicators not able to be met under any scenario.

Four water recovery scenarios reach the aggregated target range for floodplain and wetland connectivity (320 GL B, and 320 GL C, 350 GL and 415 GL) (Figure 22), with the remaining scenarios resulting in either minor improvement (278 GL) or major improvement (320 GL A, 345 GL and 390 GL). There were no Narran Lakes river channel indicators described in the Environmental Water Requirements report (though some Lower Balonne indicators do include Narran River flow indicators). Across the range of water recovery scenarios, between 2 to 3 of the 4 Narran Lakes flow indicator targets are achieved. The 154,000 ML total volume waterbird breeding indicator is not satisfied by any recovery scenario. The inner floodplain rookery habitat is also met by the baseline condition.

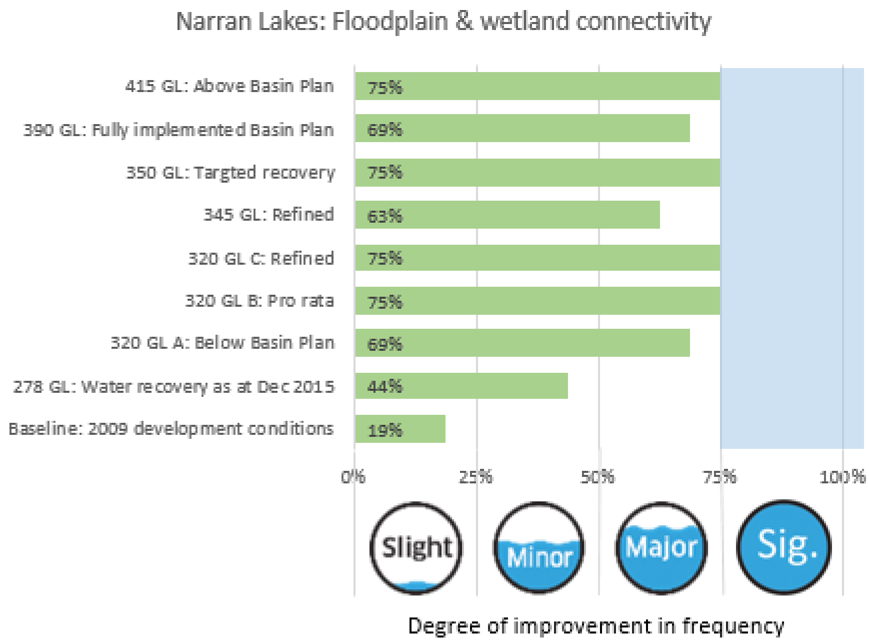


Figure 22: Narran Lakes aggregated wetland/floodplain flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

Under all scenarios, the watering needs of the Narran Lakes rookery habitat (25,000 ML total volume) and of the northern lakes and floodplains (50,000 ML total volume) are achieved. Notably, this includes the Narran Lakes Ramsar listed area. The long-term health of vegetation in the parts of the northern lakes inundated by this event is likely to be maintained (Clear Lake, Back Lake, Long Arm and the adjacent lignum swamp). This is vital for waterbird rookery sites. These flows may support waterbird breeding (though not likely in large numbers) and can provide breeding and nursery habitat for native fish species (including the endangered olive perchlet). The greatest risk occurs under the 278 GL scenario, which provides the least improvement towards the upper end of the target range. Further, the increased frequency of a 50,000 ML flow is likely to improve the filling of the northern lakes, inundate larger areas of lignum that are important foraging sites, and improve the condition of riparian vegetation.

The largest 250,000 ML total volume flow indicator is met by four scenarios: 415 GL, 350 GL and 320 GL B and 320 GL C. Under these scenarios, vegetation habitat across all of the Narran Lakes and much of the northern and central floodplains is likely to receive adequate inundation to contribute to and maintain vegetation condition. The risk of receiving inadequate inundation to is greatest under the 278 GL scenario.

The ecological objectives for Narran Lakes also include the provision of opportunities for large-scale waterbird breeding — targeted by the 154,000 ML flow indicator. No recovery scenario is able to meet this target range, and sufficient opportunities in the Narran Lakes for large-scale breeding are unlikely over the long term. The greatest improvement in frequency is under the 415, 350, 320 GL B and 320 GL C scenarios, which provide a frequency of one breeding event, on average, every 6.3 years. The smallest increase is a recurrence of one every 7.2 years.

Based on life history information on the straw-necked ibis (albeit limited), a recurrence of one opportunity every 6.3 years is likely to result in only one breeding opportunity in an ibis' lifespan. This would not be sufficient to sustain populations, and while smaller flows may trigger smaller breeding events, they would be unlikely to contribute significantly to reducing the current decline in waterbird numbers across the broader landscape.

Overall, the lowest risk scenarios for the Narran Lakes occur under the 320 GL B, 320 GL C, 350 GL and 415 GL scenarios. The 278 GL scenario presents the highest risk.

Additional opportunities to provide for waterbird breeding have already been actioned. In 2008, water purchased and released from private storages on farms upstream on the Narran River were used to extend a natural flow and breeding event in order to prevent nest abandonment. Other measures could also include the protection of environmental flows and temporary trade.

What are the Condamine–Balonne environmental results?

The results suggest that targeted water recovery is an efficient way of improving ecological outcomes in the Condamine–Balonne. Across the two areas, the 415 GL scenario results in the greatest number of flow indicators meeting the target range and presents the lowest levels of environmental risk. The 278 GL and 320 GL A scenarios are the ecologically highest risk scenarios. Based on the scenarios investigated, water recovery greater than 100 GL in the Condamine–Balonne is likely to result in better environmental outcomes. The current Basin Plan settings of 142 GL (or greater, such as the 415 GL scenario) show further improvement. Targeting of entitlement types for recovery is also likely to contribute to improved flow indicator frequencies and environmental outcomes.

Regardless of the scenario, uncertainty regarding the achievement of several ecological targets will remain. These include the provision of small flows to support waterhole refuges during prolonged dry periods; maintenance of healthy and resilient water-dependent riparian and inner floodplain ecosystems in the Lower Balonne, and large-scale waterbird breeding in the Narran Lakes. Additional measures, such as those described above, should be investigated further in order to reduce these risks.

Results: Gwydir River Catchment

About the Gwydir Wetlands

The Gwydir Wetlands are recognised as a significant refuge for waterbirds in dry times, and for supporting some of the largest waterbird breeding colonies recorded in Australia (Bennet and Green 1991). They include species listed as threatened both in NSW and nationally, and include species listed on international migratory bird agreements (Spencer 2010).

The Gwydir Wetlands are also notable for a diverse vegetation mosaic, including having one of the largest known stands of the wetland plant marsh club-rush (*Bolboschoenus fluviatilis*) in NSW (Bennett and Green 1991; McCosker and Duggin 1993). The marsh club-rush sedgeland is currently listed as a Critically Endangered Ecological Community under the *Threatened Species Conservation Act 1995* (NSW). The wetlands also support native fish. Surveys conducted in 2007 and 2008 recorded 11 species of native fish, including the threatened Murray cod (Spencer 2010).

Gwydir Wetlands, 2015

How much water recovery is being looked at?

The baseline diversion limit for the Gwydir (excluding interceptions) is 352.2 GL. Current Basin Plan legislation has a local water recovery target of 42 GL in the Gwydir, which represents a 13% reduction in the total Gwydir consumptive pool. Current Basin Plan legislation also has a shared water recovery target of 143 GL across catchments of the north to meet the needs of the Barwon–Darling system. This includes a small contribution from the Barwon–Darling itself. The shared recovery volume acknowledges the importance of upstream catchments to improving flow components and environmental outcomes in the Barwon–Darling. An estimate of 48 GL has been recovered as at December 2015.

The Northern Basin Review is looking at a range of water recovery scenarios. These range from a return of 1 GL back to the consumptive pool, through to an additional 11 GL of water recovery which includes a shared recovery component.

Gwydir River flow indicators

The flow indicators identified for the Gwydir are shown in Table 11 below. These are based on previous information compiled for the valley, with no new information developed as part of the science component of the Northern Basin Review. There are two river channel indicators identified for the Gwydir River:

- One base-flow to connect habitats along the river. Base flows are important for maintaining refuge waterhole habitats during dry times. If too many refuge waterholes dry out, local extinction of fish populations could occur with much slower re-colonisation upon the return of wetter conditions. The Gingham Waterhole is notable as an important refuge for fish during dry times.
- One fresh to connect habitats along the river and stimulate fish to breed and move. Freshes help provide more habitat, and different types of habitat for fish and other aquatic animals. Support a greater diversity of species as well as more fish.

There are seven wetland/floodplain flow indicators for the Gwydir River catchment aimed at:

- providing large enough flows for long enough to reach key flood-dependent vegetation on the floodplain to maintain its character and condition
- providing a large enough flow to reach key waterbird breeding and foraging sites for long enough to enable waterbirds to fledge their young
- providing flows often enough so that waterbirds have more than one opportunity to breed during their lives (some ducks only live for 3-4 years while some of the bigger birds such as ibis can live up to 8 years).

Note that two of the wetland/floodplain indicators are focused on outcomes in the Mallowa Creek system.

Table 11: Gwydir flow indicators (size of flow, duration, timing and how often)

Why?	Where in the landscape?	Stream gauge	Size of flow	Duration (days)	Timing	How often? (percentage of years)
Wetland/floodplain • Protect and restore Ramsar sites • Water wetlands and floodplain vegetation • Provide habitat for colonial waterbird breeding • Maintain largest stand of marsh club rush in NSW, and other important wetland vegetation • Increase food resources – exchange nutrients between river channels and floodplain • Inundate fringing vegetation, especially river cooba and red gum • Floodplain productivity (grasslands)	wetlands	Yarraman Bridge	45 GL	60	Oct-Mar	80-90
	wetlands and near-channel	Yarraman Bridge	60 GL	60	Oct-Mar	60-70
	low-level floodplain	Yarraman Bridge	80 GL	60	Oct-Mar	40-50
	mid-level floodplain	Yarraman Bridge	150 GL	60	Oct-Mar	20-30
	high-level floodplain	Yarraman Bridge	250 GL	60	Oct-Mar	12
	wetlands and low-level floodplain	Mallowa Creek Regulator	5.4 GL	120	Feb-Mar, and Aug-Sept	91
	wetlands and low-level floodplain	Mallowa Creek Regulator	4.5 GL	92	Nov-Jan	40-50
River channel • Movement between habitats • Successful fish breeding • Inundate benches and snags (habitat diversity) • Primary production supporting the food web • Connectivity through the river system • Maintenance of waterhole habitats • Breaks up extended dry spells	base flow	Yarraman Bridge	150 ML/d	45	Oct-Jan	85
	fresh	Yarraman Bridge	1,000 ML/d	2	Oct-Jan	85

What are the Gwydir environmental results?

The model results indicate that the water recovery scenarios would achieve 5 of the 9 Gwydir wetland/floodplain flow indicator targets (the two river channel indicators are not met under any scenario) (Figure 23). Based on this binary assessment, all scenarios present an equal level of environmental risk and benefit.

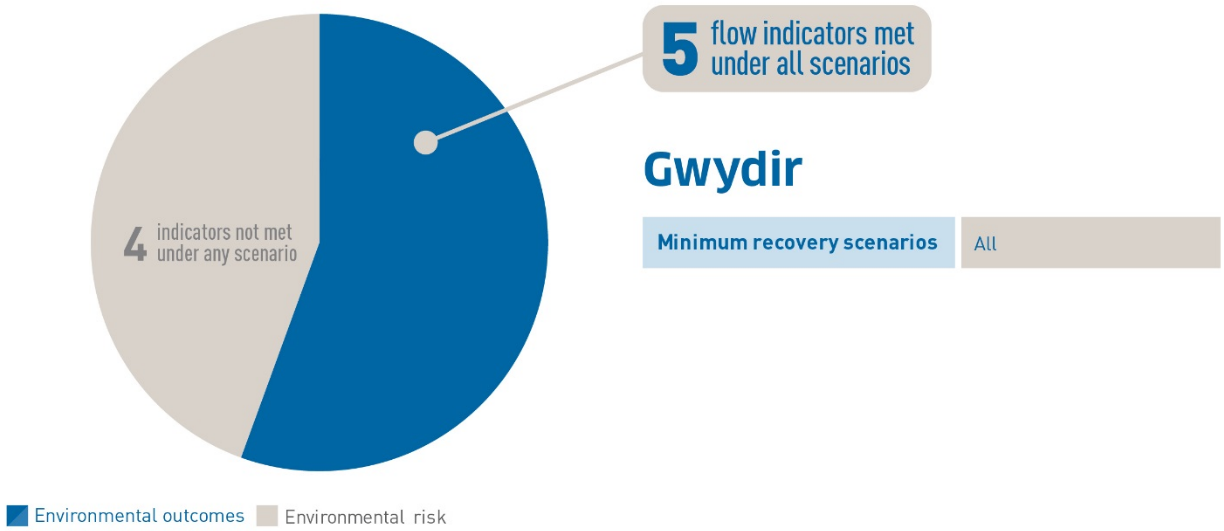


Figure 23: Minimum and maximum number of Gwydir flow indicators that can be met (and the correlating scenarios), and the number of flow indicators not able to be met under any scenario.

Figure 24 shows that no scenario is able to improve aggregated river channel connectivity frequency beyond the baseline condition. In fact, the baseline aggregated frequency exceeds that achieved by the modelled water recovery scenarios, as a result of the 1,000 ML/d (2-day duration) flow indicator. However, the difference between the baseline and water recovery scenarios is only 1% (i.e. one event over the 114-year modelling period), and the cause of this 'lost' event is a small change to the extraction pattern during this single year. Current operating constraints do not allow this type of environmental flow to be directly managed, hence this effect is an unintended and indirect result of the changes made to represent the Basin Plan in the model (i.e. the inclusion of water recovery and environmental water delivery). Also, although the shape of the event has changed, the overall volume is passing the indicator site is unaltered. The decrease in scenario results for the 1,000 ML/d flow indicator is therefore not categorised as significant, and it is expected that the environmental outcomes associated with this flow indicator are essentially constant between the baseline and water recovery scenarios. Given that baseflow is the same as the flow indicator target (85% if years), means that this component of the river channel connectivity group represents only a very minor risk (however the baseflow component does represent a risk and is discussed further below).

Figure 25 shows that there is strong improvement in wetland/floodplain connectivity across the scenarios, with four of the eight scenarios reaching that aggregated target range. Regardless of scenario, the same 5 indicators (of the 9 in total) have their individual target ranges met. These are the high, mid and low-level floodplain, and wetlands and near-channel vegetation flow indicators (including supporting colonial waterbird breeding). Three flow indicators are also met under the baseline condition: two mid and one outer floodplain flow.

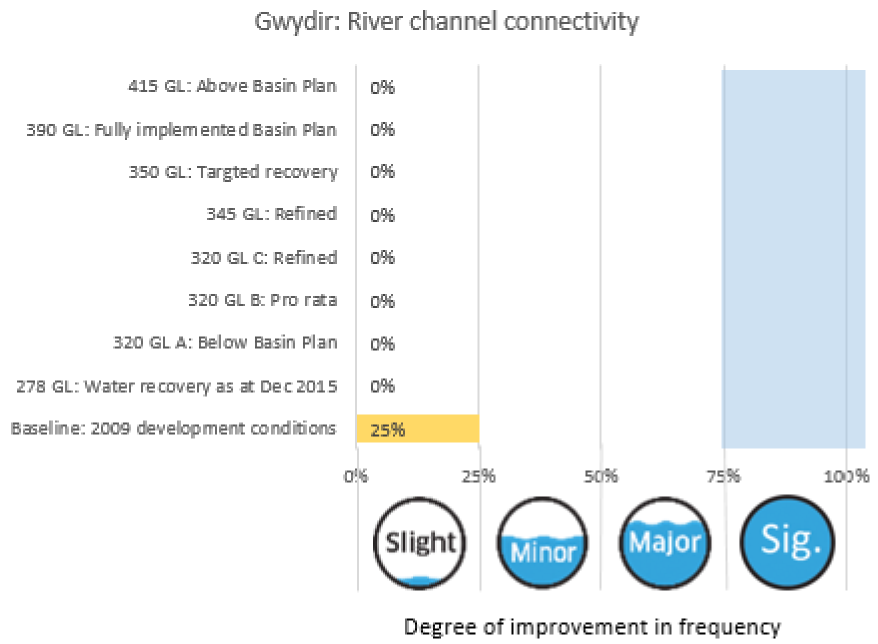


Figure 24: Gwydir River (and Mallowa Creek) aggregated river channel connectivity flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

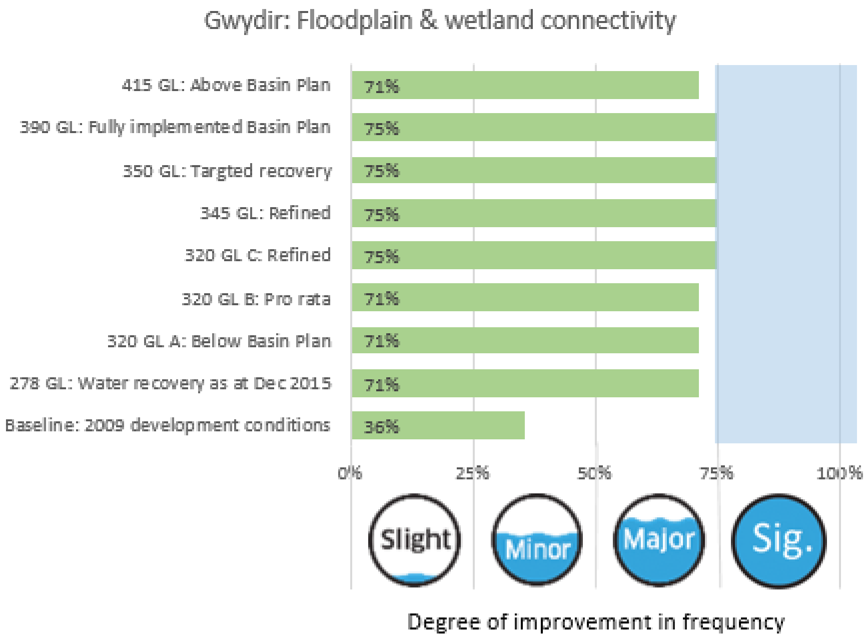


Figure 25: Gwydir River (and Mallowa Creek) aggregated wetland/floodplain flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

Based on the scenarios investigated, the results show that a Gwydir recovery volume of 47 GL (or more) is likely to result in major improvements in flow indicator frequencies. These improvements are constrained to wetland and floodplain connectivity outcomes. Additional recovery is unlikely to further improve wetland and floodplain connectivity outcomes largely due to operational constraints around the delivery of environmental water to the Lower Gwydir.

River channel connectivity

The lack of any improvement in river channel connectivity relates to the two indicators (150 ML/d and 1,000 ML/d) intended to facilitate native fish movement and recruitment by providing a base flow followed by a fresh. None of the modelled water recovery scenarios satisfy these flow indicators at the described frequency, and are quite similar to the baseline condition. The 150 ML/d flow indicator shows a significant lack of improvement in frequency toward the target range under all scenarios; while the second fresh flow (1,000 ML/d) is very close to being achieved under all scenarios. The lack of the base flow is of particular concern and will increase the risk that native fish will not get movement and spawning cues often enough, which in turn may result in a lack of population resilience, and extreme circumstances, reductions in population sizes and local extinctions. Though this risk is not expected to be greater than the current level of risk under baseline/current recovery conditions.

Notwithstanding, based on the results, the following ecological target is considered to be at risk, regardless of scenario:

- provision of a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates)

Additional measures to reduce this risk should be considered (focused on the base flow component). Measures that would warrant further investigation include Gwydir constraints relaxation (to increase the managed flow limit for environmental water across the Gingham Watercourse, the lower Gwydir River and the Mallowa Creek) and the protection of environmental water.

Wetland and floodplain connectivity

Wetland and floodplain connectivity outcomes in the Gwydir are likely to be strong across the range of recovery scenarios. Under the 390, 350, 345 and 320 GL C recovery scenarios the improvement in floodplain/wetland connectivity is significant and the residual risk to the floodplain and wetland ecology and ecosystem functions is considered to be low.

Under these scenarios there is a high likelihood that the following targets can be achieved:

- providing a flow regime that ensures the current extent of native vegetation of the riparian, floodplain and wetland communities is sustained in a healthy, dynamic and resilient condition
- providing a flow regime which supports the habitat requirements of waterbirds and is conducive to successful breeding of colonial nesting waterbirds
- providing a flow regime which supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain.

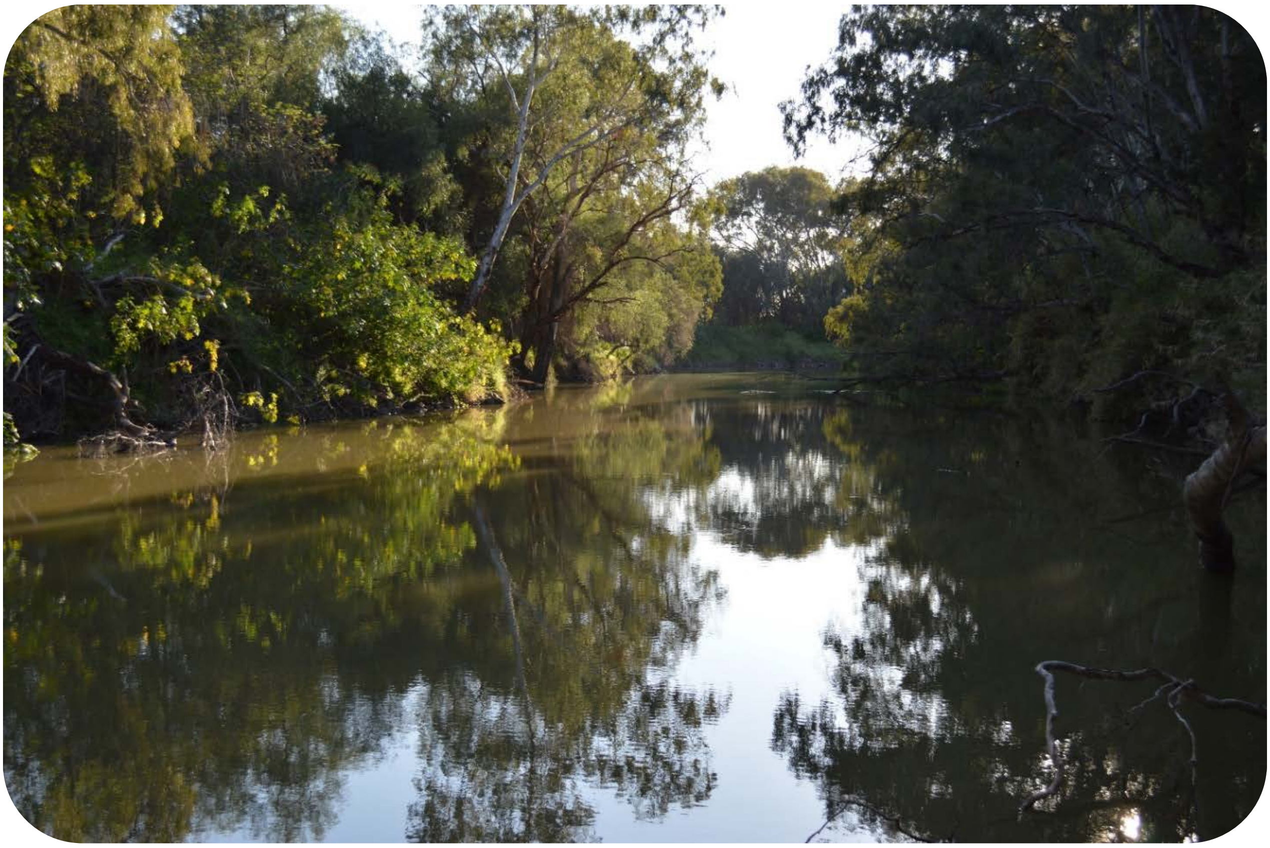
Under the 278 GL, 320 GL A, 320 GL B and 415 GL scenarios, while there was major improvement in aggregate frequencies, a minor risk to the achievement of these targets would still remain. This risk would be most apparent for the health and resilience of low-lying, near channel wetland ecology and ecosystem functions.

Results: Macquarie–Castlereagh Catchment

About the Macquarie Marshes

The Ramsar-listed Macquarie Marshes is one of the largest semi-permanent freshwater wetlands in south-east Australia, covering about 200,000 hectares. It is recognised as being internationally important because of its size, diversity of wetland types, extent of wetland communities and large-scale colonial waterbird breeding events. It regularly supports more than 20,000 waterbirds and over 500,000 during large floods (Department of the Environment, Water, Heritage and the Arts 2010). Sixteen colonial nesting waterbird species have been recorded breeding in the Macquarie Marshes, including substantial numbers of cormorants, herons, ibises and spoonbills (Kingsford and Johnson 1998; Kingsford and Auld 2005).

The Macquarie Marshes supports a variety of flood-dependent vegetation types (e.g. river red gum, lignum, common reed, cumbungi and water couch marsh) (Bowen and Simpson 2009). River red gum forests and woodlands are also a distinctive feature of the Marshes. They are among the most diverse of the wetland communities in the Marshes and many have an understorey of aquatic species (Bowen and Simpson 2009; NSW Department of Environment and Climate Change 2009). River red gum provides critical habitat for waterbirds and other wetland animals and is the tree species most used for nesting by colonial nesting waterbirds in the Marshes (Blackwood et al. 2010).



Macquarie River at Warren, October 2015

How much water recovery is being looked at?

The baseline diversion limit for the Macquarie–Castlereagh (excluding interceptions) is 424.3 GL. Current Basin Plan legislation has a local water recovery target of 65 GL for the Macquarie–Castlereagh, which represents a 15% reduction in the total consumptive pool. Current Basin Plan legislation has a shared water recovery target of 143 GL across catchments of the north to meet the needs of the Barwon–Darling system. This includes a small contribution from the Barwon–Darling itself. The shared recovery volume acknowledges the importance of upstream catchments to improving flow components and environmental outcomes in the Barwon–Darling.

Water recovered in the Macquarie–Castlereagh catchment has been estimated to be 82.5 GL as at December 2015. The Northern Basin Review is looking at a range of water recovery scenarios. These range from an additional 5 GL of water recovery through to a potential return of up to 28 GL back to the consumptive pool.

Macquarie–Castlereagh flow indicators

The wetland/floodplain flow indicators identified for the Macquarie–Castlereagh are shown in Table 12 below. These are based on previous information compiled for the valley, with no new information developed as part of the science component of the Northern Basin Review, and no in-channel flow indicators or indicators outside the marshes included for this catchment. The flow indicators aim to:

- provide large enough flows for long enough to reach key riparian and flood dependent vegetation in wetlands and on to the floodplain to maintain its character and condition

- provide a large enough flow to reach key waterbird breeding and foraging sites for long enough to enable waterbirds to fledge their young
- provide flows often enough so that waterbirds have more than one opportunity to breed during their lives (some ducks only live for 3-4 years while some of the bigger birds such as ibis can live up to 8 years).

Table 12: Macquarie–Castlereagh flow indicators (size of flow, duration, timing and how often)

Why?	Where in the landscape?	Size of flow	Timing	How often? (percentage of years)
Wetland/floodplain • Protect and restore Ramsar sites • Water wetlands and floodplain vegetation • Provide habitat for colonial waterbird breeding • Maintain marsh club rush and other important wetland vegetation • Increase food resources – exchange nutrients between river channels and floodplain • Inundate fringing vegetation, especially river cooba and red gum • Floodplain productivity (grasslands)	Wetlands and near-channel floodplain	100 GL	Volume over 5 successive months, Jun-Apr	80-85
	low-level floodplain (majority of red gum forest)	250 GL	Volume over 5 successive months, Jun-Apr	40-50
	mid-level floodplain (broader marshes including black box and coolibah)	400 GL	Volume over 7 successive months, Jun-Apr	30-40
	high-level floodplain (broader marshes and woodland vegetation)	700 GL	Volume over 8 successive months, Jun-May	17

What are the Macquarie–Castlereagh environmental results?

The model results indicate that the water recovery scenarios would achieve 4 of the 4 individual Macquarie wetland/floodplain flow indicator targets (no river channel flow indicators are described) (Figure 26). Based on this binary assessment, all scenarios present an equal level of environmental risk and benefit.

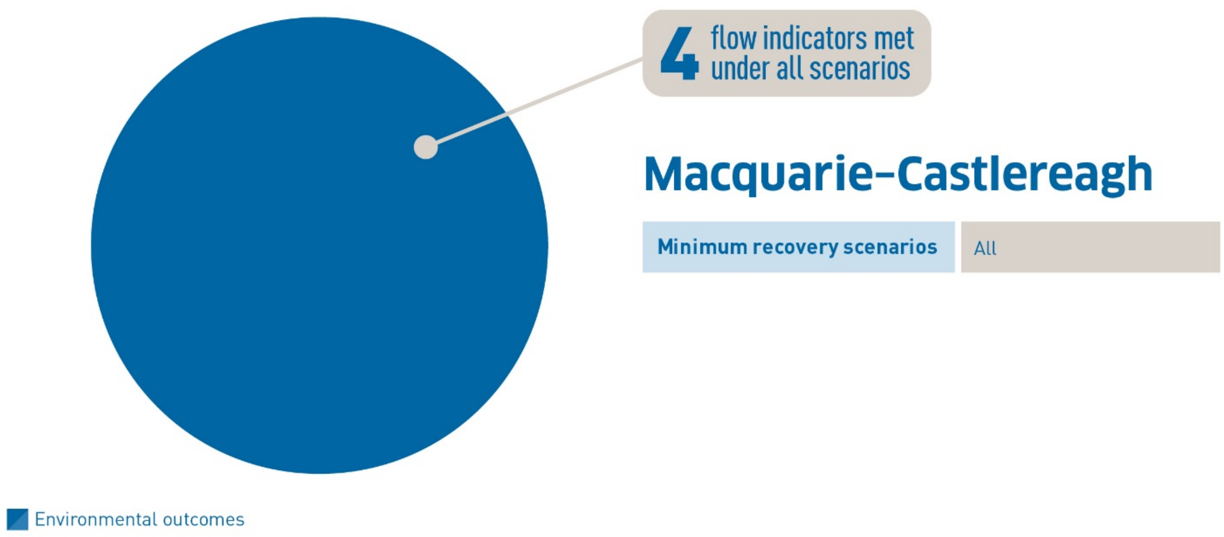


Figure 26: Minimum and maximum number of Macquarie flow indicators that can be met (and the correlating scenarios), and the number of flow indicators not able to be met under any scenario.

Figure 27 shows that all water recovery scenarios reach the target range. All scenarios reach the target range for the high, mid and low-level floodplain, and wetlands and the near-channel vegetation flow indicators (including supporting colonial waterbird breeding).

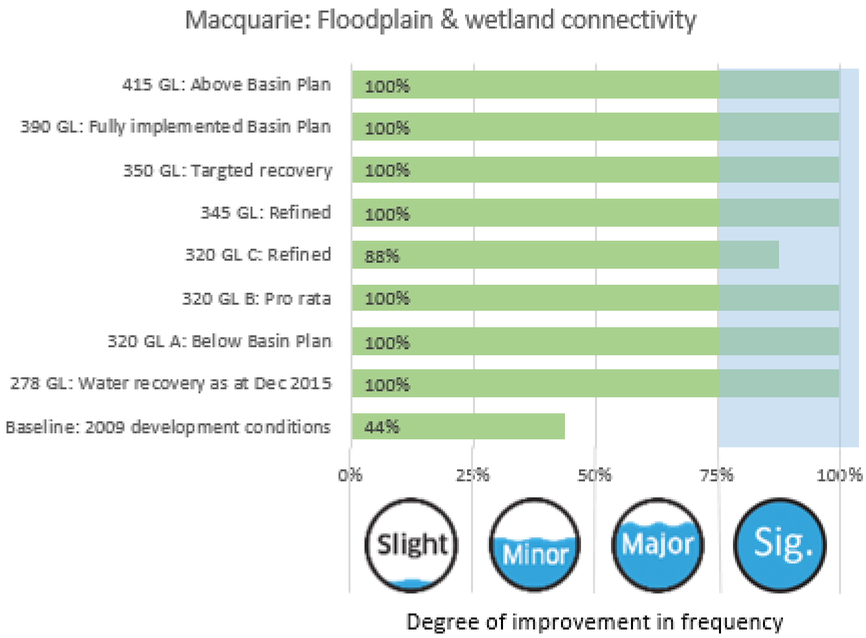


Figure 27: Macquarie–Castlereagh aggregated wetland/floodplain flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

Based on the scenarios investigated, the results show that a Macquarie recovery volumes of 55 GL (or more) is likely to result in significant improvements in flow indicator frequencies. These improvements result in all flow indicator target ranges being achieved. These improvements are related to wetland and floodplain connectivity outcomes only, as no river channel connectivity flow indicators were identified for the Macquarie.

Floodplain and wetland connectivity

Key outcomes for the Macquarie Marshes, for all scenarios, are likely to include a flow regime that will support the needs of wetland and woodland communities, resulting in the maintenance of the ecological character of this internationally recognised Ramsar site.

By maintaining the vegetation communities in the Marshes in good condition, it is more likely that conditions will be suitable for breeding of colonial nesting waterbirds. Further, providing a flow regime that supports wetland vegetation communities and waterbirds in the Marshes will also benefit other species found in the region such as fish and frogs through productivity and movement opportunities.

These results provide confidence that there is high likelihood, across the range of modelled scenarios, that the targeted environmental outcomes will be achieved:

- providing a flow regime which supports the habitat requirements of waterbirds and is conducive to successful breeding of colonial nesting waterbirds

- providing a flow regime which ensures the current extent of native vegetation of the riparian, floodplain and wetland communities is sustained in a healthy, dynamic and resilient condition
- providing a flow regime which supports movement opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates)
- providing a flow regime which supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain.

Results: Namoi River Catchment

About the Namoi

The aquatic and terrestrial environments of the Namoi catchment provide habitat for a number of threatened species and ecological communities that are protected under the *Threatened Species Conservation Act 1995* (NSW) and *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). The floodplain downstream of Narrabri supports many small lagoons, wetlands and anabranches, as well as flood runners and extensive areas of floodplain woodlands.

How much water recovery is being looked at?

The baseline diversion limit for the Namoi (excluding interceptions) is 343.3 GL. Current Basin Plan legislation has a local water recovery target of 10 GL for the Namoi, which represents a 3% reduction in the total Namoi consumptive pool. Current Basin Plan legislation has a shared water recovery target of 143 GL across catchments of the north to meet the needs of the Barwon–Darling system. This includes a small contribution from the Barwon–Darling itself. An estimate of 13 GL has been recovered as at December 2015.

The Northern Basin Review is looking at a range of water recovery scenarios. These range from no further water recovery in the Namoi up to 15 GL of further water recovery.

Namoi river lagoon near Walgett

Namoi River flow indicators

The Namoi River flow indicators are based on previous information compiled for the valley, with no new information developed as part of the science component of the Northern Basin Review The two river channel flow indicators identified for the Namoi are.

- One base-flow to connect habitats along the river. Base flows are important for maintaining refuge waterhole habitats during dry times. If too many refuge waterholes dry out, local extinction of fish populations could occur with much slower re-colonisation upon the return of wetter conditions.
- One fresh to connect habitats along the river and stimulate fish such as golden perch to breed and move. Freshes help provide more habitat, and access to different types of habitat for fish and other aquatic animals. Support for a greater diversity of fish species is also expected.

There is one wetland/floodplain flow indicator identified for the Namoi River. This indicator aims to:

- provide large enough flows for long enough to reach key flood-dependent vegetation and wetlands on the floodplain to maintain their character and condition. Overbank flows are important for nutrient exchange between the river and its floodplain, supporting both aquatic and terrestrial food webs and ecosystem functions.

Table 13: Namoi River flow indicators (size of flow, duration, timing and how often)

Why?	Where in the landscape?	Stream gauge	Size of flow	Duration (days)	Timing	How often? (percentage of years)
Wetland/floodplain • Water wetlands, lagoons, anabranches and floodplain woodlands • Maintain important wetland vegetation • Increase food resources – exchange nutrients between river channels and floodplain • Inundate fringing vegetation, especially river cooba and red gum • Floodplain productivity (grasslands)	Wetlands, anabranches and floodplain	Bugilbone	4,000 ML/d	45 with minimum duration of 7 consecutive days	Jul-Jun	22-25
River channel • Movement between habitats • Successful fish breeding • Inundate benches and snags (habitat diversity) • Primary production supporting the food web • Connectivity through the river system • Maintenance of waterhole habitats • Breaks up extended dry spells	Base flow	Bugilbone	500 ML/d	75 with minimum duration of 25 consecutive days	Jul-Jun	41-55
	Fresh	Bugilbone	1,800 ML/d	60 with minimum duration of 6 consecutive days	Jul-Jun	29-39

What are the Namoi environmental results?

The model results indicate that the water recovery scenarios would achieve between 1 and 3 of the 3 individual Namoi river channel and wetland/floodplain flow indicator targets (Figure 28). Based on this binary assessment, all scenarios, except the 278 GL, present an equal level of environmental risk and benefit. The 278 GL scenario, which meets only 1 flow indicator, and presents the highest risk scenario.

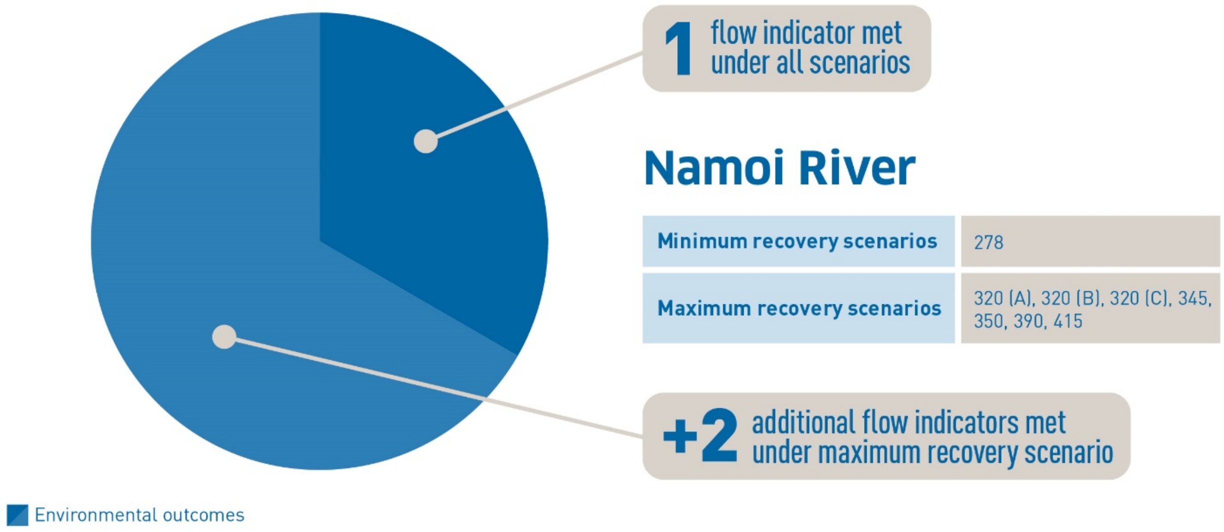


Figure 28: Minimum and maximum number of Namoi flow indicators that can be met (and the correlating scenarios), and the number of flow indicators not able to be met under any scenario.

Figure 29 and Figure 30 show that all scenarios, except the 278 GL scenario reach the aggregated target range for both river channel connectivity and floodplain/wetland connectivity. The baseline condition reaches the target range for a single flow indicator (in-channel fresh). With the exclusion of the 278 GL scenario, there is no difference among scenarios. These scenarios would be expected to result in a low level of risk to both river channel floodplain/wetland connectivity functions and a significant level of improvement in flows and likely environmental outcomes compared to 2009 baseline levels of development.

The 278 GL scenario results in major improvement in river channel connectivity; though only achieves minor improvement in wetland/floodplain connectivity. Under the 278 GL scenario, the 500 ML/d base flow and the 4,000 ML/d wetland/floodplain flow indicators are not satisfied, though there is some improvement from the baseline condition.

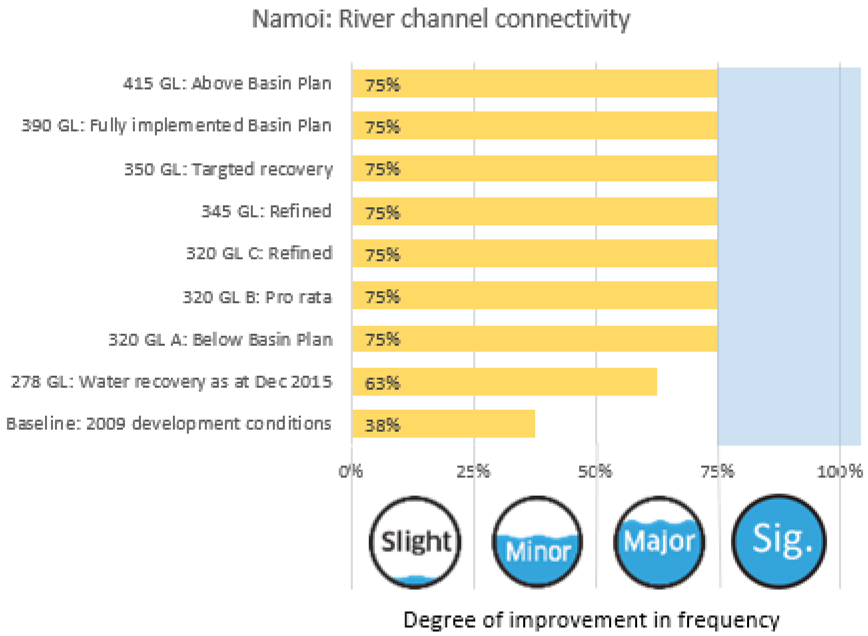


Figure 29: Namoi River aggregated river channel flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

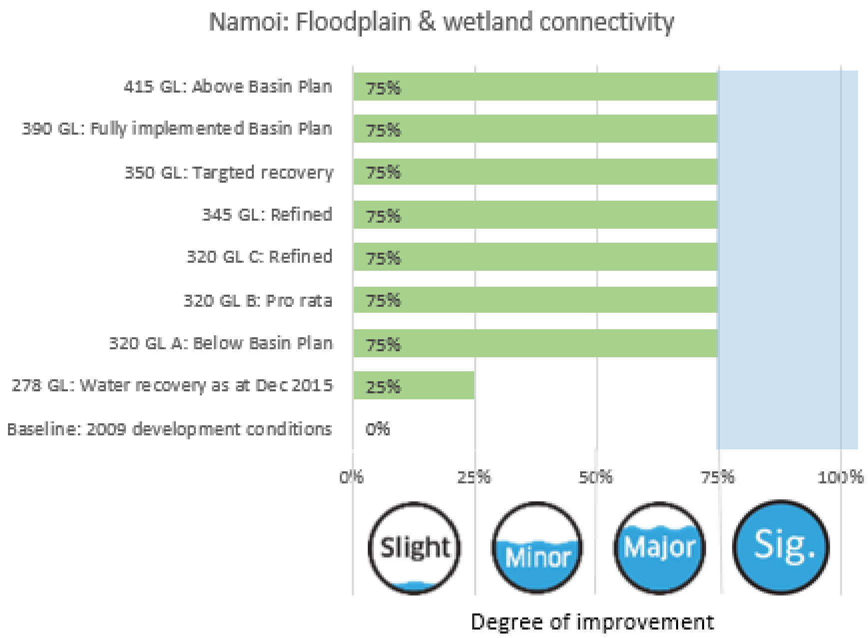


Figure 30: Namoi River aggregated wetland/floodplain flow indicator results showing the level of frequency improvement toward the target range (75%). 0% indicates no improvement for any flow indicators.

Based on the scenarios investigated, the results show an improvement in flow indicator frequency in the Namoi once recovery volumes reach approximately 20 GL (i.e. all scenarios beyond current recovery). This change is more pronounced for floodplain and wetland connectivity.

River channel connectivity

The strong river channel connectivity results for all scenarios except the 278 GL scenario, indicate that there is a high likelihood that native fish and other animals will have regular opportunities to spawn, recruit and move between a diversity of in-channel habitats. The 278 GL scenario is likely to also result in an improvement in river channel conditions, though not to the same extent as the other scenarios.

Floodplain and wetland connectivity

The achievement of the target frequency range for the floodplain and wetland connectivity indicator (in all except the 278 GL scenario) is likely to result in regular inundation of lagoons, wetlands and anabranches in the lower Namoi. This would facilitate nutrient exchange between the river and its anabranches and wetlands, provide additional areas of opportunistic and productive aquatic habitat, and help support vegetation communities and ecosystem functions. Dissolved organic carbon and other nutrients released from floodplain and in-channel features provide an important energy source for riverine organisms; this is an essential part of floodplain-river ecosystem functioning.

Under the 278 GL scenario (the only scenario that does not meet the aggregated target range, and achieves only minor improvement from baseline), nutrient cycling would occur less frequently; and the health of some water dependent vegetation communities may decline.

If water recovery continues in the Namoi, there is a high likelihood that the following ecological outcomes will be achieved:

- providing a flow regime which ensures the current extent of native vegetation of the anabranch communities is sustained in a healthy, dynamic and resilient condition
- providing a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles, invertebrates)
- providing a flow regime which supports key ecosystem functions, particularly those related to longitudinal connectivity and transport of sediment, nutrients and carbon.

At current water recovery of 278 GL there is a moderate to minor risk that these outcomes would not be achieved.

Comparing coordinated flow releases to current river operations

What is the difference between 'coordinated' and 'current' practice?
The Basin Plan includes a volume of water recovery to achieve environmental outcomes in the Barwon–Darling. This volume is shared throughout the Northern Basin — it recognises that inflows from local rainfall in the Barwon–Darling are relatively small; hence flows through this system are almost entirely reliant on the combined inflows from upstream tributaries.

For the purpose of Basin Plan modelling, it was assumed that future watering strategies for each catchment will include an element of downstream watering. It was also assumed that these strategies will include cooperation across the northern Basin to achieve Barwon–Darling environmental outcomes. This cooperation has been represented through a set of demand series located towards the end of system for each regulated catchment (i.e. the Border Rivers, Gwydir, Namoi and Macquarie–Castlereagh).

There are implicit practical challenges limiting the level of cross-catchment cooperation that can be achieved across the northern Basin. For this reason, MDBA has modelled two possible strategies:

- Strategy 1 (whole-of-North coordinated) represents a more managed system in which regulated entitlements in upstream catchments are called on to top up unregulated flows in order to coordinate a bigger or longer duration flow into the Barwon–Darling. This strategy has been applied to all recovery scenarios (except for the 390 GL current river operations).
- Strategy 2 (catchment-scale), in which catchments work individually to maintain low flow connectivity with the Barwon–Darling, represents a management strategy more in-line with current operating practices as per the Barwon–Darling Water Sharing Plan. This strategy has been applied exclusively to the 390 GL current river operations recovery scenario.

Due to their different underlying principles the strategies were targeting different parts of the flow regime. Strategy 1 attempted to maximise the rate at which water was delivered downstream (over period of a couple of weeks per event and about two events every ten years on average), whereas Strategy 2 targeted delivery of low flows (but for longer periods).

Of the two approaches, Strategy 1 is the most consistent with the overall environmentally sustainable level of take method (i.e. using flow indicators to determine the pattern of regulated releases from storage), hence this approach was adopted as standard practice for all but one of the recovery scenarios (the 390 GL current river operations) reported in this document. The outcomes of both options were presented to the Authority to inform the triple-bottom line assessment of SDL options in the northern Basin and understanding of the modelling assumptions that have been made.

Actual watering strategies to manage the environmental water recovered across the northern Basin are still undergoing development. It is not yet clear the level to which cross-catchment coordination will be implemented in practice — the two modelled strategies effectively represent either end of the ‘coordination spectrum’. Comparing the results of both options indicates the extent to which coordination can influence flows (and therefore environmental outcomes) through the Barwon–Darling.

Results for the 390 GL ‘coordinated’ and ‘current practice’ scenarios

There were measureable differences between the 390 GL ‘coordinated’ and ‘current river operations'. Across the north, the coordinated release strategy for the 390 GL scenario met the target range for 21 of 43 flow indicators. The 390 GL current river operations met the target range for 20 flow indicators; however the same set of indicators were not achieved across the two scenarios.

At the whole of north scale, current river operations were not as effective at achieving the river channel flow indicators; though both scenarios were almost equally as effective at the floodplain and wetland connectivity flow group (see Figure 31).

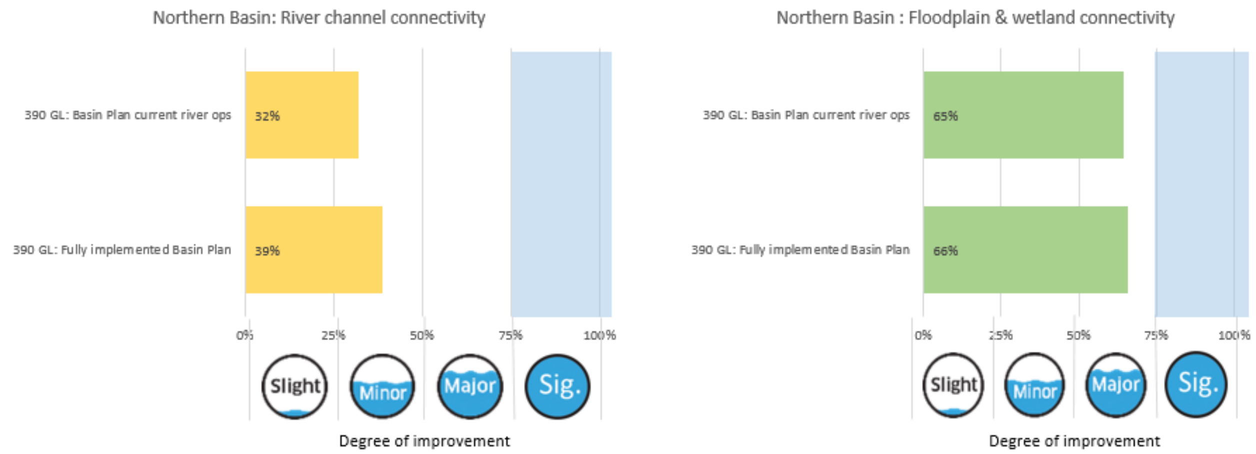


Figure 31: Degree of improvement of the river channel and floodplain/wetland connectivity groups for the 390 GL 'current river operations' and 'fully implemented Basin Plan' scenarios

The difference in the aggregated frequencies of the whole of north river channel connectivity group arises from differences in the Barwon–Darling and Border Rivers (see Figure 32) as outlined below. All other river channel connectivity results, as well as floodplain and wetland results, across all other catchments were very similar, or equal.

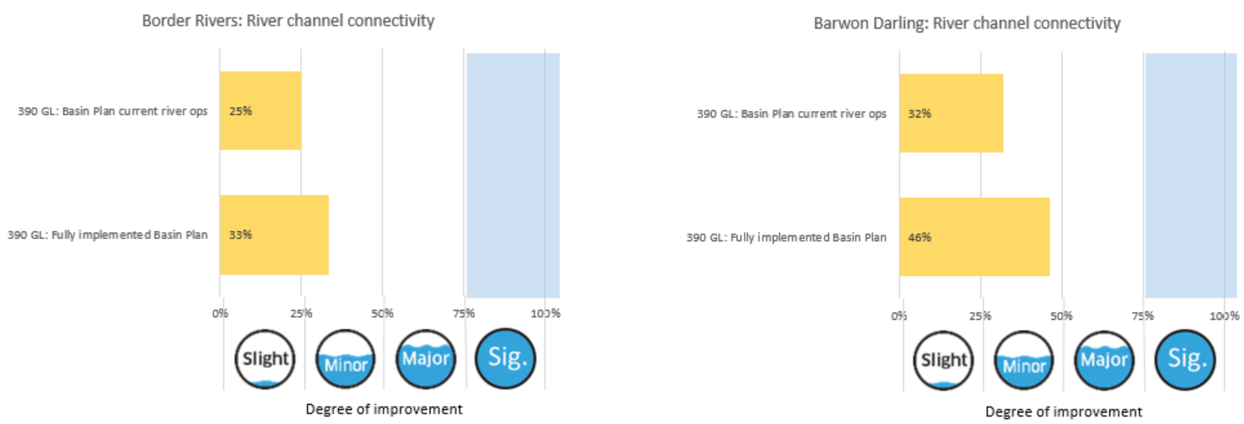


Figure 32: Degree of improvement of the river channel connectivity group for the Border Rivers and Barwon–Darling for the 390 GL 'current river operations' and 'fully-implemented Basin Plan' scenarios

Current river operations are able to increase the frequency of flow indicators (for both river channel connectivity and floodplain/wetland connectivity). However, flow coordination (which is assumed in all modelled scenarios except the 390 GL current river operations) can improve the frequency of flow indicator events beyond that achieved by current river operations, particularly with regard to river channel connectivity. This is likely due to the smaller flows required for these indicators.

While this is an important result, it must be acknowledged that flow coordination across the northern Basin has challenges in its implementation. Flow coordination is discussed in detail in the Northern Basin Review Hydrological Modelling Report.

Environmental complexity, assumptions and uncertainty

The purpose of this environmental outcomes report is to assess the likely environmental outcomes arising from a suite of proposed water recovery scenarios in the northern Basin. Given the complexity of flow/ecology relationships, the geographic size of the northern Basin, and the imperfect knowledge and data available, a series of assumptions were required to be made throughout the process.

The following are the key assumptions underpinning the northern Basin environmental outcomes report.

1. Umbrella Environmental Assets reflect the environmental water needs of the broader catchment.

To represent the water requirements of the river systems of the northern basin, seven umbrella environmental assets were used and 43 site specific flow indicators described. The water requirements of the seven large environmental assets were used as a surrogate for the water needs of the broader catchments within which they are located.

The seven umbrella environmental assets are generally located at or near the bottom of the system (e.g. large terminal wetlands, lowland floodplain complexes) and below major areas of water extraction (e.g. dams and irrigation districts). It is assumed that by meeting the water needs of downstream assets that water will have flowed through and provided environmental benefits to areas upstream. More information on how umbrella environmental assets are used in the development of sustainable diversion limits is available in this report (Swirepik et al. 2015) and in the Environmentally Sustainable Level of Take method and outcomes report.

2. Site-specific flow indicators describe a set of flow events that, if met, will result in the achievement of a set of ecological outcomes.

Ecological outcomes (based on the ecological values of an umbrella environmental assets) are used to guide the development of site-specific flow indicators. Many of the Condamine–Balonne and Barwon–Darling flow indicators were updated in response to the new environmental science work that was undertaken prior to the environmental outcomes report. Particularly given the large area of the northern Basin, and its highly variable nature, there is inherent complexity and imperfect knowledge regarding ecological responses to the flow indicators. Such complexity can confound, diminish, enhance, and in extreme cases, may prevent an ecological response to a flow regime. However, the environmental science program allowed the MDBA to update flow indicators in the Condamine–Balonne and the Barwon–Darling using the best available science.

Based on this science, and other supporting science, for the purposes of this assessment it assumed that if the flow indicators, as a set, are met, then there is high likelihood that the ecological outcomes will be met. More detail on the development of flow indicators and their relationship to ecological outcomes is available in the Environmental Water Requirements reports. The Condamine-Balonne and Barwon-Darling Environmental Water Requirements reports includes information on flow indicator assumptions and relative confidence in the evidence.

Where flow indicators are not met, this supports the importance of additional measures (not directly related to recovery volume) in increasing the likelihood of achieving ecological outcomes.

Additional toolkit measures provide the operational flexibility that helps to protect, coordinate and boost environmental outcomes for particular flow events as they pass through the system.

3. The number of flow indicators and their environmental focus across northern Basin catchments does not need to be equal across catchments for the environmental outcomes assessment to be fit for purpose.

The new science undertaken as part of the Northern Basin Review resulted in a number of new, or refined, flow indicators specified in the updated Condamine–Balonne and Barwon–Darling Environmental Water Requirements reports. The environmental science program did not focus on making changes to other northern Basin umbrella environmental assets flow indicators, and their Environmental Water Requirements reports were not changed. This has resulted in some umbrella environmental assets having more flow indicators than others; or having a different or more constrained environmental focus (e.g. the Macquarie Marshes only focuses on wetland and floodplain flows for vegetation and waterbirds, not the riverine connectivity needs of fish).

This unevenness is acknowledged by the MDBA; however, it is assumed that the current set of Environmental Water Requirements reports, and the flow indicators contained therein, are sufficient to support the requirements of the environmental assessment component of the Northern Basin Review (i.e. the comparison of water recovery scenarios to inform an SDL decision).

4. Improvement toward the achieving the frequency target range of flow indicators is assumed to be environmentally advantageous.

Many site-specific flow indicators do not achieve their target frequency range as a result of the different water recovery scenarios being applied. It is assumed that an improvement in frequency from baseline, toward the target range, represents some reduction in environmental risk. This assumption is based on the fact that the event does increase in its frequency (happens more often than under baseline conditions), and that the required volume, duration and seasonality requirements are fully met.

5. The MDBA modelling framework is assumed to adequately represent the hydrological outcomes of the various water recovery scenarios.

The MDBA uses a hydrological modelling framework to allow the various water recovery scenarios to be assessed in terms of whether or not they can achieve the frequency requirements of the flow indicators specified across the northern basin. Independent reviews of the modelling framework have confirmed that it is fit for purpose for assessing SDL options (CSIRO 2011) and provides an adequate representation of the hydrology and patterns of water resource use (MDBA in prep.b). It is acknowledged that models are an approximation and do not always reflect the variability of conditions, the most up to date water resource policies, and the potential future impacts of climate change. More information on the modelling framework is available in the Hydrologic Modelling for the Northern Basin Review report (MDBA in prep.a).

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Appendix A — Overview of Northern Basin Review reports

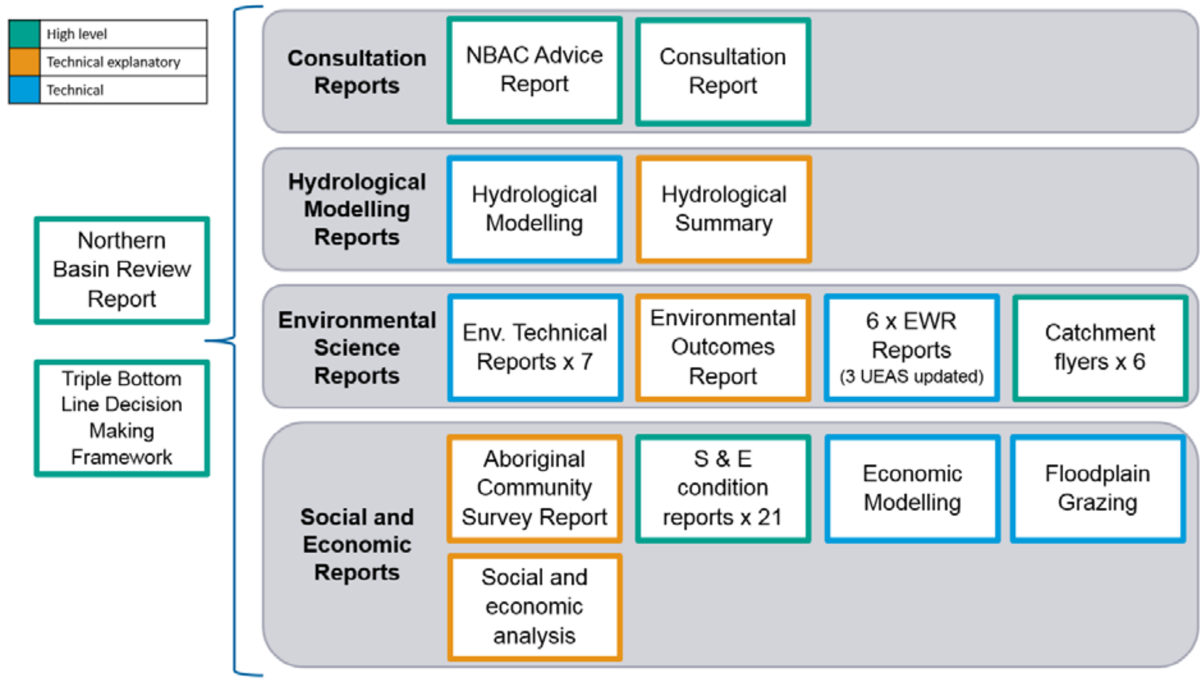


Figure 33: Reports of the Northern Basin Review and how they fit together.

Many of these reports are currently available on the MDBA website. Some reports are still in preparation and will be available once complete.

Appendix B — How flow indicator results and recovery scenarios are assessed

There are 43 flow indicators distributed across the northern Basin catchments. Each of these flow indicators is assessed against the nine recovery scenarios using hydrological modelling (MDBA in prep.a). The models determine how often each of the flow indicators are satisfied over the modelled 114 years (the frequency). This is calculated for each recovery scenario, and under baseline and without development (WOD) scenarios. These are then compared to the target frequency range outlined in the respective Environmental Water Requirements reports. The frequency is often expressed as a range. This is due to the inherent complexities and uncertainties of defining the exact requirements of ecological components. The range is described as a low uncertainty (of achieving the ecological target which means high confidence) to a high uncertainty (of achieving the ecological target which means a lower confidence).

Example flow indicator for the Lower Balonne (frequency target is underlined). The numbers in the table represent the modelled frequencies of the flow indicator for each of the different scenarios. *Bold, asterisked frequencies are those that meet (fall within) the target range.*

38,000 ML/day on the Culgoa River, measured at the Brenda gauge, for a minimum of six days, any time of the year. The frequency target is to have, on average, no longer than <u>10 (low uncertainty) to 20 (high uncertainty)</u> <u>*years between events*</u>.

Baseline	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL	415 GL
28.5	38.0	38.0	22.8	22.8	28.5	22.8	**19.0***	**16.3***

Bold, asterisked frequencies are those that meet (fall within) the target range.

From the individual flow indicator assessments, the following questions can be answered:

- Did the frequency identified in the flow indicator meet the target range under a specific recovery scenario (a binary 'yes' or 'no' assessment)?
- Did the frequency identified in the flow indicator improve toward the target range under a specific recovery scenario (degree of improvement)?

Binary assessment

The binary assessment simply tells us if the target range was met (between the high and low uncertainty frequencies), or not met. Using the example above, the binary assessment would be met by two different scenarios (the 390 GL and the 415 GL scenarios), represented below by a tick, as shown in Table 14 below.

Table 14: Example of binary assessment results based on meeting, or not meeting, the target range

Baseline	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL	415 GL
28.5	38.0	38.0	22.8	22.8	28.5	22.8	**19.0***	**16.3***
×	×	×	×	×	×	×	✓	✓

Assessing improvement towards the target frequency range

If a scenario does not achieve the target frequency range of a specific flow indicator, the degree to which its frequency improves toward the target range is also assessed. While specifying ecological responses are complex, it has been assumed that there will some reduction in risk if there is an increase in the frequency of flows.

To undertake the improvement assessment each individual flow indicator frequency result is converted to an indicator score based on the degree (percentage) to which the flow indicator frequency result moves from the baseline toward the target frequency range (as shown in Table 15 below).

Table 15: Flow indicator improvement scoring system

Indicator Score	Rationale
0 score	No improvement to slight improvement in frequency from baseline to high uncertainty target (less than 33% toward high uncertainty)
1 score	Minor improvement in frequency from baseline to high uncertainty target (33 to 66% toward high uncertainty)
2 score	Major improvement in frequency from baseline to high uncertainty target (66 to 99% toward high uncertainty)
3 score	Significant improvement as the high uncertainty target is met
4 score	Significant improvement as the high uncertainty target is met and is at least halfway toward the low uncertainty target frequency range

Based on the example given above (38,000 ML/d at Culgoa), the following scores would be applied (see Table 16 below).

Table 16: Scores applied to each scenario based on degree of improvement

Baseline	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL	415 GL
28.5	38.0	38.0	22.8	22.8	28.5	22.8	**19.0***	**16.3***
0	0	0	2	2	0	2	3	3

The key principle of the flow indicators is that they work as a group, and contribute broadly to environmental outcomes. Therefore, looking at how indicators improve in particular groups is also undertaken. Two broad flow indicator groups are used; the river channel connectivity group (i.e. baseflows and freshes), and the floodplain and wetland connectivity group (i.e. bankfull flows, overbank floodplain and wetland filling flows).

Once the river channel and wetland/floodplain flow indicator scores have been calculated for each catchment, the total score as a group is converted to a percentage of the highest possible score (number of flow indicators making up the group multiplied by the highest indicator score of 4), as shown by the example for floodplain and wetland connectivity in Table 17. The wetland/floodplain group score is also combined with the river channel connectivity group score to show an overall improvement for a particular catchment. As this can mask poor performance in one group, but good improvements in the other, it is important to understand the individual results when using this information.

Table 17: Example aggregation scoring process for wetland/floodplain grouping

Group	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL	415 GL
Score for floodplain and wetland connectivity group in the Lower Balonne (4 flow indicators - highest possible score is 4 x 4=16)	1+0+3+0= 4	1+0+3+0= 4	2+0+2+2= 6	1+0+3+2= 6	2+1+3+2= 8	2+1+2+2= 7	2+1+3+3= 9	2+1+3+3= 9
percent of highest possible score	4/16= 25%	4/16= 25%	6/16= 38%	6/16= 38%	8/16= 50%	7/16= 44%	9/16= 56%	9/16= 56%

Using this method, the higher the percentage score, the greater the improvement in frequency for the flow indicator group, within the specific catchment. Once a group score reaches 75% or above, the lower end of the group target frequency range (high uncertainty) has been achieved.

In this report, flow indicator group results are shown mostly in graphic form (as below for the Lower Balonne umbrella environmental assets floodplain and wetland connectivity group at Figure 34).

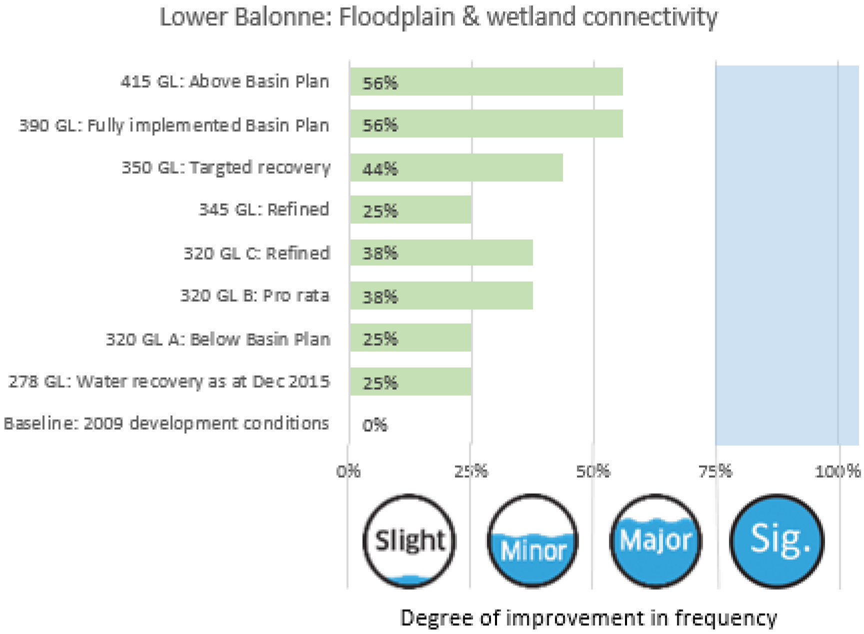


Figure 34: Improvement in the wetland/floodplain connectivity flow indicator group for the Lower Balonne UEA under seven water recovery scenarios. Light green box indicates target frequency range.

The degree of improvement is from slight, minor, major and significant, based on the aggregated frequency improvement as shown at Figure 35.

Slight improvement in aggregated frequency from baseline to high uncertainty target, 0 to 24% aggregated score

Minor improvement in aggregated frequency from baseline to high uncertainty target, 25 to 49% aggregated score

Major improvement in aggregated frequency from baseline to high uncertainty target, 50 to 74% aggregated score

Aggregated high uncertainty target frequency met or exceeded (i.e. more than 75%)

Figure 35: Categorisation of the degree to which aggregated frequencies improve

The individual and group results method described here underpins the reporting of flow indicators against the various recovery scenarios.

Secondary analyses

The pattern and duration of spells (i.e. the period of time between a flow event occurring) can also be important for assessing the environmental outcomes of the different water recovery scenarios. The MDBA has considered the spells between relevant flow indicator events within the 114-year record of the hydrological modelling to see if there are ecologically meaningful differences in the length of spells between different water recovery scenarios. This spells analysis is considered complementary to the long-term average flow indicator frequency results as it provides additional information to better understand the environmental outcomes of the scenarios being considered. The spells analysis generally considers the maximum period between the flow indicator event occurring and the number of spells (time periods) that are longer than an ecological threshold associated with that flow indicator, if available.

Some examples of ecological thresholds (identified from the literature) for spells analysis include:

- 4 and 10 years between longitudinal connectivity opportunities, representing a moderate and high risk to the spawning and recruitment of golden perch — a flow dependent native fish species (DSITI 2015)
- 9 years between inundation events for low-level wetlands, representing the viability of wetland plant seeds based on ribbon weed (*Vallisneria australis*), a common aquatic plant, having seeds that will remain viable in dry wetland sediments for up to nine years (Roberts and Marston 2011)
- 10 and 13 years between inundation events for river red gum (*Eucalyptus camaldulensis*) forests and woodlands, representing an indicative period to cause decline from good to critical condition for modelling state and transitions in floodplain vegetation (Casanova 2015).
- 14 years between inundation events for black box (*Eucalyptus largiflorens*), representing an indicative period to cause decline from good to critical condition for the purposes of modelling state and transitions in floodplain vegetation (Casanova 2015).
- 11 years between inundation events for lignum (*Duma florulenta*), representing an indicative period to cause decline from good to critical condition for the purpose of modelling state and transitions in floodplain vegetation (Casanova 2015)
- 8 years between waterbird breeding events in the Narran Lakes Nature Reserve, representing the longest observed period between straw-necked ibis (*Threskiornis spinicollis*) breeding in the Narran Lakes between 1999 and 2008 (Brandis and Bino 2016)

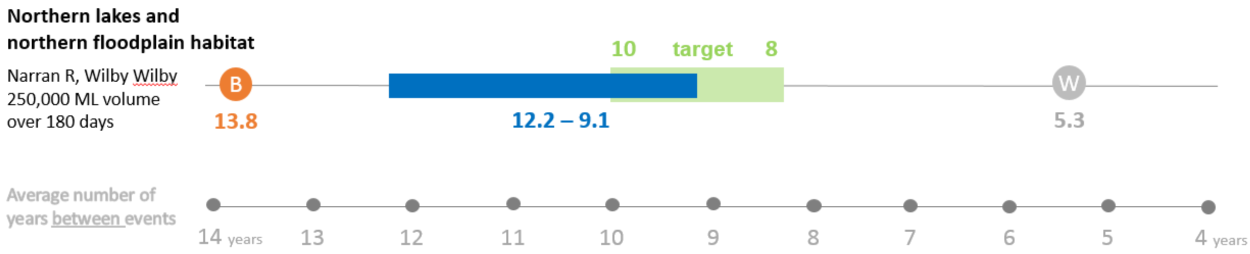
These thresholds are being used to compare the results of model scenarios. The actual ecosystem response could be different, given the highly complex nature of ecosystems and the fact that flow indicators assess important aspects of the flow regime rather than the whole flow regime. However, the thresholds are based on research and provide a good basis to add to the overall assessment of the recovery scenarios.

Appendix C — Individual flow indicator rationales and results

Outlined below are the 43 flow indicators and how the modelled water recovery scenarios increase (or decrease) how often the flow event occurs compared to the modelled '2009 baseline levels of development' and the 'without-development' settings.

The scientific evidence underpinning the flow indicators is available in the relevant Environmental Water Requirements reports available online at the MDBA website.

The individual flow indicator results are reported using (in part) the graphic below (Figure 36).



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
13.8	12.2	11.0	**9.1***	**9.1***	11.0	**10.0***	11.0	11.0	**9.9***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

Figure 36: Explanatory graphic showing individual flow indicator results range; the target range; the baseline frequency; and the 'without development' frequency.

The graphic and the associated table shows the following key points:

Flow indicator: the description of the flow event being assessed in terms of its magnitude (flow rate or volume), duration and timing (i.e. for the example above, 250,000 ML total volume over 18 days in the Narran River measured at the Wilby Wilby gauge).

Frequency metric and scale line: details how frequency is measured and shows the scale. The metric can change for each indicator and may include for example percentage of years with an event or the number of years between events (i.e. for the example above, the average number of years between the specified flow event/indicator).

Baseline (B): shows the frequency under the baseline 2009 conditions of development, and should be read against the scale line immediately below (i.e. for the example above, 13.8 years between the specified flow event/indicator occurring).

Without development (W): shows the frequency under without development conditions, and should be read against the scale line immediately below (i.e. for the example above, there were 5.3 years on average between the specified flow event/indicator occurring).

Target range: shows the frequency target range that, if met, gives a greater degree of certainty around achieving the desired ecological outcomes for the flow indicator (i.e. for the example above, the specified flow event/indicator should occur between every 10-8 years on average).

Water recovery scenarios: shows the frequency range achieved by the modelled water recovery scenarios as a group (i.e. for the example above, the average number of years between events will be between 12.2 and 9.1 years depending on scenario). The exact frequency is shown in the tables below the graphics.

Note that the 390 GL B current river operations is included in the table and graphic results; however is not discussed explicitly in this section. For a description of how the current river operations compare to the fully implemented Basin Plan assumptions, see the relevant chapter in main body of the report.

Barwon–Darling Flow Indicators

There are eleven flow indicators specified for the Barwon–Darling, the majority of which have been updated based on new information gathered as part of the Northern Basin Review. There are seven in-channel connectivity indicators (and their sub-components) and four floodplain and wetland connectivity indicators (and their subcomponents) as shown in Figure 37.

The environmental assessment outlined below relies on the scientific information found in the Barwon–Darling Environmental Water Requirements Report. This report also describes the rationale underpinning the flow indicators.

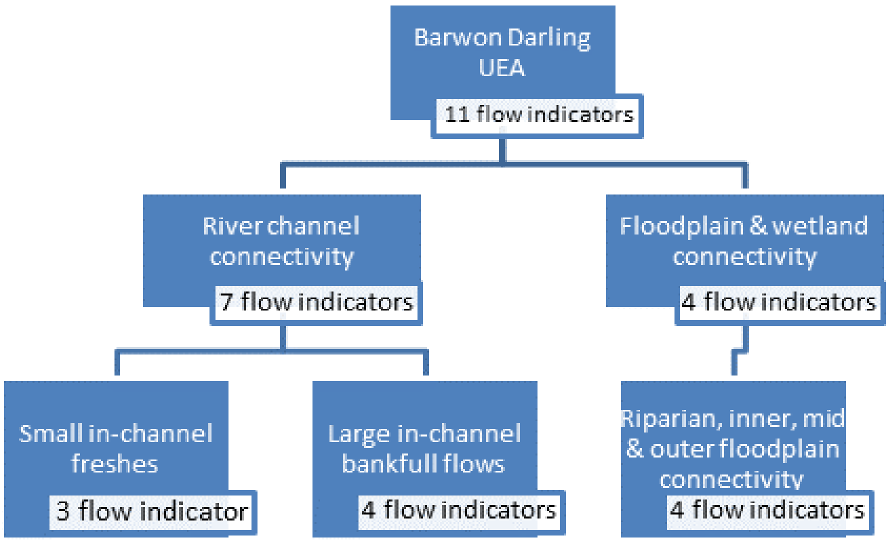


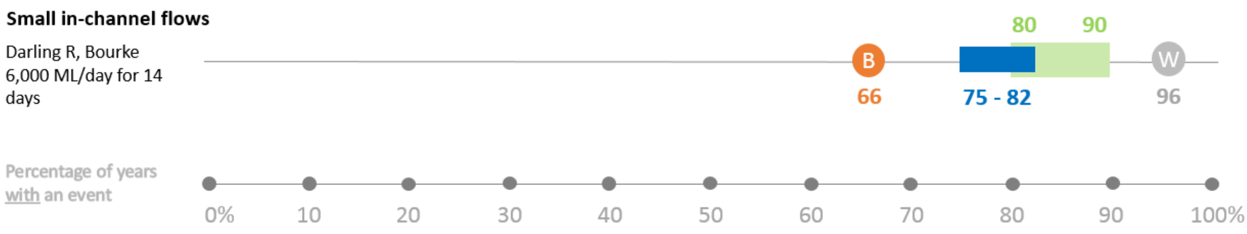
Figure 37: Breakdown of Barwon–Darling flow indicators into flow component groups and sub-groups

River Channel Connectivity Results (Barwon–Darling)

Small in-channel freshes

There are three (Bourke, Louth and Wilcannia) flow indicators specified for protecting small in-channel freshes in the Barwon–Darling. These freshes will pass through the Barwon–Darling to provide river system outcomes. The duration of the in-channel flow indicators at each flow indicator gauge is consistent with the system hydrology and has been informed by ecological considerations (outlined in the EWR Reports). Generally, the durations target spawning and recruitment requirements, and carbon and nutrient absorption rates.

BD1. Small in-channel fresh - 6,000 ML/day on the Darling River, measured at the Bourke gauge, for a minimum of fourteen days, any time of the year. The frequency target is to have the flow event occur between 80-90% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
66	78	**80***	**80***	**80***	**82***	**82***	**82***	75	**82***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the percentage of years with a flow event is less often than under without development conditions (66% of years with an event compared to 96% of years with an event). The target range is for this flow event to occur 80-90% of years, which reflects the requirement to have a small fresh occur close to annually. This frequency range aims to provide regular maintenance and condition opportunities for the fish community.
- The modelled water recovery scenarios markedly improve the frequency. All scenarios achieve the target range, except the 278 GL scenario (and the 390 GL B (current river operations). Improvement is equal amongst those that achieve the range, except for 320 GL B and 320 GL C which result in a lower frequency.
- All scenarios, except the 390 GL B scenario, include a coordinated delivery strategy that looks for opportunities to use tributary releases to build upon unregulated event coming from the Condamine–Balonne. The large reduction in the 390 GL B scenario shows the impact of changing the delivery strategy. It should be noted that while there are less events of this magnitude in 390 GL B, there is an increase in flows up to around 4,000 ML/d at Bourke.
- The ecological outcome from the scenarios that meet the target range is increased opportunities to access habitat and productivity improvements to help fish grow and maintain condition. Further, native fish which respond to flow will have the opportunity to move within the confines of the weirs which act as barriers at this flow rate. Access to varied habitat and the ability to move freely gives native fish the opportunity to find varied food resources; access different habitats, and ultimately helps establish and/or support healthy and resilient populations.

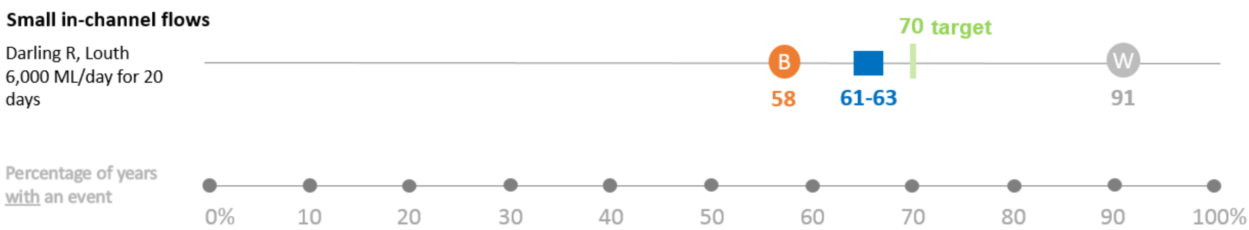
The sequencing of this small fresh flow indicator has been considered to assess the number of periods between events lasting longer than 1 and 2 years (Table 18). These intervals between the events were selected to reflect the intention to have a small fresh occur regularly and close to annually. These intervals are not considered a critical interval based on evidence of ecological thresholds, but do provide another line of evidence to consider differences between the water recovery scenarios.

The spells analysis (Table 18 and Appendix E) shows that the water recovery scenarios can reduce the number of one and two year spells from the baseline conditions (31 and 8 spells, respectively). No scenario can eliminate these spells but the 345 GL, 390 GL A and 415 GL scenarios reduce the spells by the most. The 390 B scenario performs the worst followed by the 278 GL scenario which includes the smallest recovery volume.

Table 18: Spell statistics for the 6,000 ML/d for 14 days flow indicator at Bourke on the Darling River

Water Recovery Scenario	Maximum period between events (years)	No. of spells longer than 1 years	No. of spells longer than 2 years
Baseline	2	31	8
278 GL	2	22	3
320 GL A	2	21	2
320 GL B	2	21	2
320 GL C	2	21	2
345 GL	2	19	1
350 GL	2	20	1
390 GL Basin Plan	2	19	1
390 GL Current ops	2	23	5
415 GL	2	19	1
Without development	1	0	0

BD2. Small in-channel fresh - 6,000 ML/day on the Darling River, measured at the Louth gauge, for a minimum of twenty days, between August and May. The frequency target is to have the flow event occur 70% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
58	61	61	63	62	63	63	63	63	63

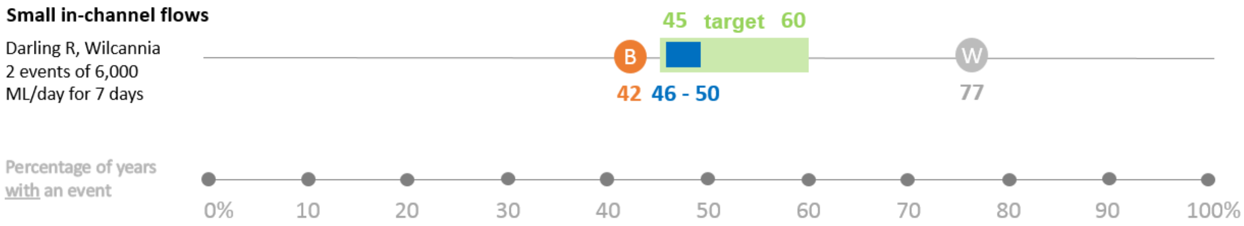
* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the percentage of years with a flow event is less often than under without development conditions (58% of years with an event compared to 91% of years with an event). The target frequency range is for the flow event to occur 70% of years.

- The modelled water recovery scenarios slightly improve the frequency but no scenario achieves the target frequency range. The 278 GL and 320 GL A scenarios results in the lowest frequency increase; while the 320 GL B, 345 GL, 350 GL, 390 GL and 415 GL scenarios provide the greatest (although there is only 2% difference).
- The ecological outcome of this result, under all scenarios, is that longer duration freshes are likely to show only a small improvement with little benefit to native fish populations. This is particularly relevant for in-channel specialists such as Murray cod where access to snag habitat can improve breeding responses.

BD3. Small in-channel fresh - 6,000 ML/day on the Darling River, measured at the Wilcannia gauge, for a minimum of fourteen days, twice each year. The event can occur any time of the year. The frequency target is to have the flow event occur between 45-60% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
42	**46***	**46***	**46***	**48***	**49***	**46***	**48***	**49***	**50***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

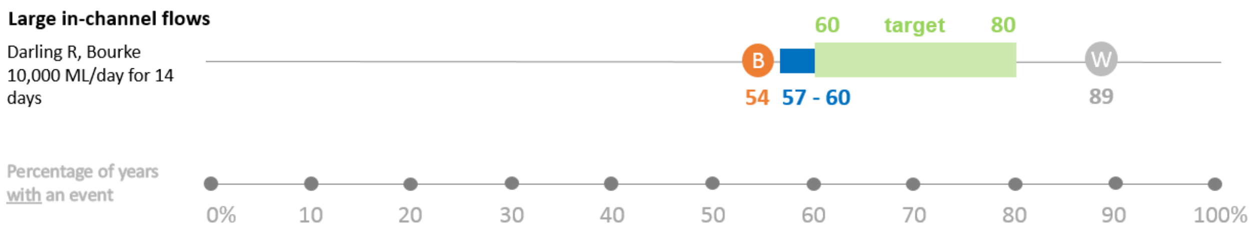
- Under baseline conditions, the percentage of years with the flow event is less often than under without development conditions (42% of years with an event compared to 77% of years with an event). The target range is for this flow event to occur 45-60% of years.
- The modelled water recovery scenarios do improve the frequency, and all scenarios reach the target range.
- While only small differences between the scenarios exist, the 390 GL B and 345 GL scenarios results in the largest increase in frequency (49%). The increased frequency under the 390 GL B scenario, compared to 390 GL A may be due to the more regular released from tributary dams to provide flows to the Barwon–Darling, as they are not linked to the whole of north delivery strategy which requires an unregulated flow out of the Condamine–Balonne to trigger releases.
- The ecological outcome of this result is the inundation of more benches and other habitat features more often, which would lead to increased productivity benefits to the river system's food web. This is considered important for improved condition of fish (especially important for pre-spawning fitness) and other aquatic biota.

Large in-channel freshes

There are four (Bourke x 2, Louth and Wilcannia) flow indicators specified for protecting large in-channel freshes in the Barwon–Darling. The duration of these flow indicators differ for each flow indicator and they do serve different purposes. Generally, they relate to the hatch time of native fish eggs (first Bourke indicator); breeding outcomes (second Bourke indicator and Louth); and absorption of carbon and nutrients from inundated benches and the dispersal and movement of aquatic species. The Wilcannia duration also links to spawning and recruitment outcomes for fish species that are opportunistic and quicker to respond such as bony bream, golden perch and spangled perch.

The timing for the two 10,000 ML/d flow indicators at Bourke and the 21,000 ML/d flow indicator at Louth is August to May. The two coldest months of the year are excluded because fish responses are expected to be subdued. This timing is also consistent with existing knowledge of spawning and recruitment requirements for Murray cod (August to December) and the other native fish species in the northern Basin. The timing for the Wilcannia indicator is any time of year, as the benefits of increased nutrient spiralling would provide benefits to aquatic food webs throughout the year, and also provide expanded access to habitat.

BD4. Large in-channel freshes - 10,000 ML/day on the Darling River, measured at the Bourke gauge, for a minimum of fourteen days, between August and May. The frequency target is to have the flow event occur 60-80% of years.



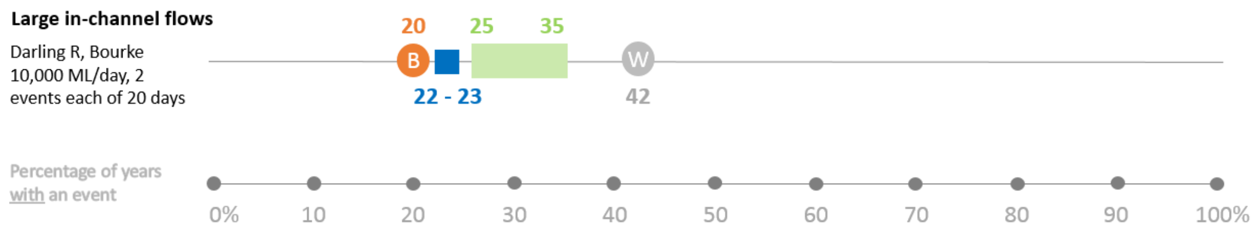
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
54	59	59	59	58	59	59	59	57	**60***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the flow event happens less often than under development conditions (54% of the time compared to 89% of the time). The target range is for this flow event to occur 60-80% of the time.
- The modelled water recovery scenarios do result in an improvement in frequency of this event (between 57-60% depending on scenario). While all scenarios perform similarly, only the 415 GL scenario actually reaches the target range.
- The ecological outcome of this result is likely to be improved opportunities for large scale fish movements, which is of significant important for those species that undertake large-scale migrations such as golden perch and silver perch. Benches and snags will also be inundated more regularly (than baseline), which provides increased access to aquatic habitat. Combined, the opportunity to move, spawn and access habitat is likely to improve mixing of populations (genetic diversity) and enhance fish condition.

BD5. Large in-channel freshes - 10,000 ML/day on the Darling River, measured at the Bourke gauge, for a minimum of fourteen days, twice each year. The event should occur between August and May. The frequency target is to have the flow event occur between 25-35% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
20	23	22	23	22	22	23	22	22	22

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the flow event happens less often than under development conditions (20% of the time compared to 42% of the time). The target range is for this double flow event to occur 25-35% of the time.
- The modelled water recovery scenarios do result in an improvement in the frequency of the flow indicator.
- The water recovery scenarios perform similarly (between 22-23% of years); however, no scenario reaches the target range.
- The ecological outcomes of this result is that there is likely to be improved conditions for large scale flow dependent fish breeding but not the frequency targeted. During dry periods, there could be considerable stress on the recruitment of native fish larvae and juveniles, particularly as the second flow event provides for dispersal, access to habitat, and suitable prey. Golden perch and other flow dependent fish may also not receive sufficiently regular cues for migration, which may result in a reduction in the fish community size, health and/or resilience.

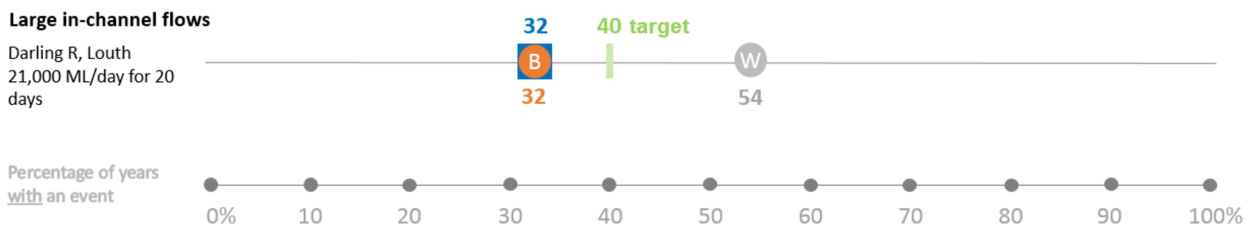
Critical thresholds (spells analysis) have been used to consider if there are ecologically significant sequencing differences between the water recovery scenarios. A moderate risk threshold of longer than four years between the event, and a high risk threshold of longer than ten years were adopted. These thresholds are based on thresholds of concern used by the Queensland government for water resource planning to represent risks to the spawning and recruitment and therefore the population of golden perch in dryland rivers (DSITI 2015).

The spells analysis (see Table 19 and Appendix E) shows that under all water recovery scenarios the high risk critical threshold contained in the baseline conditions scenario is eliminated. The moderate risk threshold is breached under all water recovery scenarios and there is only a marginal difference or no difference across the water recovery scenarios (between 11 and 12 spells as compared to 12 under baseline). This compares to six moderate risk and no high risk spells under without development. The maximum period between events shows the same change from baseline for all scenarios, with a reduction from 11 years under baseline conditions to 9 years.

Table 19: Spell statistics for the 2 x 10,000 ML/d for 20 days flow indicator at Bourke on the Darling River

Water Recovery Scenario	Maximum period between events (years)	No. of spells longer than 1 years	No. of spells longer than 2 years
Baseline	11	12	1
278 GL	9	11	0
320 GL A	9	12	0
320 GL B	9	11	0
320 GL C	9	12	0
345 GL	9	12	0
350 GL	9	11	0
390 GL Basin Plan	9	12	0
390 GL Current ops	9	12	0
415 GL	9	12	0
Without development	6	6	0

BD6. Large in-channel freshes - 21,000 ML/day on the Darling River, measured at the Louth gauge, for a minimum of twenty days, between August and May. The frequency target is to have the flow event occur 40% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
32	32	32	32	32	32	32	32	32	32

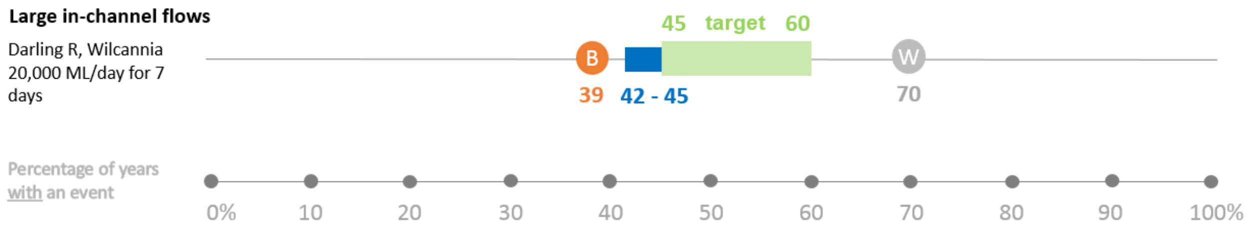
* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the flow event happens less often than under without development conditions (32% of the time compared to 54% of the time). The target range is for this flow event to occur 40% of the time.
- The modelled water recovery scenarios do not result in any improvement in how often Louth large in-channel flow events occur, and remain at baseline condition (32% of years), despite the recovery scenario applied.
- The likely ecological outcome of this result is that all native fish species, including in-channel specialist native fish such as Murray cod, will have fewer opportunities to access ideal habitat and move throughout the system. The longer duration of this bankfull event can support increased fish access to off river habitat; however there will not be an improvement in this flow indicator, limiting lateral connectivity opportunities for fish, as well as associated nutrient spiralling benefits that would result from bench

inundation. During prolonged dry periods, this may result in reduced fish community size, health and/or resilience.

BD7. Large in-channel freshes - 20,000 ML/day on the Darling River, measured at the Wilcannia gauge, for a minimum of seven days, any time of the year. The frequency target is to have the flow event occur 45-60% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
39	42	**45***	**45***	**45***	**45***	**45***	**45***	44	**45***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the flow event happens less often than under development conditions (39% of years compared to 70% of years). The target range is for this flow event to occur 45-60% of the time.
- The modelled water recovery scenarios do result in an improvement in frequency (between 44%-45% of years depending on scenario).
- Most scenarios achieving the target range, while the 390 GL B falls just short (44%), but this is not considered significant. The 278 GL scenario is the worst performing scenario with a frequency of 42% of years.
- Those scenarios that meet the target range, are considered to provide sufficiently regular inundation of benches for increased nutrient spiralling. There will also be increased longitudinal connectivity, as well as access to off-channel wetlands, which is important for many fish (such as olive perchlet and Darling River hardyhead). Access to the wetlands provides a boom in food supply and access to ideal spawning and nursery habitats.

Floodplain and Wetland Connectivity Results (Barwon–Darling)

Riparian, inner, mid and outer floodplain connectivity

There are four (Bourke x 3 and Wilcannia) flow indicators specified for protecting floodplain and wetland connectivity in the Barwon–Darling. For each of the flow indicators, timing is not constrained as floodplain flows historically occur at any time of year, and water on floodplains and in wetlands is generally retained beyond the flow event.

BD8. Riparian connectivity - 30,000 ML/day on the Darling River, measured at the Bourke gauge, for a minimum of twenty four days, any time of the year. The frequency target is to have the flow event occur, on average, once every 2-3 years.

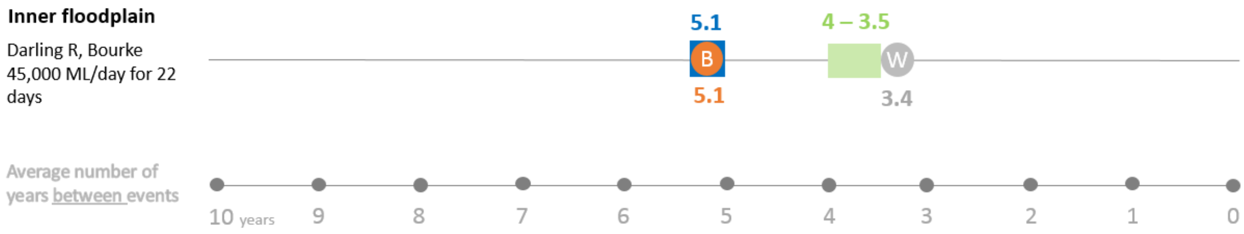
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
4.1	3.9	3.8	3.9	3.9	3.9	3.8	3.8	3.9	3.8

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the average time between flow events is much longer compared to without development conditions (4.1 years without an event compared to 1.8 years). The target range for this flow event is for there to be between 2-3 years on average between events, consistent with the flooding requirements to sustain riparian and wetland vegetation such as river red gum forests and lignum.
- The water recovery scenarios do result in a small improvement in reducing the time between flows (between 3.9 to 3.8 years depending on scenario); however, the target range is not met under any scenario.
- The ecological consequence of this result is that under prolonged dry periods, the flooding requirements to sustain vigorous river red gum forests and lignum, and to re-fill wetlands near the channel may not be achieved. Further, without the ideal flow frequency (such as in prolonged periods without a bankfull types of flow), increases in riverbank collapse and erosion problems may also occur as a result of poorer riparian vegetation condition. Maintenance of benches and waterholes for hydraulic diversity is also more likely to be compromised.
- There will also be reduced opportunities for native fish to access anabranches and secondary channels. This is particularly problematic for floodplain specialist species. These fish generally have a life-span less than five years and benefiting greatly from access to off-river habitats. These habitats form an important nursery for juveniles with significant habitat diversity and aquatic productivity. Reduced access to these habitats may have significant impacts on these populations.

BD9. Inner floodplain connectivity - 45,000 ML/day on the Darling River, measured at the Bourke gauge, for a minimum of twenty two days, any time of the year. The frequency target is to have the flow event occur, on average, once every 3.5-4 years.



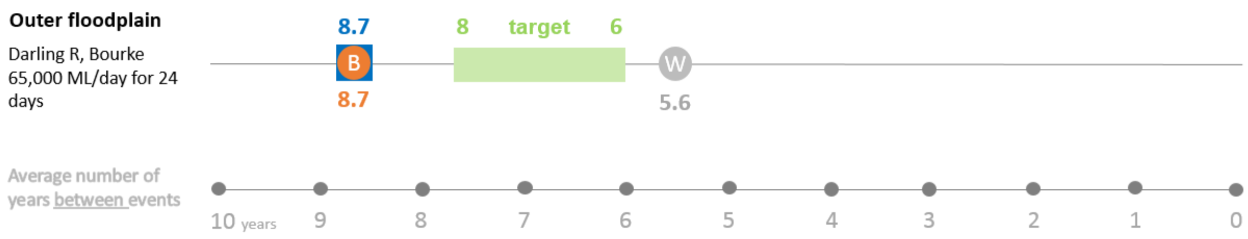
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the average time between flow events is much longer compared to without development conditions (5.1 years without an event compared to 3.3 years). The target range for this flow event is for there to be between 4-3.5 years on average between events. This range is within the range of the watering requirements of river red gum woodlands, and would sustain wetland communities including lignum.
- The water recovery scenarios do not result in any improvement in frequency, indicating that the level of water recovery is not sufficient to shift this part of the flow regime. All scenarios perform equally (and equal to baseline condition) and do not meet the target range.
- The ecological consequence of this result is that under prolonged dry periods, the flooding requirements to sustain river red gum woodlands (such as along anabranches and flood runners) and wetland communities, including lignum, may not be achieved. Lakes such as the Poopelloe Lake, Victoria Lake and Eucalyptus Lake in the Talyawalka - Teryaweynya system would not have sufficiently regular inflows, which would have likely consequences for supporting waterbirds to the same scale as in the past, including for migrating birds.
- The result would also not provide additional benefit for access to temporary, opportunistic and productive floodplain and wetland habitat for many floodplain fish specialists and other water-dependent biota (e.g. aquatic insects as a key part of the aquatic food web).

BD10. Outer floodplain connectivity - 65,000 ML/day on the Darling River, measured at the Bourke gauge, for a minimum of twenty four days, any time of the year. The frequency target is to have the flow event occur, on average, once every 6-8 years.



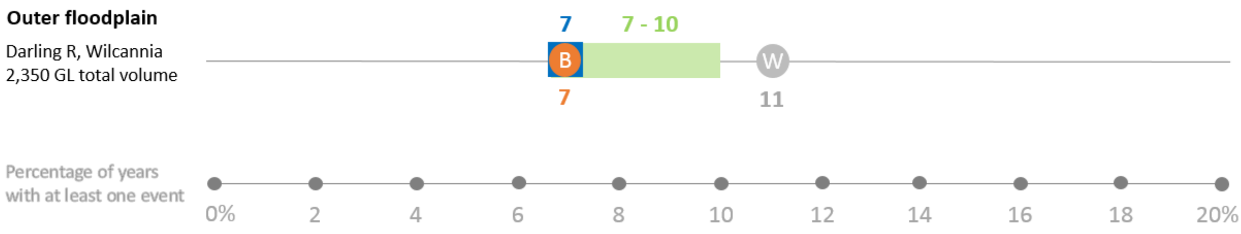
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the average time between a Bourke mid floodplain connectivity flow event is much longer compared to without development conditions (8.7 years without an event compared to 5.6 years). The target range represents the type of frequency these flows would have occurred historically in the Darling River, and is also reasonably consistent with and is close to the critical interval of river red gum woodlands and lignum.
- The modelled water recovery scenarios do not result in any reduction in the average time between Bourke mid floodplain connectivity flows.
- All scenarios perform equally (and equal to baseline condition) and do not meet the target range.
- The ecological consequence of this result is that under prolonged dry periods, the flooding requirements to sustain vigorous growth for black box would not be achieved. Further, given the target range was based on close to the critical interval of river red gum woodlands and lignum, these species/communities would also be at considerable risk under all scenarios during prolonged dry periods. However, it is acknowledged that these two species may remain alive if inundation occurs at a lower frequency, their condition is likely to be poor, and more frequent subsequent wetting may be required to improve their health and vigour.
- There will also be reduced opportunities for native fish to access anabranches and secondary channels. This is particularly problematic for floodplain specialist species. These fish generally have a life-span less than five years and benefiting greatly from access to off-river habitats. These habitats form an important nursery for juveniles with significant habitat diversity and aquatic productivity. Reduced access to these habitats may have significant impacts on these populations.

BD11. Outer floodplain connectivity - Greater than 30,000 ML/d to achieve an annual inflow volume of 2,350 GL. This is measured on the Darling River at the Wilcannia gauge, and can occur at any time of the year. The frequency target is to have at least 7-10% of years include this event.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
7	7	7	7	7	7	7	7	7	7

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Darling River (Wilcannia) outer floodplain flow event happens less often than under development conditions (7% of years with an event compared to 11% of years). The target range is based on the flooding requirements of black box trees and lignum shrubs, and is consistent with the system hydrology. This flow would inundate virtually all wetlands on the Darling floodplain (Brennan et al. 2012).
- The water recovery scenarios do not result in any increase in the percentage of years with an outer floodplain connectivity flow event of this magnitude.
- All scenarios perform equally (and equal to baseline condition); which forms the ‘high uncertainty’ end of the target range. This result shows there is no improvement made toward the 'low uncertainty' end of the target.
- The ecological consequence of this result is that under all scenarios the filling of lakes in the Talyawalka -Teryaweynya system, as well as inundating wetlands and vegetation communities on the outer Darling floodplain. This result is likely to broadly sustain many of the vegetation communities that are less flood dependent. Further, when inundated, the Talyawalka system’s lakes and the broader Darling floodplain inundation are expected to provide foraging habitat for large numbers of waterbirds, and also mass exchange of nutrients, sediment and recruitment and dispersal opportunities for a range of native aquatic animal (including native fish) and plant species.

There are critical intervals between inundation events that are described in the literature that can be considered for Barwon–Darling floodplain. These are based on a range of information sources including: a review of the scientific literature regarding the water requirements of five floodplain tree species from across the Murray–Darling Basin (Casanova 2015); and an assessment of the viability of wetland plant seeds based on research on Ribbon weed (Roberts and Marston 2011). These thresholds, while not prescriptive and based on average requirements, do provide a means to compare modelled water recovery scenarios. The thresholds identified include:

- 9 years between inundation events for low-level wetlands, representing the viability of wetland plant seeds based on Ribbon weed, a common aquatic plant, having seeds that will remain viable in dry wetland sediments for up to nine years (Roberts and Marston 2011)
- 10 and 13 years between inundation events for river red gum forests and woodlands, representing an indicative period to cause decline from good to critical condition for modelling state and transitions in floodplain vegetation (Casanova 2015).
- 14 years between inundation events for black box, representing an indicative period to cause decline from good to critical condition for the purposes of modelling state and transitions in floodplain vegetation (Casanova 2015).

The maximum period between events for the floodplain and wetland connectivity flow indicators is shown in Table 20. These periods are longer than the identified thresholds in the literature. In addition, no water recovery scenario is able to reduce the maximum dry spell from baseline conditions across all indicators. This supports the conclusions of the frequency analysis which shows that the water recovery scenarios have little to no impact on the frequency of floodplain connectivity for the Barwon–Darling River.

Table 20: Maximum period between events for the four floodplain and wetland connectivity flow indicators in the Barwon–Darling for the modelled scenarios.

Water Recovery Scenario	30,000 SFI Maximum time between events (years)	45,000 SFI Maximum time between events (years)	65,000 SFI Maximum time between events (years)	2,350 GL SFI Maximum time between events (years)
Baseline	18.7	28.6	28.9	29
278 GL	18.7	28.6	28.9	29
320 GL A	18.7	28.6	28.9	29
320 GL B	18.7	28.6	28.9	29
320 GL C	18.7	28.6	28.9	29
345 GL	18.7	28.6	28.9	29
350 GL	18.7	28.6	28.9	29
390 GL Basin Plan	18.7	28.6	28.9	29
415 GL	18.7	28.6	28.9	29
Without development	9.4	14.6	18.7	29

Border Rivers Flow Indicators

There are three flow indicators specified for the Border Rivers all of which are based on information from the original assessment undertaken to develop indicators. They are in-channel connectivity indicators (and their sub-components) only (as shown in Figure 38 below).

The environmental assessment outlined below relies on the scientific information found in the [Lower Border Rivers Environmental Water Requirements Report](). This report also describes the rationale underpinning the flow indicators.

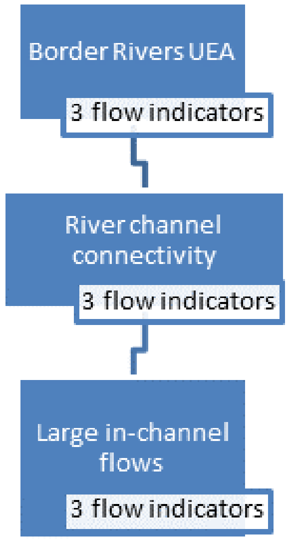
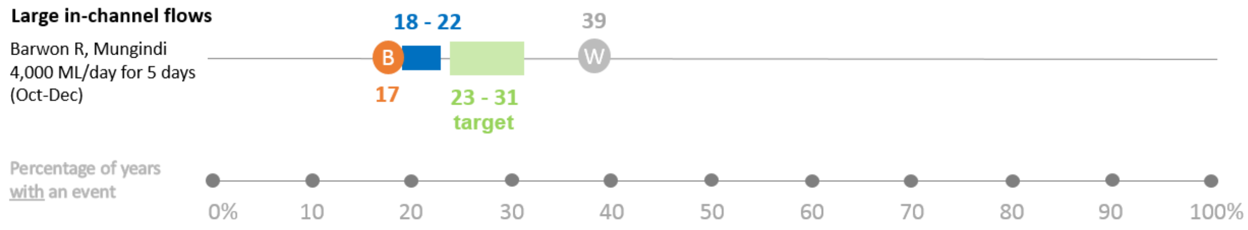


Figure 38: Breakdown of Border Rivers flow indicators into flow component group and sub-group

Provision of large in-channel flows

There are three flow indicators specified for the Border Rivers. The flow indicators below, while all specifying the same volume (4,000 ML/d), differ in their seasonality (the months they are required). These differences generally target different native fish life cycles and some ecosystem functions.

BR1. Border Rivers large in-channel flows –4,000 ML/day on the Barwon River, measured at the Mungindi gauge, for a minimum of five days, between October and December. The frequency target is to have the flow event occur between 23-31% of years.



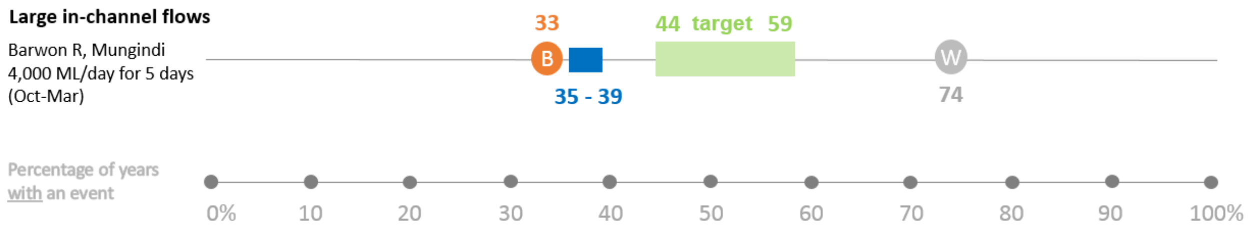
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
17	18	22	20	20	22	22	22	22	22

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Barwon River (at Mungindi) large in-channel flow event happens less often than under without development conditions (17% compared to 39% of years with the event). The target range is for this flow event to occur, on average, 23-31% of years.
- The modelled water recovery scenarios do result in a small improvement in increasing the frequency of events (between 20-22% of years, depending on scenario), but none of the scenarios meet the target range.
- The 320 GL A, 345 GL, 350 GL, 390 GL and 415 GL scenarios all achieve the highest frequency result (of 22%), but are still slightly short of the target range. The highest risk scenario is the 278 GL scenario (18%).
- The ecological consequence of the 320 GL A, 345 GL, 350 GL, 390 GL and 415 GL scenarios is likely to be some improvement in flow conditions for native fish species (in particular golden perch); however the minimum ideal flow conditions to support habitat interactions, breeding and recruitment are still not being met, placing pressure on the recovery of native fish populations. Key ecosystem functions associated with bench inundation, and river and floodplain wetland and lagoon connectivity, will also be most enhanced under these scenarios, but still below the target frequency range of flows.
- The 278 GL scenario presents the greatest risk that native fish spawning and recruitment may not happen regularly enough (in particular golden perch), and result in a reduction of population resilience, health and /or size. A small reduction in general ecosystem function may also arise due to a lessening in frequency of bench inundation and river/floodplain connectivity.

BR2. Border Rivers large in-channel flows –4,000 ML/day on the Barwon River, measured at the Mungindi gauge, for a minimum of five days, between October and March. The frequency target is to have the flow event occur between 44-59% of years.



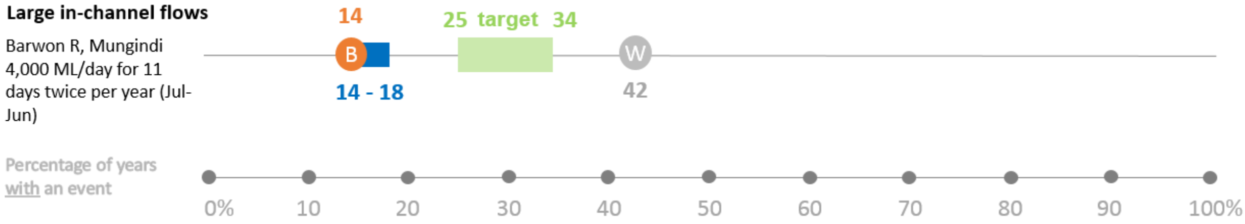
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
33	35	37	37	37	39	38	38	36	39

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Barwon River (Mungindi) large in-channel flow event happens less often than under development conditions (33% compared to 74% of years with the event). The target range is for this flow event to occur, on average, 44-59% of years.
- The modelled water recovery scenarios do result in a small improvement in increasing the frequency of events (between 35-39% of years, depending on scenario).
- No scenario reaches the target range: the 345 GL and 415 GL scenarios result in the greatest increase in frequency (39% of years). The highest risk scenario is the 278 GL scenario (35% of years).
- The ecological consequence of these results (which are reasonably similar across all scenarios) is that opportunities for native fish species may not be sufficient for population health and resilience, particularly during prolonged dry periods. Further, the natural high flows occurring in late summer will not be supported every year. These high flows inundate in-channel benches (and often coincide with leaf fall for dominant eucalyptus species), which then enables the organic material on these benches to become a food source for many aquatic organisms and contribute to nutrient cycling processes.

BR3. Border Rivers large in-channel flows –4,000 ML/day on the Barwon River, measured at the Mungindi gauge, for a minimum of eleven days, twice per year, any time of the year. The frequency target is to have the flow event occur b



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
14	14	17	15	15	16	16	18	18	18

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

etween 25-34% of years.

- Under baseline conditions (2009 levels of development before water recovery), the Barwon River (Mungindi) large in-channel flow event happens less often than under development conditions (14% compared to 42% of years with the event). The target range is for this flow event to occur, on average, 25-34% of years.
- The modelled water recovery scenarios result in a very small improvement in increasing the frequency of events (between 14-18% of years, depending on scenario).
- No scenario reaches the target range: the 390 GL and 415 GL scenarios result in the greatest increase in frequency (18% of years). The highest risk scenario is the 278 GL (15% of years).
- The ecological consequence of these results (which are reasonably similar across all scenarios) is that opportunities for native fish species may not be sufficient for population health and resilience, particularly during prolonged dry periods. Further, the natural high flows occurring in late summer and follow up pulse in late winter will not be supported every year. These high flows inundate in-channel benches, which then enables the organic material on these benches to become a food source for many aquatic organisms and contribute to nutrient cycling processes.

Condamine–Balonne (Lower Balonne) Flow Indicators Results

There are nine flow indicators specified for the Lower Balonne comprising of five river channel connectivity indicators (and their sub-components) and four floodplain and wetland connectivity indicators (and their sub-components) as shown in Figure 39. The majority of these have been updated based on new information gathered as part of the Northern Basin Review.

The environmental assessment outlined below relies on the scientific information found in the Condamine–Balonne Environmental Water Requirements Report. This report also describes the rationale underpinning the flow indicators.

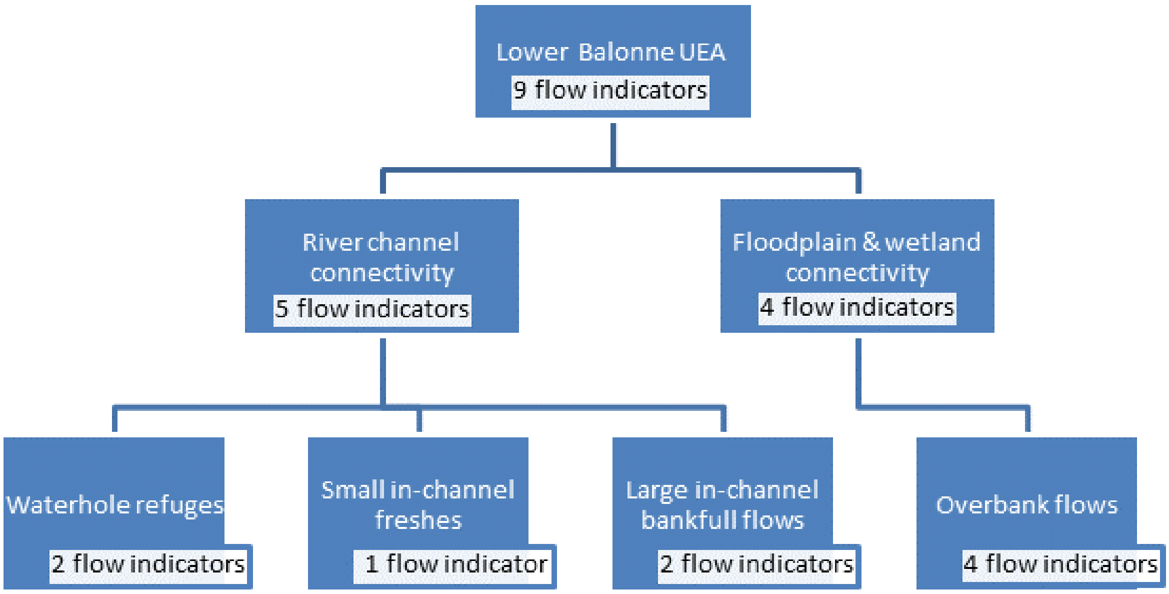


Figure 39: Breakdown of Lower Balonne flow indicators into flow component groups and sub-groups

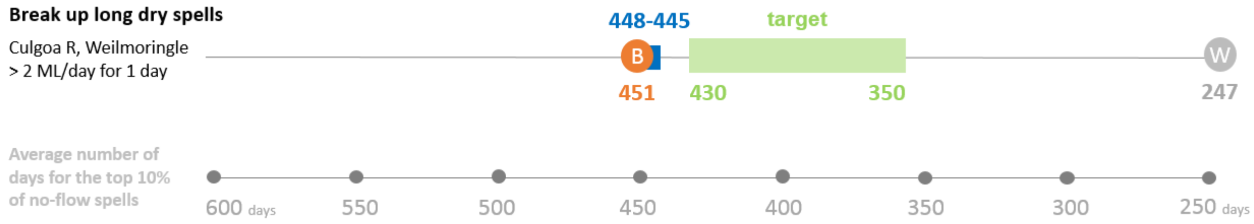
River Channel Connectivity Results (Lower Balonne)

Refuge Waterhole Indicators

There are two flow indicators specified for maintaining the network of waterhole refuges in the Lower Balonne. One described at Weilmoringle gauge on the Culgoa River, and the other described at Narran Park gauge on the Narran River

The frequency requirement of the flow indicators considers the longest 10% of no-flow periods across the 114 year modelled time period. Considering a range of the longest no-flow periods rather than the single longest no-flow spell was done to ensure results are not determined by a single event.

CB1. Waterhole refuge - Any flow (taken as a minimum of 2 ML/d) on the Culgoa River, measured at the Weilmoringle gauge, for a minimum of one day, any time of the year. The frequency target is to have a period between no-flow events of no longer than 350-430 days for the average of the top 10% of no-flow periods (longest 23 to 25 no-flow periods depending on scenario).



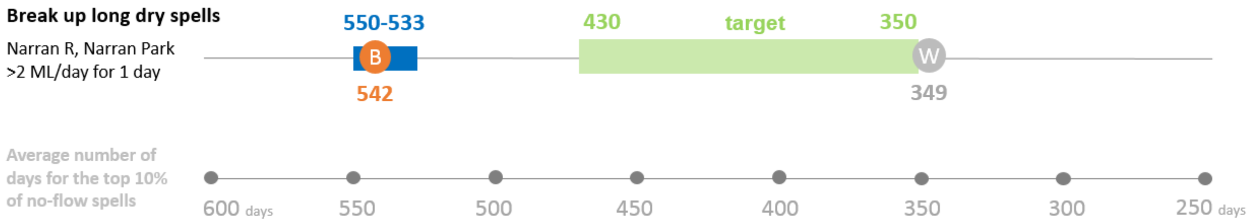
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
451	447	445	447	448	445	448	447	447	447

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the average periods of no-flow (for the top 10% of no-flow spells) at Weilmoringle gauge on the Culgoa River is much longer compared to without development conditions (from 451 days compared to 247 days).
- Based on waterhole persistence research (DSITI 2015), the 350 day target aims to maintain a minimum of seven waterholes along the Culgoa River, with at least four of these to a depth of more than 0.5 m. The 430 days target provides at least two refuge waterholes to at least 0.5 m.
- The modelled water recovery scenarios result in little improvement in frequency from the baseline conditions; and all scenarios are well short of the target range. The differences between scenarios is not considered an improvement to the maintenance of waterholes.
- During prolonged dry periods, there is likely to be a lack of a refuge waterhole network in the lower reaches of the river system. Without management intervention this creates a considerable risk of reduced population resilience (numbers, distribution, and genetic diversity), or even the prospect of increased local extinctions for native fish and other aquatic biota.

CB2. Waterhole refuge - Any flow (taken as a minimum of 2 ML/d) on the Narran River, measured at the Narran Park gauge, for a minimum of one day, any time of the year. The frequency target is to have a period between no-flow events of no longer than 350-470 days for the average of the top 10% of no-flow periods (longest 24 to 29 no-flow periods depending on scenario).



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
542	550	534	533	539	540	540	539	539	539

* Denotes that the target range was met

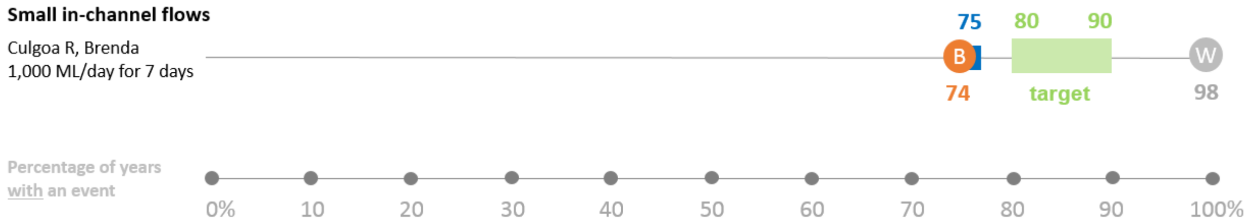
The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the periods of no-flows (top 10%) for the Narran River waterhole refuge flow indicator are much longer compared to without development conditions (from 542 days compared to 349 days).
- The modelled water recovery scenarios result in little, to nil, improvement in frequency from the baseline conditions; and all scenarios are well short of the target range. The differences between scenarios is not considered an improvement to the maintenance of waterholes.
- During prolonged dry periods, there is likely to be a lack of a refuge waterhole network in the lower reaches of the river system. Without management intervention this creates a considerable risk of reduced population resilience (numbers, distribution, and genetic diversity), or even the prospect of increased local extinctions. Much larger flows are anticipated to be needed to enable repopulation.
- The modelling shows no significant improvements to the no-flow/low flow part of the flow regime, which is the result of the impact of water regulating structures such as Beardmore Dam and there being no demand placed in the modelling to actively deliver low flows.

Small in-channel freshes

There is one flow indicator specified to represent small in-channel freshes in the Lower Balonne. This flow event is likely to inundate the lower sections of the main river channels over hundreds of kilometres. This flow event was assessed as the minimum flow to be confident about providing system scale connectivity. It is highly likely to pass down the entire length of the Culgoa and Narran rivers, and also down at least part of the Bokhara River. The target frequency range aims to provide a small fresh close to annually to improve habitat conditions for instream vegetation, fish, frogs and other aquatic biota.

CB3. Small in-channel fresh - 1,000 ML/day on the Culgoa River, measured at the Brenda gauge, for a minimum of seven days, any time of the year. The frequency target is to have the flow event occur between 80-90% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
74	75	75	75	75	75	75	75	75	75

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the 1,000 ML/d small fresh at Brenda on the Culgoa River happens less often than under without development conditions (from 98% of years, to 74% of years).
- The modelled water recovery scenarios all result in little improvement in frequency from the baseline conditions; and all scenarios are short of the target.
- Based on the frequency performance alone (as shown above) there is no difference between the scenarios. This is likely due to a combination of the impact of water regulating structures such as Beardmore Dam and the hydrological model settings, as there are a limited number of water harvesting licences that pump water at lower flows and these licences were not targeted.
- Ecologically, this result represents a very small shift in the hydrology across scenarios for small freshes to connect habitats, including waterholes.

The sequencing of the small fresh flow indicator has been considered to assess the number of periods between events lasting longer than 2 and 3 years (Table 10). These intervals between the events were selected to reflect the intention to have a small fresh occur regularly and close to annually. These intervals are not considered a critical interval based on evidence of ecological thresholds, but do provide another line of evidence to consider differences between the water recovery scenarios.

The spells analysis (Table 21 and Appendix E) shows that the water recovery scenarios do not reduce the number of two year spells from the baseline conditions (11 spells). The 320 GL B, 320 GL C, 345 GL, 390 GL and 415 GL scenarios reduce the number of three year dry periods from two to one.

The modelled water recovery scenarios result in limited improvement from the baseline. All scenarios are well short of the target range, with the spells analysis indicating that the 320 GL B, 320 GL C, 415 GL and 390 GL scenarios are marginally better at reducing extended dry periods.

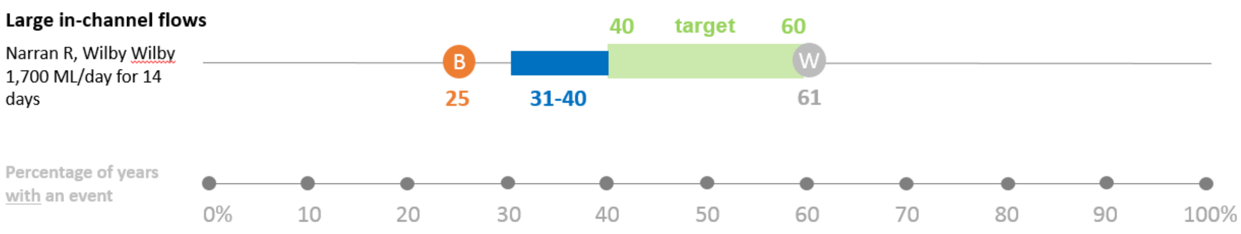
Table 21: Spell statistics for the 1,000 ML/d for seven day flow indicator at Brenda on the Culgoa River

Water Recovery Scenario	Maximum period between events (years)	No. of spells longer than 2 years	No. of spells longer than 3 years
Baseline	3.5	11	2
278 GL	3.5	11	2
320 GL A	3.5	11	2
320 GL B	3.5	11	1
320 GL C	3.5	11	1
345 GL	3.5	11	1
350 GL	3.5	11	2
390 GL Basin Plan	3.5	11	1
415 GL	3.5	11	1
Without development	1.7	0	0

Large in-channel freshes

Two flow indicators have been identified to represent large in-channel flow events that are almost bankfull in the Culgoa and Narran rivers. The duration is 14 days based on the hatch time for Murray cod eggs which also meets the needs of other native fish in the region; especially golden perch which need freshes to meet specific life-cycle requirements. Murray cod do not necessarily need freshes for spawning but these flows are considered appropriate to enhance breeding outcomes. The frequency is for the freshes to occur roughly every 2 years based on advice from experts about the requirements of fish in dryland rivers (NSW DPI 2015). The timing of August to May excludes the two coldest months of the year when fish responses are expected to be subdued due to low water temperature.

CB4. Large in-channel flow - 1,700 ML/day on the Narran River, measured at the Wilby Wilby gauge, for a minimum of fourteen days, between August and May. The frequency target is to have the flow event occur between 40-60% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
25	31	37	40*	40*	39	40*	39	39	40*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the Narran River (Wilby Wilby) 1,700 ML/d large in-channel flow event happens less often than under development conditions (from 25% of years with an event compared to 61% of years with an event).

- The modelled water recovery scenarios do improve the frequency of the Narran large in-channel flow indicator.
- The 278 GL and 320 GL scenarios do not increase the frequency as much as the other scenarios. This is likely because the 278 GL and 320 GL scenarios have a smaller volume of water recovery in the Narran system (7 GL and 17 GL as compared to 21 GL to 30 GL for the others).
- The 320 GL B, 320 GL C, 350 GL and 415 GL scenarios reach the target range, with the 390 GL scenario and the 345 GL scenario very close (within 1% of the lower end of the target range).
- Ecologically, the 320 GL B, 320 GL C, 345 GL, 350 GL and 415 GL scenarios provide more opportunities for aquatic biota to move, feed and breed, which is especially important for flow dependent native fish species such as golden perch, silver perch, spangled perch and Hyrtl's tandan. Improving this part of the flow regime is expected to improve the population condition and resilience of a range of aquatic species including fish, frogs and turtles.
- Under the recovery scenarios that do not meet the target range, there will be less opportunities for fish to move and breed to improve population condition.
- Increased frequencies of this type of flow event also help to improve the condition of near channel vegetation which can help to increase bank stability, and provide additional food resources.

Critical thresholds (spells analysis) have been used to consider if there are ecologically significant sequencing differences between the water recovery scenarios. A moderate risk threshold of longer than four years between the event, and a high risk threshold of longer than ten years were adopted. These thresholds are based on thresholds of concern used by the Queensland government for water resource planning to represent risks to the spawning and recruitment and therefore the population of golden perch in dryland rivers (DSITI 2015).

The spells analysis (see Table 22 and Appendix E) shows that under the 320 GL B, 350 GL, 390 GL and 415 GL scenarios the high risk critical threshold of 10 years is eliminated. This high risk threshold is breached under the baseline conditions, and in the 278 GL and 320 GL scenarios. The moderate risk threshold of four years is breached under all water recovery scenarios but there are less of these spells in the 320 GL B, 320 GL C, 350 GL, 390 GL and 415 GL scenarios (from seven to six moderate risk spells). This compares to only two moderate risk and no high risk spells under without development.

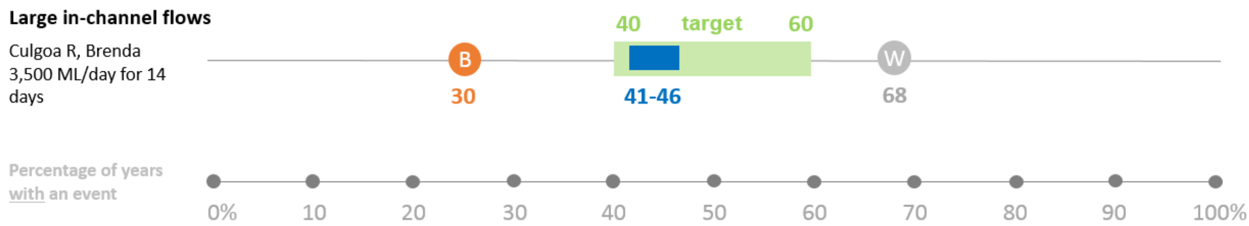
The maximum period between events shows a change between scenarios. All water recovery scenarios show a reduction from baseline conditions, the 278 GL and 320 GL scenarios are 10.1 years (i.e. just breaching the high risk critical threshold) and all other water recovery scenarios have a maximum period between events of 8 years.

This maximum spell is important for low-level areas of the floodplain that are inundated as a result of this large fresh. Nine years between inundation events has been identified as a critical threshold for low-level wetlands, as it represents the viability of wetland plant seeds based on research on Ribbon weed (*Vallisneria australis*). Ribbon weed is a common aquatic plant, having seeds that will remain viable in dry wetland sediments for up to nine years (Roberts and Marston 2011). The maximum spell for the 278 GL and the 320 GL scenarios breach this threshold, representing an increased risk to this parts of the floodplain.

Table 22: Spell statistics for the 1,700 ML/d for fourteen days flow indicator at Wilby Wilby on the Narran River.

Water Recovery Scenario	Maximum period between events (years)	No. of spells longer than 4 years (moderate risk)	No. of spells longer than 10 years (high risk)
Baseline	12.7	7	1
278 GL	10.1	7	1
320 GL A	10.1	7	1
320 GL B	8	6	0
320 GL C	8	6	0
345 GL	8	8	0
350 GL	8	6	0
390 GL Basin Plan	8	6	0
415 GL	8	6	0
Without development	5.7	2	0

CB5. Large in-channel flow - 3,500 ML/day on the Culgoa River, measured at the Brenda gauge, for a minimum of fourteen days, between August and May. The frequency target is to have the flow event occur between 40-60% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
30	42*	43*	46*	44*	45*	41*	46*	46*	46*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the Culgoa River (Brenda) 3,500 ML/d large in-channel flow event happens less often than under baseline conditions (from 30% of years with an event compared to 68% of years with an event).
- The modelled water recovery scenarios all improve the frequency of the large in-channel indicator, with all achieving the target range.
- The 350 GL scenario results in the smallest increase in frequency (41%); likely because there was less recovery of the lower flow threshold water harvesting entitlement types in the Culgoa River (as compared to the other scenarios) with recovery volume focused on mid-high entitlement types to improve floodplain connectivity. The highest frequency increase is achieved under the 415 GL, 390 GL, and 320 GL B scenarios (46%).

- Ecologically, all scenarios are likely to provide sufficient opportunities for aquatic biota to move, feed and breed, which is especially important for flow dependent native fish such as golden perch, silver perch, spangled perch and Hyrtl's tandan. The condition of near channel vegetation is also likely be improved, which can be important for vegetation condition, bank stability and additional food resources.
- Improvements are expected to be greatest under the 415 GL, 390 GL and 320 GL B scenarios.

The same critical threshold analysis as done for the large Narran River large fresh flow indicator has been applied. The spells analysis in Table 23 shows that under the 320 GL, 320 GL B, 345 GL, 390 GL, and 415 GL scenarios the high risk critical threshold of 10 years is eliminated. This high risk threshold is breached under baseline conditions twice, and in the 278 GL, 320 GL C and 350 GL scenarios once. The high risk threshold being breached in the 350 GL scenario is a result of the targeted nature of the water recovery for the scenario, with entitlements associated with floodplain connectivity (overland flow and floodplain harvesting licences) being more heavily targeted. The 278 GL scenario represents a much smaller recovery volume at 65 GL and performs poorly as a result.

The moderate risk threshold of four years is breached under all water recovery scenarios but there is a reduced risk from baseline conditions for all scenarios (from seven spells). All scenarios except the 350 GL scenario reduce this to five spells and the 350 GL scenario reduces this to six spells. This compares to only one moderate risk and no high risk spells under without development.

The maximum period between events also shows a change between scenarios. The water recovery scenarios show varying levels of reduction from baseline conditions (10.8 years). The 278 GL, 320 GL C and 350 GL scenarios shows the least reduction at 10.1 years (i.e. just breaching the high risk critical threshold). The 320 GL scenario has a maximum period of 8 years, and the 320 GL B, 390 GL and the 415 GL scenarios have a maximum period between events of 7.6 years.

This maximum spell is important for low-level areas of the floodplain that are inundated as a result of this large fresh. Nine years between inundation events has been identified as a critical threshold for low-level wetlands, as it represents the viability of wetland plant seeds based on research on Ribbon weed (*Vallisneria australis*) (Roberts and Marston 2011). Ribbon weed is a common aquatic plant, having seeds that will remain viable in dry wetland sediments for up to nine years (Roberts and Marston 2011). The maximum spell for the 278 GL, 320 GL C and 350 GL scenarios breach this threshold, representing an increased risk to this parts of the floodplain.

Table 23: Spell statistics for the 3,500 ML/d for fourteen day flow indicator at Brenda on the Culgoa River

Water Recovery Scenario	Maximum time between events (years)	No. of spells longer than 4 years (moderate risk)	No. of spells longer than 10 years (high risk)
Baseline	10.8	7	2
278 GL	10.1	5	1
320 GL A	8	5	0
320 GL B	7.6	5	0
320 GL C	10.1	5	1

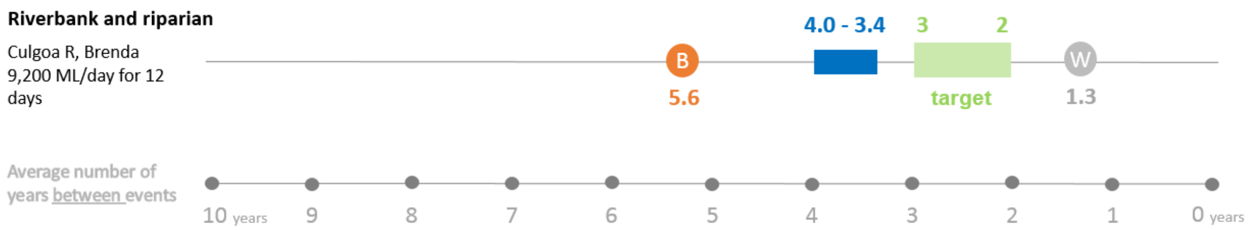
Water Recovery Scenario	Maximum time between events (years)	No. of spells longer than 4 years (moderate risk)	No. of spells longer than 10 years (high risk)
345 GL	8	5	0
350 GL	10.1	6	1
390 GL Basin Plan	7.6	5	0
415 GL	7.6	5	0
Without development	4.4	1	0

Floodplain and Wetland Connectivity Results (Lower Balonne)

Riparian, inner, mid and outer floodplain connectivity

There are four floodplain connectivity flow indicators, of increasing size (in terms of how far they spread out). The durations for each of the four flow indicators represents the median duration for all events that exceeded the threshold under the without development scenario. For each of the flow indicators, timing is not constrained as floodplain flows historically occur at any time of year and water on floodplains and in wetlands is generally retained beyond the flow event. The frequency target range is expressed as the average number of years between an events, and considers the types of floodplain vegetation that are inundated by the different flows and their average watering requirements (Casanova 2015; Roberts and Marston 2011). These frequencies also consider observed and modelled hydrology data to ensure consistency with the hydrology of the Lower Balonne.

CB6. Riparian connectivity - 9,200 ML/day on the Culgoa River, measured at the Brenda gauge, for a minimum of twelve days, any time of the year. The frequency target is to have, on average, no longer than 2-3 years between events.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
5.6	4.0	4.0	3.7	3.9	3.9	3.6	3.5	3.5	3.4

* Denotes that the target range was met

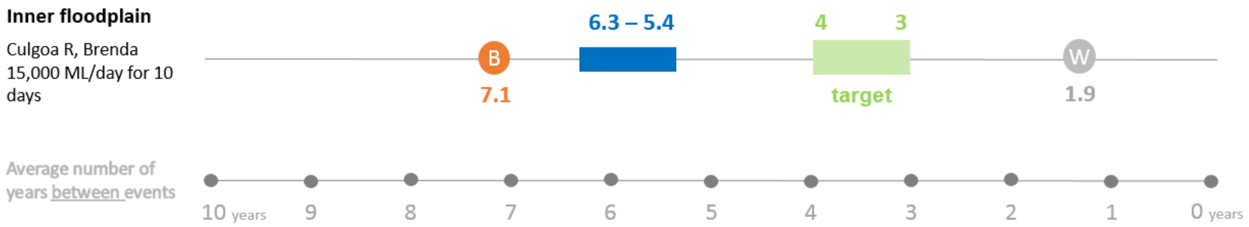
The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the time between the riparian connectivity flow occurring is much longer compared to without development conditions (5.6 years between an event compared to 1.3 years between an event). The target range is for this flow event to occur, on average, between two and three years. Many wetlands, creeks and river channels within the riparian zone would have been inundated with at least this frequency under without development. This frequency is also consistent with the requirements of river red gum forests and lignum.

- The water recovery scenarios do result in an improvement in reducing the time between riparian connectivity events (between 4 and 3.4 years depending on scenario). The difference is significant as it represents a six month reduction in the period between events to improve conditions for the riparian zone.
- The 415 GL scenario has the greatest improvement compared to the other scenarios. The 278 GL and 320 GL scenarios result in the lowest increases.
- Not meeting the target, particularly in prolonged dry periods, may result in riparian red gum and wetland vegetation being in poorer condition. There could be reduced quality and extent of lignum, which is relied upon by many animals (including waterbirds) for habitat.
- There will be increased opportunities for floodplain specialist fish species to access anabranches and secondary channels for all scenarios, with the opportunities increasing with the larger recovery volume scenarios. This is important as these fish generally have a life-span less than five years and benefit from having access to off-river habitats. These habitats form an important nursery for juveniles with significant habitat diversity and aquatic productivity.
- This type of flow is important for improving riparian vegetation condition and for geomorphic processes such as waterhole scouring and maintenance of benches and other floodplain features.

Spell analysis is discussed as a group for all floodplain flow indicators further below.

CB7. Inner floodplain connectivity - 15,000 ML/day on the Culgoa River, measured at the Brenda gauge, for a minimum of ten days, any time of the year. The frequency target is to have, on average, no longer than 3-4 years between events.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
7.1	6.3	6.3	6.3	6.3	6.3	6.0	5.4	5.4	5.4

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

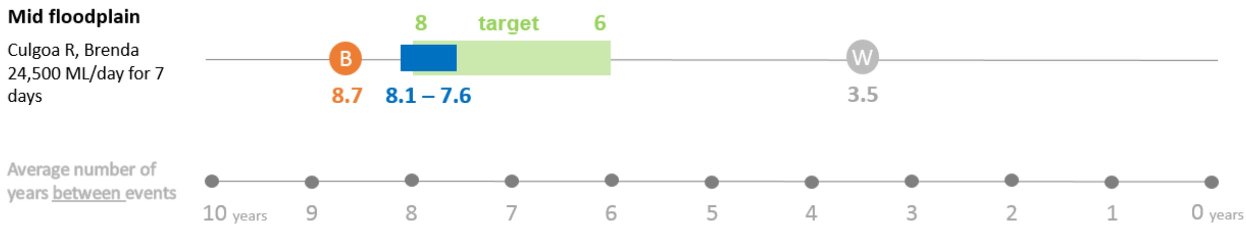
- Under baseline conditions, the time between the inner floodplain connectivity flow event occurring is much longer compared to without development (7.1 years between events compared to 1.9 years between events). The target range is for this flow event to occur, on average, every three and four years. This frequency is consistent with the watering requirements for vigorous growth in river red gum woodlands and black box woodlands and to sustain lignum shrublands.
- The modelled water recovery scenarios do result in an improvement in reducing the time between inner floodplain connectivity events occurring (between 6.3 and 5.4

years depending on scenario). The difference is significant as it represents close to a year reduction in the period between events.

- The 390 GL scenarios and the 415 GL scenario have the most improved frequency result compared to the other scenarios; however, these scenarios are well short of achieving the target range.
- Ecologically, over prolonged dry periods, these frequencies of inundation could result in vegetation being in poorer condition, and could reduce habitat diversity, including foraging habitat for migrating birds. As the frequency reduces, access to temporary, opportunistic and productive habitat would also be reduced native fish species, especially floodplain fish specialists, and other water-dependent biota. The average period between events for some of the scenarios is longer than five years which is longer than the life-span for many of the floodplain specialist fish.

Spell analysis is discussed as a group for all floodplain flow indicators further below.

CB8. Mid floodplain connectivity - 24,500 ML/day on the Culgoa River, measured at the Brenda gauge, for a minimum of seven days, any time of the year. The frequency target is to have, on average, no longer than 6-8 years between events.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
8.7	7.6*	7.6*	8.1	7.1*	7.6*	8.1	7.6*	7.6*	7.6*

* Denotes that the target range was met

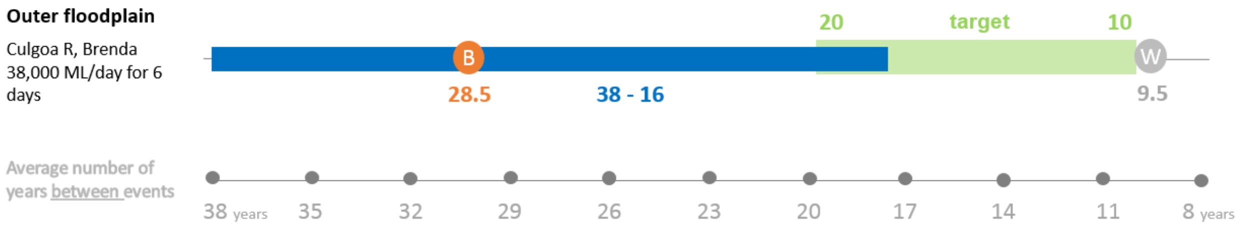
The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the time between the mid-floodplain connectivity flow occurring is much longer compared to without development conditions (8.7 years between an event compared to 3.5 years between an event). The target range is for this flow event to occur, on average, between eight and six years. Flows of this frequency will support the requirements to maintain areas of the floodplain that are not inundated as frequently, including some areas of lignum and coolabah woodlands.
- The water recovery scenarios do result in an improvement in reducing the time between mid-floodplain connectivity events occurring (between 8.1 and 7.6 years depending on scenario). This represents a six-month reduction in the period between events across the scenarios.
- The 278 GL, 320 GL, 345 GL, 390 GL and 415 GL scenarios meet the target range. The other scenarios (320 GL B and the 350 GL) are very close to also achieving the target range and miss out by just one flow event.
- There is a reasonable likelihood of scenarios that meet the target supporting woodland vegetation communities. As a secondary consideration, these scenarios

would be expected to support river red gum and lignum in the middle part of the floodplain, although their condition is likely to be poorer, and more frequent subsequent watering may be required to improve their health. This flow event is important as it represents more significant flooding with floodwater returning to the rivers. The exchange of nutrient rich flows between the river and floodplain, linking terrestrial and aquatic food webs, is likely to be enhanced across the scenarios.

Spell analysis is discussed as a group for all floodplain flow indicators further below.

CB9. Outer floodplain connectivity - 38,000 ML/day on the Culgoa River, measured at the Brenda gauge, for a minimum of six days, any time of the year. The frequency target is to have, on average, no longer than 10-20 years between events.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
28.5	38.0	38.0	22.8	22.8	28.5	22.8	**19.0***	**19.0***	**16.3***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the time between the outer floodplain connectivity flow occurring is much longer compared to without development conditions (28.5 years between an event compared to 9.5 years between an event). The target range is for this flow event to occur, on average, between 10 to 20 years. This is based on research on the requirements of grassland communities similar to those of the Lower Balonne (NSW DEWCC 2011).
- The water recovery scenarios both result in an increase and decrease in the time between outer floodplain connectivity events occurring (between 38 and 16 years, depending on scenario).
- The 390 GL and 415 GL scenarios achieve the target range; but the 415 GL has a greater level of frequency improvement (16.3 years, on average, between events).
- The 278 GL and 320 GL scenarios result in a poorer outcome compared to the baseline condition. For these scenarios, inundation of this part of the floodplain is expected to be similar to baseline conditions. The large shift in frequency is caused by the reduction in the peak flow of one outer floodplain connectivity event so the required duration is not met. The change in frequency looks large as there are so few events of this magnitude. There are only 3 events under baseline conditions and the 390 GL and 415 GL scenarios increase this to 5 and 6 events respectively – this compares to 11 events under without development.
- The 390 GL and 415 GL scenarios are likely to provide the greatest improvement to the productivity of grasslands and coolabah on the outer floodplain, which is important

for providing terrestrial animal habitat and energy sources for aquatic animals. Improvements to the mass exchanges of nutrients, sediment and animals, resulting from the increased number of large inundation events, will help sustain a wide variety of communities across the floodplain. The likelihood of a healthy outer floodplain is considerably reduced under the 320 GL and 278 GL scenarios.

There are critical intervals between inundation events that are described in the literature that can be considered for Lower Balonne floodplain. These are based on a range of information sources including: a review of the scientific literature regarding the water requirements of five floodplain tree species from across the Murray–Darling Basin (Casanova 2015); an assessment of the viability of wetland plant seeds based on research on Ribbon weed (Roberts and Marston 2011); and anecdotal information from landholders from the Lower Balonne region. These thresholds, while not prescriptive and based on average requirements, do provide a means to compare modelled water recovery scenarios. The thresholds identified include:

- 5 years between inundation events for the inner floodplain (area inundated by a flow rate of 9,200 ML/d at Brenda). This is based on anecdotal information indicating that coolabah trees start to die after this time period.
- 9 years between inundation events for low-level wetlands, representing the viability of wetland plant seeds based on Ribbon weed (*Vallisneria australis*), a common aquatic plant, having seeds that will remain viable in dry wetland sediments for up to nine years (Roberts and Marston 2011)
- 10 and 13 years between inundation events for river red gum (*Eucalyptus camaldulensis*) forests and woodlands, representing an indicative period to cause decline from good to critical condition for modelling state and transitions in floodplain vegetation (Casanova 2015).
- 14 years between inundation events for black box (*Eucalyptus largiflorens*), representing an indicative period to cause decline from good to critical condition for the purposes of modelling state and transitions in floodplain vegetation (Casanova 2015).

The maximum period between events for the floodplain and wetland connectivity flow indicators is shown in Table 24 and Appendix E. These periods are much longer than the identified thresholds. However, the maximum period between events shows that there are major reductions between scenarios for the 9,200 ML/d and 15,000 ML/d flow indicators. This shows that some water recovery scenarios can shift high risk prolonged dry spells that are present under the baseline conditions. The major differences include:

- The 415 GL, 390 GL, 350, 320 GL C and 320 GL B scenarios show the largest improvement with reductions in the 9,200 ML/d flow indicator.
- Only the 415 GL and 390 GL scenarios improve the 15,000 ML/d flow indicator.
- The 320 GL A and 278 GL scenarios show no change for any of the flow indicators
- The 24,500 ML/d and 38,000 ML/d flow indicators show no change in the maximum period between events for any of the water recovery scenarios.

Table 24: Maximum period between events for the four floodplain and wetland connectivity flow indicators in the Lower Balonne for the modelled scenarios.

Water Recovery Scenario	9,200 SFI Maximum time between events (years)	15,000 SFI Maximum time between events (years)	24,500 SFI Maximum time between events (years)	38,000 SFI Maximum time between events (years)
Baseline	28.5	55.1	55.1	55.1
278 GL	28.5	55.1	55.1	55.1
320 GL A	28.5	55.1	55.1	55.1
320 GL B	19.2	55.1	55.1	55.1
320 GL C	19.2	55.1	55.1	55.1
345 GL	28.5	55.1	55.1	55.1
350 GL	19.2	55.1	55.1	55.1
390 GL Basin Plan	19.2	28.5	55.1	55.1
415 GL	19.2	28.5	55.1	55.1
Without development	5.3	8.9	10.9	55.1

To further consider this, analysis was done to relax the duration requirement to one day for the 9,200 ML/d and 15,000 ML/d flow indicators (Table 25 and Table 26). These indicators were chosen as they inundate vegetation that is most relevant to the thresholds identified in the literature. This analysis yielded results that better align with the thresholds and shows differences between scenarios. The major differences include:

- For the 9,200 ML/d flow indicator, there are 5 year spells in the baseline conditions and all water recovery scenarios but no 9-14 year spells. The 278 GL scenario has the highest level of risk with 8 spells longer than 5 years (same as baseline). The 320 GL A scenario reduces the number to 5 and all other scenarios half the number to 4.
- For the 15,000 ML/d flow indicator, there is a similar pattern with the 278 GL and 320 GL A scenarios having more 5 year spells at 8 (same as baseline). The number of 5 year spells reduces to 4 for all other scenarios. All scenarios show improvement from Baseline for 9 year spells with at least one less spell of this length. The 390 GL and 415 GL scenarios show additional improvement by reducing the number of 9 year spells to 2. All water recovery scenarios show the same improvement from Baseline for 10 and 14 year spells.
- This indicates the 278 GL and 320 GL A scenarios result in more stress for vegetation in the inner floodplain as compared to the other scenarios. The 390 GL and 415 GL scenarios can provide additional benefit for floodplain vegetation.
- This compares to no spells of these lengths for without development.

Table 25: Spell statistics for the 9,200 ML/d threshold with a minimum one day duration.

Water Recovery Scenario	5 years between events	9 years between events	10 years between events	14 years between events
Baseline	8	0	0	0
278 GL	8	0	0	0
320 GL A	5	0	0	0
320 GL B	4	0	0	0
320 GL C	4	0	0	0
345 GL	4	0	0	0
350 GL	4	0	0	0
390 GL Basin Plan	4	0	0	0
415 GL	4	0	0	0
Without development	0	0	0	0

Table 26: Spell statistics for the 15,000 ML/d threshold with a minimum one day duration.

Water Recovery Scenario	5 years between events	9 years between events	10 years between events	14 years between events
Baseline	8	5	5	1
278 GL	8	4	2	0
320 GL A	8	4	2	0
320 GL B	7	4	2	0
320 GL C	7	3	2	0
345 GL	7	4	2	0
350 GL	7	4	2	0
390 GL Basin Plan	7	2	2	0
415 GL	7	2	2	0
Without development	4	0	0	0

Condamine–Balonne (Narran Lakes) Flow Indicators Results

There are four flow indicators specified for the Narran Lakes, which are all floodplain and wetland connectivity indicators as shown in Figure 40. The majority of these have been updated based on new information gathered as part of the Northern Basin Review

The environmental assessment outlined below relies on the scientific information found in the Condamine–Balonne Environmental Water Requirements report, which can be found in the Condamine–Balonne Environmental Water Requirements Report. This report also describes the rationale underpinning the flow indicators.

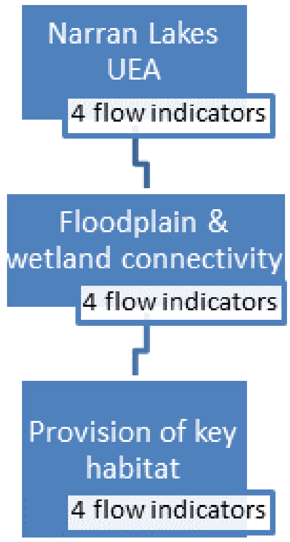


Figure 40: Breakdown of Narran Lakes flow indicators into flow component groups and sub-groups

Floodplain and Wetland Connectivity Results (Narran Lakes)

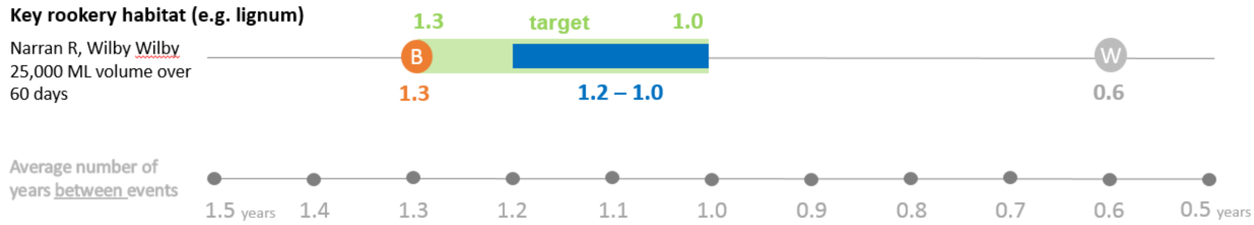
Provision of key habitat

Four site-specific flow indicators have been selected for the Narran Lakes to reflect a flow regime that would support the vital habitat and foraging requirements of migratory birds and waterbirds.

- Key rookery habitat - This indicator targets the key rookery habitat of the northern lakes (Clear Lake, Back Lake, Long Arm and the adjacent lignum swamp).
- Habitat of the northern lakes and floodplains - this indicator targets the habitat of the northern lakes and northern floodplains.
- Large-scale waterbird breeding - this indicator targets providing opportunities for large-scale waterbird breeding events; and based on historic data, results in a guaranteed successful breeding outcome for straw-necked ibis. A flow event of this magnitude would be beneficial for vegetation on a third of the northern floodplain and about 20% of the central floodplain.
- Habitat of the Narran Lakes, and northern central floodplains - this indicator targets habitat across all of the Narran Lakes and much of the northern and central floodplain.

For each of the flow indicators, timing is not constrained as floodplain flows historically occur at any time of year and water on floodplains and in wetlands is generally retained beyond the flow event.

NL1. Key rookery habitat - 25,000 ML total volume over a 60 day period on the Narran River, measured at the Wilby Wilby gauge, any time of the year. The frequency target is to have, on average, no longer than 1-1.3 years between events.



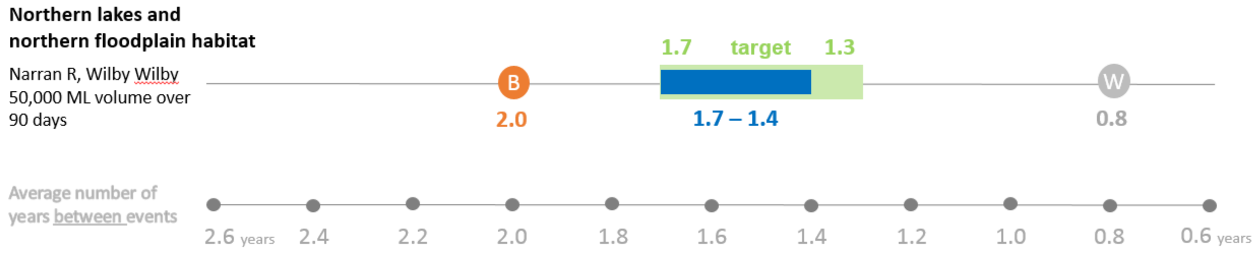
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
1.3*	1.2*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the average time between the flow indicator occurring is much longer compared to without development conditions (1.3 years between an event compared to 0.6 years between an event). The target range is for this flow event to occur, on average, between 1.3 and 1 year. This is to provide inundation regularly enough for large clumps of lignum (approximately 60% cover) to thrive in the key bird rookery habitats.
- The modelled water recovery scenarios all achieve the lower end of the target range for the ecological outcome (between 1.2 and 1 year).
- The 278 GL scenario is the only scenario that performs differently, and also results in the smallest increase in frequency away from the baseline condition.
- The long-term health of vegetation in the parts of the northern lakes inundated by this event is likely to be maintained (Clear Lake, Back Lake, Long Arm and the adjacent lignum swamp). This is vital habitat for waterbirds (associated with the Narran Lakes Nature Reserve Ramsar site). These flows may also support waterbird breeding (though unlikely to be in large numbers).

NL2. Habitat of the northern lakes and floodplains - 50,000 ML total volume over a 90 day period on the Narran River, measured at the Wilby Wilby gauge, any time of the year. The frequency target is to have, on average, no longer than 1.3-1.7 years between events.



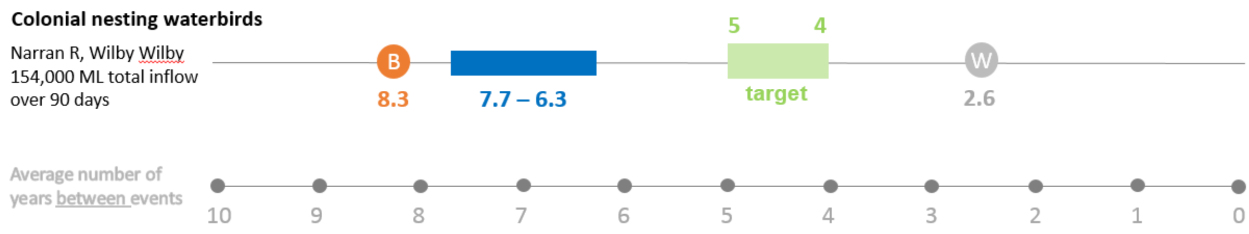
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
2.0	1.7*	1.5*	1.4*	1.4*	1.5*	1.4*	1.4*	1.4*	1.4*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the average time between the flow indicator occurring is much longer compared to without development conditions (2 years between an event compared to 0.8 years between an event). The target range is for this flow event to occur, on average, between 1.7 and 1.3 years. This is to provide inundation regularly enough to allow large clumps of lignum (approximately 20% cover) to thrive in the broader key bird rookery habitats.
- The modelled water recovery scenarios result in a considerable improvement in reducing the time between events occurring (between 1.7 and 1.4 years). The scenarios with an average period between events of 1.4 years have 11 additional events compared to the 278 GL scenario and 5 more compared to the 320 GL scenario. This increase in the number of events provides a range of benefits including improvements to the long-term condition of vegetation and more opportunities for aquatic biota and waterbirds to make use of the Narran Lakes.
- All scenarios meet the target range, with the 320 GL B, 320 GL C, 350 GL, 390 GL and 415 GL scenarios having the greatest improvement.
- The long-term health of vegetation in the northern lakes associated with this indicator is likely to be maintained (Clear Lake, Back Lake, Long Arm and the adjacent lignum swamp). The increased inundation, as compared to the 25 GL flow indicator, is likely to improve the filling of the northern lakes, inundate larger areas of lignum that are important foraging sites and improve the condition of riparian vegetation. These flows are also more likely to support waterbird breeding (though unlikely to be in the thousands of nests).

NL3. Large-scale waterbird breeding - 154,000 ML total volume over a 90 day period on the Narran River, measured at the Wilby Wilby gauge, any time of the year. The frequency target is to have this event occur, on average, at least once every 4-5 years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
8.3	7.7	6.7	6.3	6.3	7.2	6.3	6.7	6.7	6.3

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the average time between the flow indicator occurring is much longer compared to without development conditions (8.3 years between an event compared to 2.6 years between an event). The target range is for this flow event to occur once, on average, every four to five years. This is to provide conditions suitable for breeding to take place twice in a straw-necked ibis' breeding lifespan.
- The modelled water recovery scenarios do result in an improvement in reducing the average period of time between an event occurring (between 7.7 and 6.3 years depending on scenario). However, none of the modelled scenarios reach the target range. The difference between scenarios is significant difference as it represents a 1.4 year reduction in the frequency to improve opportunities for waterbird breeding events.
- The 415 GL, 350 GL and 320 GL B scenarios perform equally, reducing the average period of years between events to 6.3. The 278 GL scenario results in the smallest improvement followed by the 345 GL scenario.
- The scenarios that performed best included a higher recovery volume for the Narran River. This is important as recovering water from Narran River, especially water harvesting licences, has been shown to provide the best inflow outcomes for the Narran Lakes.
- Based on the (average) frequency results above, it is likely that some waterbirds (e.g. straw-necked ibis) will only have one opportunity to breed in their lifetimes. At this breeding recurrence, some waterbird populations are likely to continue to decline, particularly if on-going research shows that other suitable breeding areas are usually synchronised with Narran Lakes.

Expert advice by Brandis and Bino (2016) recommended that MDBA analyse the waterbird breeding flow indicator to assess if scenarios achieve at least two opportunities in every eight years (representing low uncertainty) and two opportunities in every ten years (representing high uncertainty). These recommendations are based upon the same life-history traits of straw-necked ibis that MDBA has used for the flow indicator (though for reporting above a 1 in 4/5 year average was used as a surrogate).

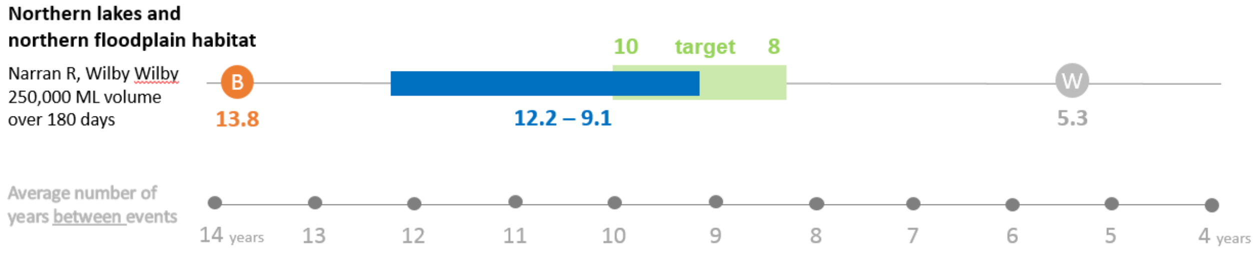
Table 27 presents how often two events in any eight and ten year period occurred across the 114 year model period for each water recovery scenario. The main findings include:

- Even under without development condition, there were periods where there were not two events within the 8 and 10 periods. This indicates that there would naturally be extended periods where straw-necked ibis would not have had ideal conditions.
- However, there is a significant reduction in these conditions occurring under Baseline. The two events in any 8 year period reduces from 79% to 24% and the two events in any 10 year period reduces from 91% to 30%.
- The water recovery scenarios all show improvement, with the 320 GL B, 320 GL C, 350 GL, and 415 GL scenarios having the greatest (this is also reflected in the frequencies above). This result re-emphasises the importance of the volume of recovery, especially in the Narran River, to reduce risks to waterbird breeding.

Table 27: Spells analysis for the waterbird breeding flow indicator (2 in 8/10 years)

Water Recovery Scenario	% of time 2 events occur in any 8 year period	% of time 2 events occur in any 10 year period
Baseline	24	30
278 GL	25	31
320 GL A	27	34
320 GL B	32	41
320 GL C	32	41
345 GL	25	31
350 GL	32	41
390 GL Basin Plan	27	34
415 GL	32	41
Without development	79	91

NL4. Habitat of the Narran Lakes, and central and northern floodplains - 250,000 ML total volume over a 180 day period on the Narran River, measured at the Wilby Wilby gauge, any time of the year. The frequency target is to have, on average, no longer than 8-10 years between events.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
13.8	12.2	11.0	**9.1***	**9.1***	11.0	**10.0***	11.0	11.0	**9.9***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions, the average time between the flows indicator occurring is much longer compared to without development conditions (13.8 years without an event compared to 5.3 years without an event). The target range is for this flow event to occur, on average, between eight and ten years. This range represents the critical period for survival of lignum in Narran Lakes (in small form and sparse) and other key vegetation species on northern and central floodplains.
- The modelled water recovery scenarios do result in a noticeable improvement in reducing the time between riparian connectivity events occurring (between 12.2 and 9.1 years depending on scenario).
- The 415 GL, 350 GL, 320 GL C and 320 GL B scenarios achieve the target range, with the 320 GL C and 320 GL B performing strongest (9.1 years). The highest risk scenario is the 278 GL scenario (12.2 years).
- The ecological consequence of the 320 GL, 350 GL and 415 GL scenarios is likely to be increased periods of stress for vegetation habitat for much of the northern and central floodplains. This area is foraging habitat for waterbird and can support other water dependent species on the floodplain.
- Under the 278 GL, 320 GL and the 390 GL scenarios, the lack of suitably frequent inundation is likely to be a reduction in health of the floodplain vegetation (compared to those scenarios that achieved the target range).

The maximum period between events for the four Narran Lakes flow indicators is shown in Table 28. The main results are:

- The maximum period of the 25 GL and 50 GL indicators are the same as Baseline conditions and do not change between scenarios (7.5 years). When compared to the critical thresholds identified in the literature (as described in the Lower Balonne section) this period is not considered significant and supports the frequency assessment which showed all flow indicators achieve the target frequency range.

- The 154 GL indicator shows that the 278 GL scenario provides no improvement from Baseline conditions, while all other scenarios are able to break the maximum spell by roughly 10 years.
- The 250 GL indicator does not change from Baseline conditions indicating that the recovery volumes are not enough to break this significant fifty year dry spell.

Table 28: Maximum period between events for the four Narran Lakes flow indicators for the modelled scenarios.

Water Recovery Scenario	25 GL SFI Maximum time between events (years)	50 GL SFI Maximum time between events (years)	154 GL SFI Maximum time between events (years)	250 GL SFI Maximum time between events (years)
Baseline	7.5	7.5	29.7	54.7
278 GL	7.5	7.5	29.7	54.7
320 GL A	7.5	7.5	19.2	54.7
320 GL B	7.5	7.5	19.2	54.7
320 GL C	7.5	7.5	19.2	54.7
345 GL	7.5	7.5	19.2	54.7
350 GL	7.5	7.5	19.2	54.7
390 GL Basin Plan	7.5	7.5	19.2	54.7
415 GL	7.5	7.5	19.2	54.7
Without development	3.1	3.2	10.9	54.7

Gwydir Wetland Flow Indicators

There are nine flow indicators specified for the Gwydir Wetland, all of which are based on information from the original assessment undertaken to develop indicators. They are two river channel indicators and seven floodplain and wetland connectivity flow indicators (and their sub-components) as shown in Figure 41 below. Two of the floodplain and wetland connectivity flow indicators relate to the Mallowa Creek watercourse, whereas the remainder are focussed on the Lower Gwydir and Gingham channel.

The environmental assessment outlined below relies on the scientific information found in the Gwydir Wetland Environmental Water Requirements report, which can be found in the Gwydir Wetland Environmental Water Requirements Report. This report also describes the rationale underpinning the flow indicators.

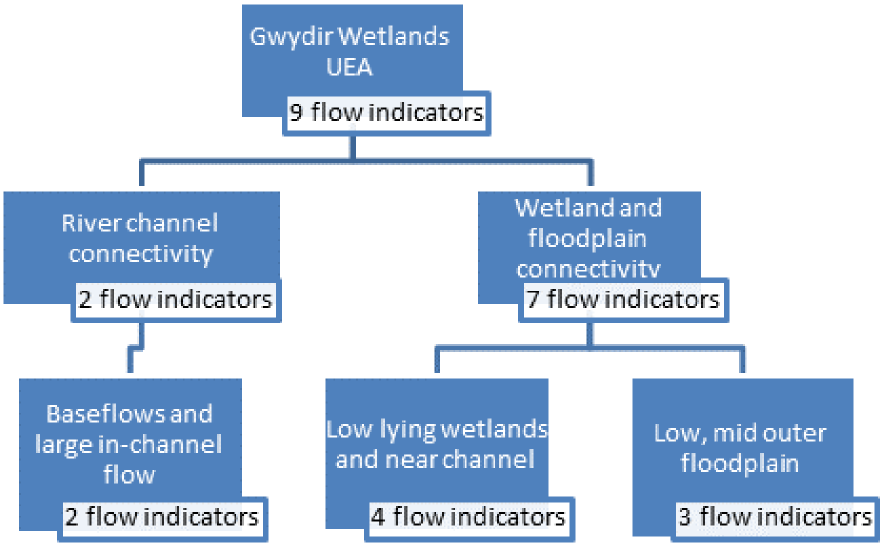
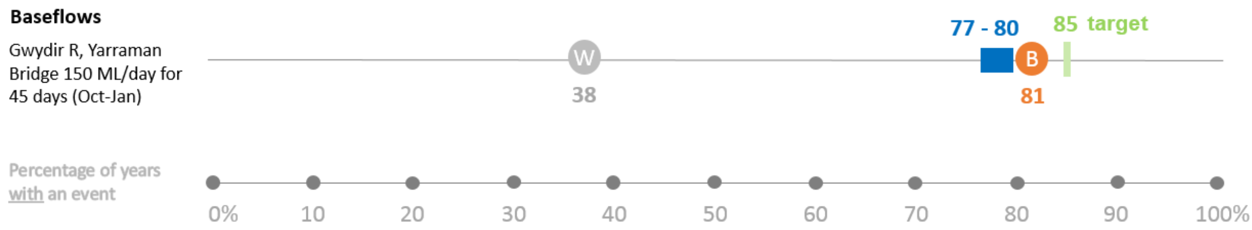


Figure 41: Breakdown of Gwydir Wetlands flow indicators into flow component groups and sub-groups

Provision of baseflows

There is one base flow indicator for the Gwydir. This indicator works in tandem with the large in channel fresh to support native fish outcomes.

G1. Gwydir Wetland base flows – 150 ML/day on the Gwydir River, measured at Yarraman Bridge gauge, for a minimum of forty-five days, between October and January. The frequency target is to have the flow event occur 85% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
81	79	79	80	79	79	80	80	77	80

* Denotes that the target range was met

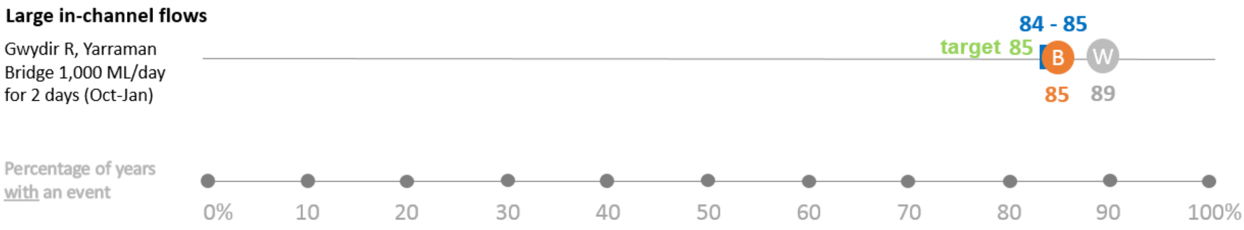
The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- This indicator works in tandem with the flowing large in-channel fresh indicator below and is targeted at native fish spawning, recruitment and maintenance.
- Under baseline conditions (2009 levels of development before water recovery), the percentage of time the 150 ML/d baseflow occurs is more frequent compared to without development conditions (81% compared to 38% of years with the event). It is acknowledged that the frequency target of this flow component (85% of years) exceeds the frequency under without-development conditions (38% of years), and is only slightly greater than current baseline conditions (81% of years). This reflects the high degree of regulation, particularly the delivery of irrigation water (which has increased baseflow frequency), and the frequency is considered appropriate to support environmental outcomes in a modified ecosystem, with it expected that native fish have adapted to the increased base flows from regulation, requiring improved frequency of these to support spawning, recruitment and maintenance needs.
- The modelled water recovery scenarios result in a small range of frequency outcomes (between 77-80% of years, depending on scenario).
- The 320 GL B, 350 GL, 390 GL and 415 GL present the greatest increase in frequency.
- Given the results of the 1,000 ML/d flow indicator below (which is linked to this indicator), the ecological consequence across scenarios is that the elevated baseflow (150 ML/d) may not occur frequently enough to restore and maintain the health, size and/or resilience of native fish populations (which may include carp gudgeon, bony bream and spangled perch). This risk is present under all scenarios to a similar degree.

Provision of large in-channel flows

There is one large in-channel flow indicator for the Gwydir. This indicator works in tandem with the baseflow to support native fish outcomes.

G2. Gwydir Wetland large in-channel flows – 1,000 ML/day on the Gwydir River, measured at Yarraman Bridge gauge, for a minimum of two days, between October and January. The frequency target is to have the flow event occur 85% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
85*	84	84	84	84	84	84	84	**85***	84

* Denotes that the target range was met

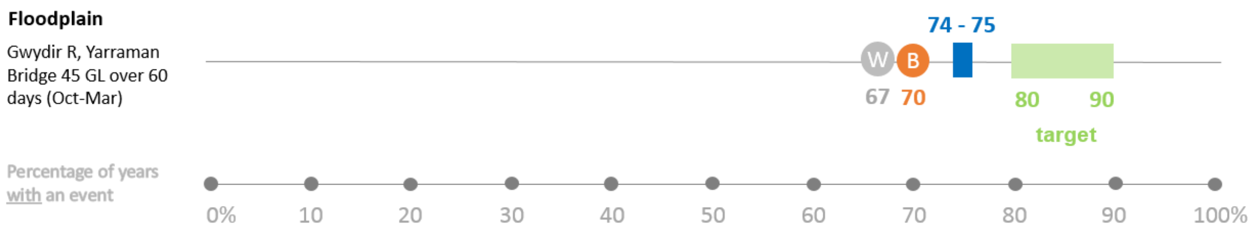
The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- This indicator works in tandem with the extended base flow indicator above and is targeted at native fish spawning, recruitment and maintenance.
- Under baseline conditions (2009 levels of development before water recovery), the percentage of time the 1,000 ML/d large in-channel flow occurs is less compared to without development conditions (85% compared to 89% of years with the event). The target range is for this flow event to occur, on average, 85% of years. The proposed frequency is set to match the frequency under current arrangements (85% of years), which is also similar to the frequency under without-development conditions (89% of years).
- The modelled water recovery scenarios result in either no change from baseline (the 390 GL scenario), or a very minor (1%) reduction in the frequency of the event (all other scenarios). Only the 390 GL scenario achieves the target range; although the difference between scenarios is not considered significant.
- Given the results of the 150 ML/d flow indicator above (which is linked to this indicator), the ecological consequence across scenarios is that while the short-duration fresh (this indicator) is reasonably well attained across scenarios equally, the elevated baseflow referred to above (150 ML/d) may not occur frequently enough to restore and protect the health, size and/or resilience of native fish populations (which may include carp gudgeon, bony bream and spangled perch) which would be expected to have adapted to the increased base flows from regulation, requiring improved frequency of these to support spawning, recruitment and maintenance needs. This risk is present under all scenarios to a similar degree.

Provision of wetland/floodplain connectivity flows

There are five wetland/floodplain connectivity flow of increasing magnitude in order to inundate the riparian, mid and outer floodplain areas.

G3. Gwydir Wetland riparian floodplain flows – 45 GL total volume on the Gwydir River, measured at Yarraman Bridge gauge, over a sixty day period, between October and March. The frequency target is to have the flow event occur between 80-90% of years.



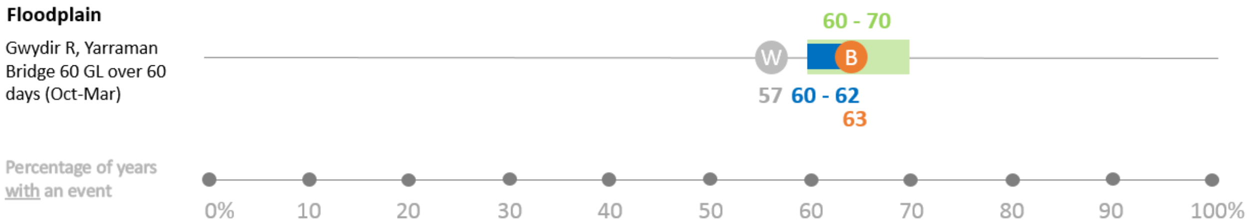
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
70	75	75	75	75	75	75	74	75	75

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Gwydir River (Yarraman Bridge gauge) 45 GL floodplain flow event happens more often than under without development conditions (70% compared to 67% of years with the event - which reflects the high degree of regulation in the system). The target range is for this flow event to occur, on average, 80-90% of years and is based on the watering requirements of semi-permanent wetland species (such as club rush, water couch and cumbungi).
- The modelled water recovery scenarios result in a frequency of events between 74-75% of years, depending on scenario; however, all scenarios are outside the target range, and result in a frequency of 74% of years.
- Under all scenarios there is some risk that some semipermanent wetland species would not be watered frequently enough to maintain health and vigour. This is particularly so for marsh club rush; while cumbungi and water couch are likely to be more resilient (based on Roberts & Marston 2011).
- There will also be reduced opportunities for native fish to access anabranches and secondary channels. This is particularly problematic for floodplain specialist species. These fish generally have a life-span less than five years and benefiting greatly from access to off-river habitats. These habitats form an important nursery for juveniles with significant habitat diversity and aquatic productivity. Reduced access to these habitats may have significant impacts on these populations.

G4. Gwydir Wetland mid-floodplain flows – 60 GL total volume on the Gwydir River, measured at Yarraman Bridge gauge, over a sixty day period, between October and March. The frequency target is to have the flow event occur between 60-70% of years.



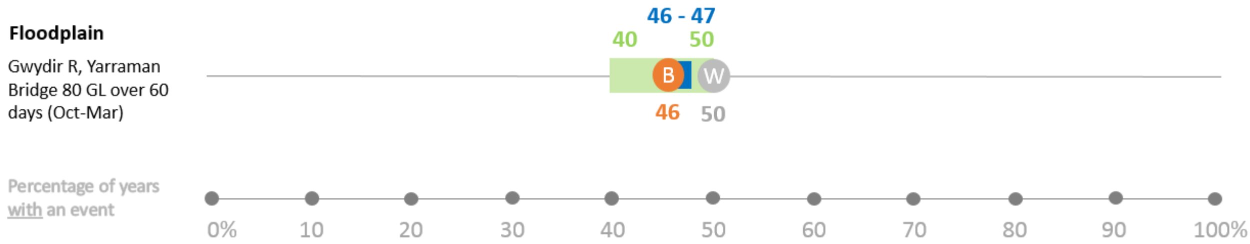
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
63*	62*	62*	62*	61*	61*	61*	61*	62*	60*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Gwydir River (Yarraman Bridge gauge) 45 GL floodplain flow event happens more often than under without development conditions (63% compared to 57% of years with the event - which reflects the high degree of regulation in the system). The target range is for this flow event to occur, on average, 60-70% of years and is based on the watering requirements of semi-permanent wetland species (such as club rush, water couch and cumbungi) and some floodplain wetland fringing species (lignum, river cooba and coolibah).
- The modelled water recovery scenarios result in a frequency of events between 60-62% of years, depending on scenario. All scenarios reach the target range and would be expected to inundate nearly 5,800 ha of semi-permanent wetland; almost 3,000 ha of floodplain wetland vegetation; and 4,000 ha of floodplain vegetation.
- Under all scenarios there is likely to be sufficient regular watering of some semi-permanent wetland species (water couch and cumbungi) and some floodplain and wetland fringing species (lignum, river cooba and coolibah) to maintain health and vigour.
- There will also be reduced opportunities for native fish to access anabranches and secondary channels. This is particularly problematic for floodplain specialist species. These fish generally have a life-span less than five years and benefiting greatly from access to off-river habitats. These habitats form an important nursery for juveniles with significant habitat diversity and aquatic productivity. Reduced access to these habitats may have significant impacts on these populations.

G5. Gwydir Wetland mid-floodplain flows – 80 GL total volume on the Gwydir River, measured at Yarraman Bridge gauge, over a sixty day period, between October and March. The frequency target is to have the flow event occur between 40-50% of years.



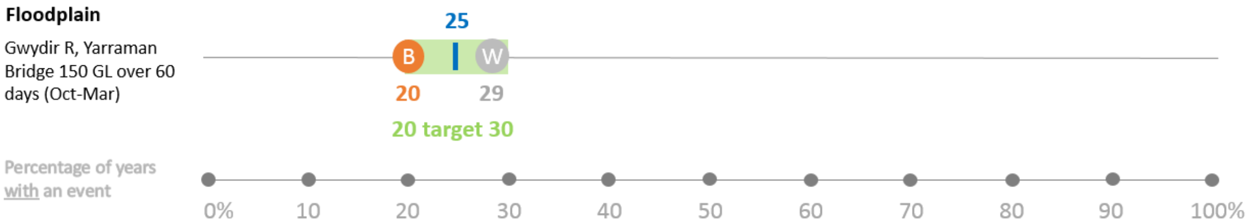
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
46*	46*	46*	47*	47*	47*	47*	47*	46*	46*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Gwydir River (Yarraman Bridge gauge) 80 GL floodplain flow event happens less often than under without development conditions (46% compared to 50% of years with the event). The target range is for this flow event to occur, on average, 40-50% of years and is based on the watering requirements of semi-permanent wetland species (such as club rush, water couch and cumbungi) and floodplain wetland species (such as lignum, river cooba and coolibah).
- The modelled water recovery scenarios result in a nil to very small improvement in increasing the frequency of events (between 46-47% of years, depending on scenario). However, all scenarios are within the target range with the 320 GL B 320 GL C, 345 GL, 350 GL and 390 GL scenarios resulting in the greatest increases in frequency (47% of years).
- This flow indicator would be expected to inundate approximately 25,000 ha of floodplain, inundating a large amount of semi-permanent wetland (e.g. water couch, cumbungi common reed, etc.) and floodplain wetland (e.g. river cooba, river red gum, etc.), and starting to inundate floodplain vegetation (woodlands, grasslands). Under all scenarios it is likely that these species (and other relevant species) would be watered regularly to maintain enough health, and in turn provide critical habitat for waterbirds and other wetland animals.

G6. Gwydir Wetland outer-floodplain flows – 60 GL total volume on the Gwydir River, measured at Yarraman Bridge gauge, over a sixty day period, between October and March. The frequency target is to have the flow event occur between 20-30% of years.



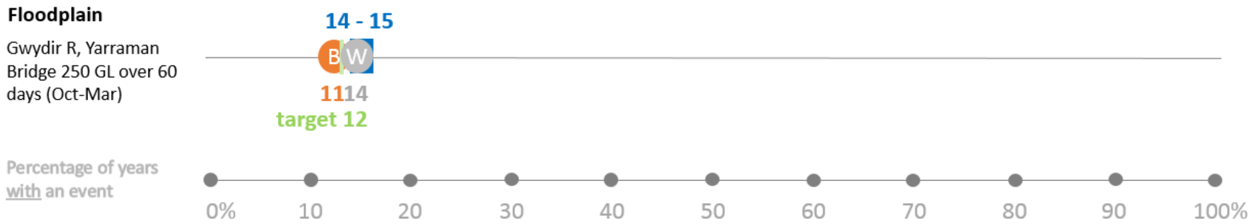
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
20*	25*	25*	25*	25*	25*	25*	25*	25*	25*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Gwydir River (Yarraman Bridge gauge) 150 GL floodplain flow event happens less often than under without development conditions (20% compared to 29% of years with the event). The target range is for this flow event to occur, on average, 20-30% of years and is based on the watering requirements of floodplain wetland species (such as lignum, river cooba and coolibah) and floodplain vegetation species (such as coolibah and black box woodlands).
- The modelled water recovery scenarios result in an improvement in increasing the frequency of events (to 25% of years, equal across all modelled scenarios).
- All scenarios reach the target range, and result in the same frequency outcome (25%).
- This flow indicator would be expected to inundate approximately 45,000 ha of floodplain, inundating almost all of the semi-permanent wetlands (e.g. water couch, cumbungi common reed, etc.), the majority of floodplain wetland (e.g. river cooba, river red gum, etc.), and areas of floodplain vegetation (woodlands, grasslands). Under all scenarios it is likely that these species (and other relevant species) would be watered regularly enough to maintain health and provide opportunities for colonial waterbird breeding.

G7. Gwydir Wetland outer-floodplain flows – 250 GL total volume on the Gwydir River, measured at Yarraman Bridge gauge, over a sixty day period, between October and March. The frequency target is to have the flow event occur 12% of years.



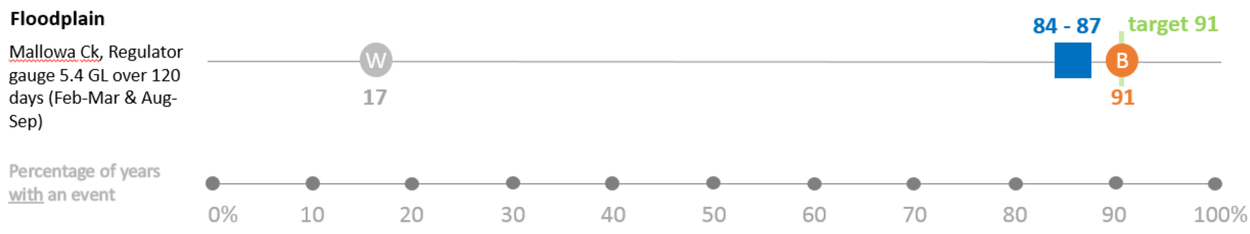
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
11	14*	14*	14*	14*	14*	15*	15*	14*	15*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Gwydir River (Yarraman Bridge gauge) 250 GL floodplain flow event happens less often than under without development conditions (11% compared to 14% of years with the event). The target range is for this flow event to occur, on average, 12% of years and is based on the watering requirements of floodplain vegetation species (such as coolibah and black box woodlands).
- The modelled water recovery scenarios result in an improvement in increasing the frequency of events (between 14-15% of years, depending on scenario).
- All scenarios reach and exceed the target range with the 350 GL, 390 GL and 415 GL scenarios resulting in the greatest increases in frequency (15% of years).
- This flow indicator would be expected to inundate approximately 72,000 ha of floodplain, inundating almost all of the semi-permanent wetlands (e.g. water couch, cumbungi common reed, etc.), a large majority of floodplain wetland (e.g. river cooba, river red gum, etc.), and almost a third of floodplain vegetation (woodlands, grasslands). Under all scenarios it is likely that these species (and other relevant species) would be watered regularly enough to maintain health and provide opportunities for colonial waterbird breeding.

G8. Gwydir Wetland riparian-floodplain flows – 5.4 GL total volume on Mallowa Creek, measured at the Regulator gauge, over a 120 day period, between February-March & August-September. The frequency target is to have the flow event occur 91% of years.



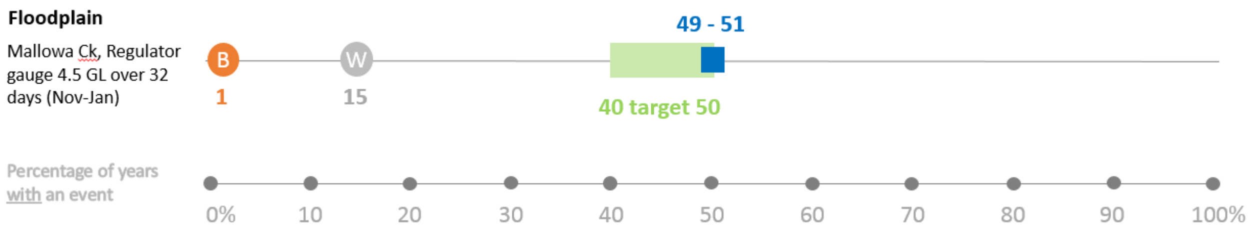
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
91*	84	84	84	87	87	86	86	84	85

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Mallowa Creek (Regulator gauge) 5.4 GL floodplain flow event happens more often than under without development conditions (91% compared to 17% of years with the event). The frequencies at which these flows are proposed exceed those that occurred under modelled without-development conditions. This is because the proposed flow indicators aim to deliver the required volume of water within the limits of regulated flow delivery, requiring a relatively low flow to be delivered over a long period of time. Under without-development conditions flows would have been more 'flashy' with high flow rates for short periods of time. Owing to regulation of the watercourses, and adjacent agricultural land development, it is no longer possible to deliver flows in this pattern. The target range is for this flow event to occur, on average, 91% of years (the same as baseline condition)
- The modelled water recovery scenarios result in a decrease in the frequency of events from baseline (to between 84-87% of years depending on scenario). The 345 GL and 320 GL C scenarios result in the highest frequency result; while the 278 GL and 320 GL A scenarios result in the lowest frequency. The 345 GL and 320 GL C scenarios would result in the highest likelihood that the remaining lignum, coolibah and river red gum communities would maintain health and vigour; however there would remain risk to these species and communities particularly during prolonged dry periods.

G9. Gwydir Wetland riparian-floodplain flows – 4.5 GL total volume on Mallowa Creek, measured at the Regulator gauge, over a 32 day period, between November and January. The frequency target is to have the flow event occur between 40-50% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
1	50*	50*	50*	49*	49*	50*	50*	51*	49

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Mallowa Creek (Regulator gauge) 4.5 GL floodplain flow event happens less often than under without development conditions (1% compared to 15% of years with the event). The frequencies at which these flows are proposed (40-50%) exceed those that occurred under modelled without-development conditions. This is because the proposed flow indicators aim to deliver the required volume of water within the limits of regulated flow delivery, requiring a relatively low flow to be delivered over a long period of time. Under without-development conditions flows would have been more 'flashy' with high flow rates for short periods of time. Owing to regulation of the watercourses, and adjacent agricultural land development, it is no longer possible to deliver flows in this pattern.
- The target range (40-50% of years) is targeted to ensure that the remaining river cooba – lignum, and coolibah/river red gum are maintained in healthy, resilient and dynamic condition by providing flows in the hotter summer months.
- The modelled water recovery scenarios result in an increase in the frequency of events from baseline and above without development conditions (to between 49-51% of years depending on scenario). The 390 GL B scenario results in the highest frequency result (51%); however all scenarios reach the target range.
- The achievement of the target means that the Mallowa Creek system's remaining river cooba – lignum, and coolibah/river red gum will receive follow up watering to mitigate the drying effects of the hot summer months. However, the outcomes of this remain unclear due to the shortfall in frequency of the initial flow indictor of 5.4 GL (described above). Regardless, there is likely to be very little difference between scenarios.

Macquarie Marshes Flow Indicators

There are four flow indicators specified for the Macquarie Marshes. They are four floodplain and wetland connectivity flow indicators only (and their sub-components) as shown in Figure 42 below; and all of which are based on information from the original assessment undertaken to develop indicators.

The environmental assessment outlined below relies on the scientific information found in the Macquarie Marshes Environmental Water Requirements Report. This report also describes the rationale underpinning the flow indicators.

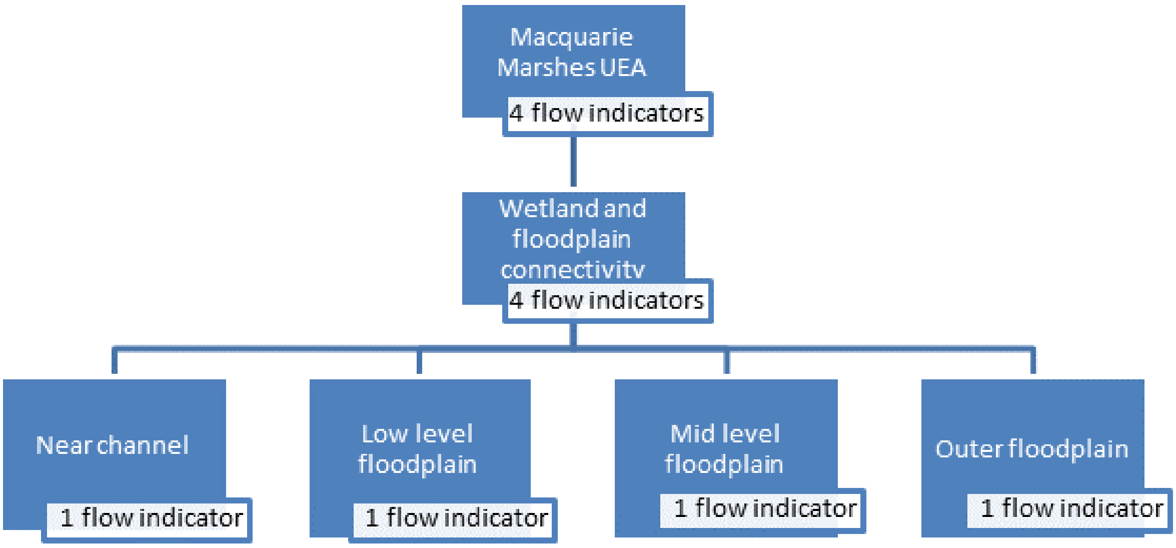
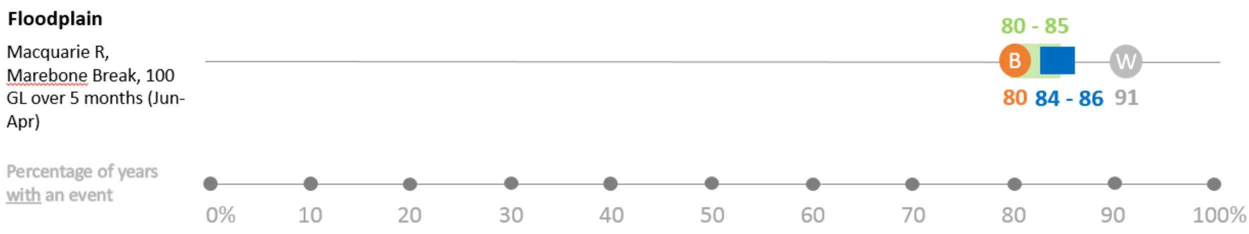


Figure 42: Breakdown of Macquarie Marshes flow indicators into flow component groups and sub-groups

Wetland and floodplain connectivity

The wetland and floodplain connectivity flow indicators scale up in volume in order to inundate an increasingly larger portion of the Macquarie Marshes. As the volume increases, the frequency target range gets smaller and smaller.

M1. Macquarie Marshes riparian-floodplain flows – 100 GL total volume on the Macquarie River, measured at Marebone Break gauge, over a five month period, between June and April. The frequency target is to have the flow event occur between 80-85% of years.



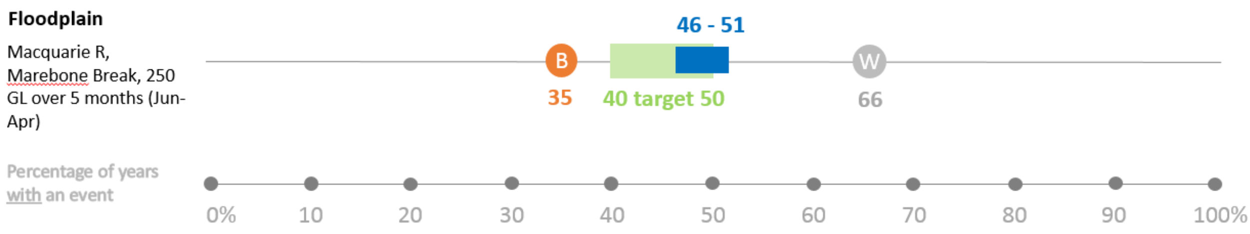
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
80*	85*	85*	84*	82*	85*	85*	85*	85*	86*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Macquarie River (Marebone Break) 100 GL floodplain flow event happens less often than under without development conditions (80% compared to 91% of years with an event). The target range is for this flow event to occur, on average, 80-85% of years and is based on the watering requirements of near channel floodplain key vegetation species.
- The modelled water recovery scenarios result in improvement in increasing the frequency of events (between 82-86% of years, depending on scenario).
- All scenarios reach the target range, with the 415 GL scenario achieving the greatest increase in frequency (86% of years). The highest risk scenario is 320 GL C scenario (82% of years), though it still falls well within the target range and is considered to be very low risk. The 320 GL C scenario has the lowest increase in frequency due to the lower comparative volume of water recovered from the Macquarie–Castlereagh.
- This flow indicator (regardless of scenario) will likely result in the regular inundation of approximately 19,000 ha of floodplain. The ecological outcomes of this are likely to be the maintenance of the semi-permanent wetlands and lower elevation vegetation communities (including some river red gum forest), particularly under the 415 GL scenario. These flows are also expected to provide outcomes to support life-cycle and habitat requirements of native fish including opportunities for increased movement and access to food sources.

M2. Macquarie Marshes inner-floodplain flows – 250 GL total volume on the Macquarie River, measured at Marebone Break gauge, over a five month period, between June and April. The frequency target is to have the flow event occur between 40-50% of years.



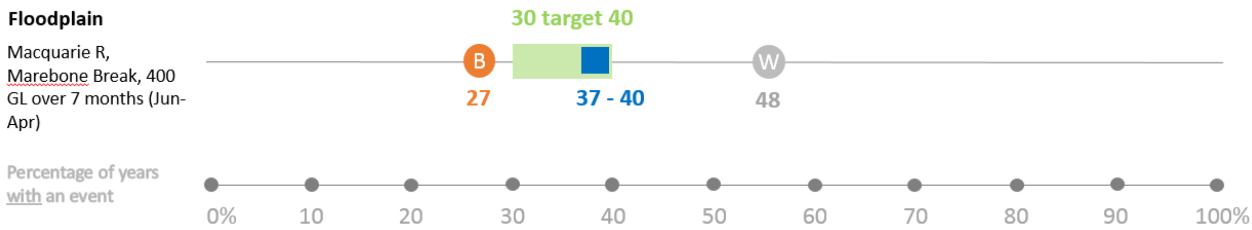
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
35	**48***	**48***	**51***	**46***	**46***	**48***	**48***	**49***	**50***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Macquarie River (Marebone Break) 250 GL floodplain flow event happens less often than under without development conditions (35% compared to 66% of years with the event). The target range is for this flow event to occur, on average, 40-50% of years and is based on the watering requirements of low-level floodplain key vegetation species.
- The modelled water recovery scenarios result in an improvement in the frequency of events (between 46-51% of years, depending on scenario).
- All scenarios reach the target range with the 320 GL B resulting in the greatest increases in frequency (51% of years). The highest risk scenarios are the 345 GL and 320 GL C scenarios (46% of years), though they still fall well within the target range and are considered to be very low risk.
- This flow indicator will result in the inundation of approximately 50,000 ha of floodplain. The ecological outcomes of this are likely to be the maintenance of a larger proportion of the marshes (beyond that inundated by the 100 GL flow indicator), including the majority of river red gum forest and wetland communities, particularly under the 320 GL B scenario. These flows are also expected to provide outcomes to support life-cycle and habitat requirements of waterbirds and native fish including provision of cues for spawning and movement and access to food sources.

M3. Macquarie Marshes riparian-floodplain flows – 400 GL total volume on the Macquarie River, measured at Marebone Break gauge, over a seven month period, between June and April. The frequency target is to have the flow event occur between 30-40% of years.



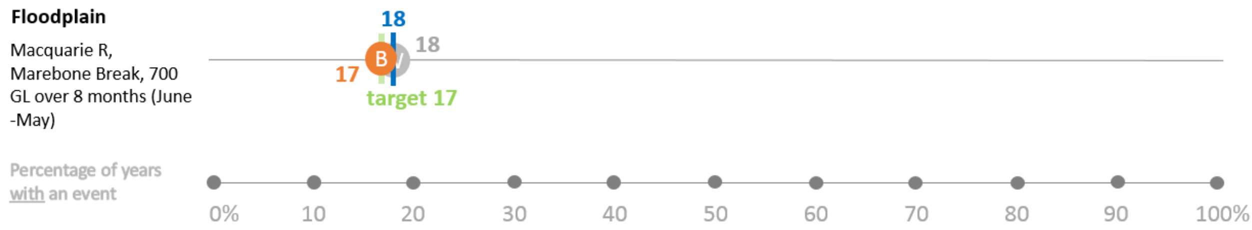
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
27	**37***	**37***	**38***	**34***	**37***	**37***	**37***	**40***	**39***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Macquarie River (Marebone Break) 400 GL floodplain flow event happens less often than under without development conditions (27% compared to 48% of years with the event). The target range is for this flow event to occur, on average, 30-40% of years and is based on the watering requirements of key vegetation species.
- The modelled water recovery scenarios result in an improvement in the frequency of events (between 37-40% of years, depending on scenario).
- All scenarios reach the target range with the 415 GL scenario resulting in the greatest increases in frequency (39% of years) (The 390 GL B results in 40% of years, and is discussed separately in the main body of the report).
- This flow indicator will result in the inundation of approximately 80,000 ha of floodplain. The resulting ecological outcomes are the regular watering of the broader Marshes, including woodland communities, at a frequency that will maintain health across a variety of vegetation species and communities. These flow events are also likely to result in condition that favour larger waterbird breeding events and are expected to provide outcomes to support life-cycle and habitat requirements of native fish including increased opportunities for movement and access to food sources.

M4. Macquarie Marshes riparian-floodplain flows – 700 GL total volume on the Macquarie River, measured at Marebone Break gauge, over an eight month period, between June and May. The frequency target is to have the flow event occur between 17% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
17	**18***	**18***	**18***	**18***	**18***	**18***	**18***	**18***	**18***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Macquarie River (Marebone Break) 700 GL floodplain flow event happens less often than under without development conditions (17% compared to 18% of years with the event). The target range is for this flow event to occur, on average, 17% of years, and is based on the watering requirements of outer floodplain key vegetation species.
- The modelled water recovery scenarios result in a very small improvement in increasing the frequency of events (to 18% of years, with all scenarios resulting in the same frequency).
- All scenarios reach the target range and there is no difference in their capacity increase the average frequency of this flow event.
- This flow indicator will result in the inundation of approximately 145,000 ha of floodplain. The resulting ecological outcomes are the regular watering of the broader Marshes, including woodland communities, at a frequency that will maintain health across a variety of vegetation species and communities. These flow events are also likely to result in condition that favour larger waterbird breeding events and are expected to provide outcomes to support life-cycle and habitat requirements of native fish including increased opportunities for movement and access to food sources.

Namoi River Flow Indicators

There are three flow indicators specified for the Namoi River. They are two in-channel indicator and one floodplain and wetland connectivity flow indicator as shown in Figure 43 below. These are based on information from the original assessment undertaken to develop indicators

The environmental assessment outlined below relies on the scientific information found in the Lower Namoi Environmental Water Requirements Report. This report also describes the rationale underpinning the flow indicators.

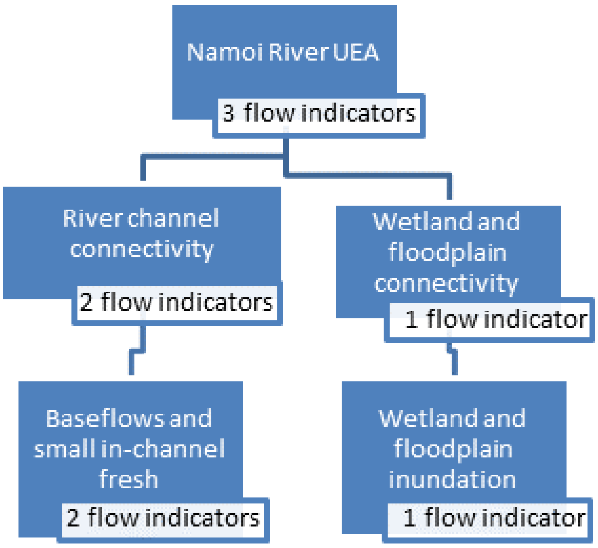
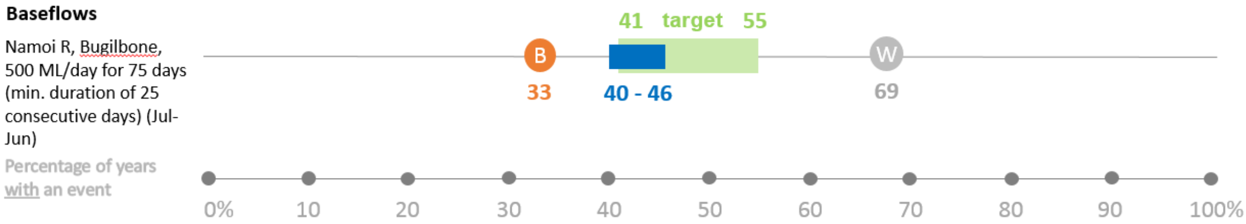


Figure 43: Breakdown of Namoi River flow indicators into flow component groups and sub-groups

Provision of river-channel connectivity flows

There are two in-channel flow indicators identified for the Namoi River (a baseflow and a small in-channel fresh). These flows target longitudinal connectivity, nutrient cycling and native fish (and other aquatic biota).

N1. Namoi River base flows – 500 ML/day on the Namoi River, measured at Bugilbone gauge, for a minimum of 75 days, any time of year. The frequency target is to have the flow event occur between 41-55% of years.



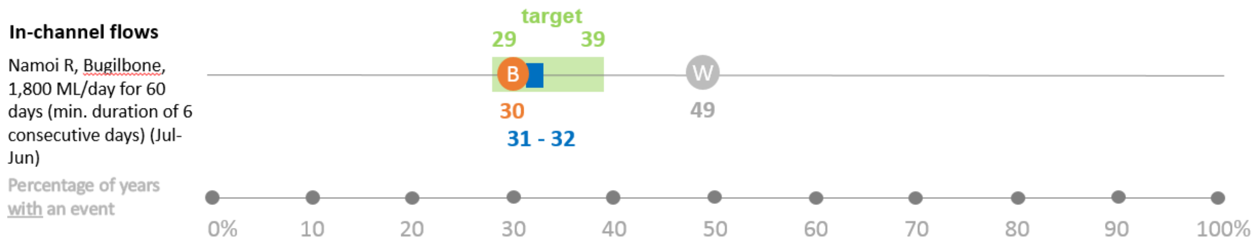
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
33	40	**45***	**45***	**45***	**46***	**46***	**46***	**43***	**45***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Namoi River (Bugilbone) 500 ML/d baseflow event happens less often than under without development conditions (33% compared to 69% of years with an event). The target range is for this flow event to occur, on average, 41-55% of years.
- The modelled water recovery scenarios result in an improvement in the frequency of events (between 40-46% of years, depending on scenario).
- All scenarios except the 278 GL reach the target range, with the 345, 350 GL and 390 GL scenarios achieving the greatest increase in frequency (46% of years). The highest risk scenario is the 278 GL (40% of years).
- The 345, 350 GL and 390 GL scenarios provide the greatest likelihood that healthy river pools will be maintained and in turn will provide greater habitat availability by wetting banks and bars present at low levels in the river channel.
- The 278 GL just misses the target range, and therefore has the greatest risk that river pools will not receive sufficiently regular baseflows, which may then lead to a reduction in habitat availability for native fish species and other biota.

N2. Namoi River in-channel flows – 1,800 ML/day on the Namoi River, measured at Bugilbone gauge, for a minimum of 6 days, any time of year. The frequency target is to have the flow event occur between 29-39% of years.



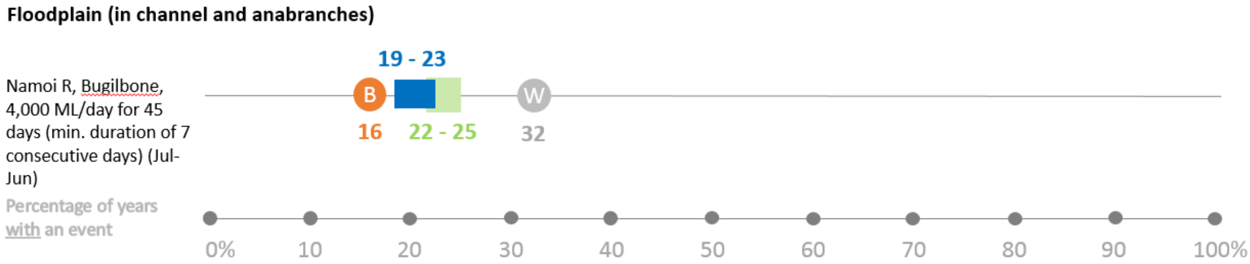
Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
30*	32*	32*	32*	32*	32*	32*	32*	31*	32*

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Namoi River (Bugilbone) 1,800 ML/d river channel flow event happens less often than under without development conditions (30% compared to 49% of years with an event). The target range is for this flow event to occur, on average, 29-39% of years (which encompasses the baseline frequency).
- The modelled water recovery scenarios result in a very minor improvement in increasing the frequency of events (between 31-32% of years, depending on scenario); however, they all fall within the target range.
- All scenarios perform very similarly. Under all scenarios ecosystem function (e.g. through nutrient cycling) and increased habitat availability (by wetting banks and benches present in the river channel) is likely to be protected and maintained.

N3. Namoi River floodplain flows – 4,000 ML/day on the Namoi River, measured at Bugilbone gauge, for a minimum of 45 days (minimum duration of 7 consecutive days), any time of year. The frequency target is to have the flow event occur between 22-25% of years.



Baseline	278 GL (recovery at Dec 2015)	320 GL A (volume below Basin Plan)	320 GL B (pro rata)	320 GL C (refined)	345 GL (refined)	350 GL (targeted recovery)	390 GL A (fully implemented Basin Plan)	390 GL B (current river ops)	415 GL (above Basin Plan)
16	19	**22***	**22***	**22***	**22***	**22***	**22***	**23***	**22***

* Denotes that the target range was met

The 390 GL fully implemented Basin Plan is the legislated water recovery target that is under review

- Under baseline conditions (2009 levels of development before water recovery), the Namoi River (Bugilbone) 4,000 ML/d floodplain flow event happens less often than under without development conditions (16% compared to 32% of years with an event). The target range is for this flow event to occur, on average, 22-25% of years.
- The modelled water recovery scenarios result in an improvement in increasing the frequency of events (between 19-23% of years, depending on scenario).
- All scenarios except the 278 GL reach the target range, with other scenarios performing equally well (22%). (The results of the 390 GL B is discussed in separately in the main body of the report). The highest risk scenario is the 278 GL scenario (19% of years).
- The ecological consequence of all scenarios except the 278 GL is that the requirements of key water dependent vegetation communities are likely to be met.
- The 278 GL scenario would present the greatest risk to key water dependent vegetation communities as the target range is not met, though improvement from baseline would occur.

Appendix D —Site-specific flow indicator frequency results

Table 29: Flow indicator frequency results for each water recovery scenarios

SFI ID	Flow event	Low uncertainty target range	High uncertainty target range	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
CB 1	2 ML/d for 1 day any time of the year at Weilmoringle on the Culgoa River (refuges) (frequency results shown as average number of days of top 10% of dry spells)	350	430	247	451	447	445	447	448	445	448	447	447	447
CB 2	2 ML/d for 1 day any time of the year at Narran Park on the Narran River (refuges) (frequency results shown as average number of days of top 10% of dry spells)	350	470	349	542	550	534	533	539	540	540	539	539	539
CB 3	1,000 ML/d for 7 days any time of the year at Brenda on the Culgoa River (small fresh) (frequency results shown as percent of years with at least one event)	90	80	98	74	75	75	75	75	75	75	75	75	75
CB 4	1,700 ML/d for 14 days between Aug and May at Wilby Wilby on the Narran River (large fresh) (frequency results shown as percent of years with at least one event)	60	40	61	25	31	37	40	40	39	40	39	39	40
CB 5	3,500 ML/d for 14 days between Aug and May at Brenda on the Culgoa River (large fresh) (frequency results shown as percent of years with at least one event)	60	40	68	30	42	43	46	44	45	41	46	46	46
CB 6	9,200 ML/d for 12 days any time of the year at Brenda on the Culgoa River (riparian zone) (frequency results shown as the average period in years between events)	2	3	1.3	5.6	4.0	4.0	3.7	3.9	3.9	3.6	3.5	3.5	3.4
CB 7	15,000 ML/d for 10 days any time of the year at Brenda on the Culgoa River (inner floodplain) (frequency results shown as the average period in years between events)	3	4	1.9	7.1	6.3	6.3	6.3	6.3	6.3	6.0	5.4	5.4	5.4
CB 8	24,500 ML/d for 7 days any time of the year at Brenda on the Culgoa River (middle floodplain) (frequency results shown as the average period in years between events)	6	8	3.5	8.7	7.6	7.6	8.1	7.1	7.6	8.1	7.6	7.6	7.6

SFI ID	Flow event	Low uncertainty target range	High uncertainty target range	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
CB 9	38,000 ML/d for 6 days any time of the year at Brenda on the Culgoa River (outer floodplain) (frequency results shown as the average period in years between events)	10	20	9.5	28.5	38.0	38.0	22.8	22.8	28.5	22.8	19.0	19.0	16.3
NL 1	25 GL inflow over 60 days any time of the year at Wilby Wilby on the Narran River (waterbird breeding habitat) (frequency results shown as the average period in years between events)	1	1.3	0.6	1.3	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
NL 2	50 GL inflow over 90 days any time of the year at Wilby Wilby on the Narran River (waterbird breeding and foraging habitat) (frequency results shown as the average period in years between events)	1.3	1.7	0.8	2.0	1.7	1.5	1.4	1.4	1.5	1.4	1.4	1.4	1.4
NL 3	250 GL inflow over 180 days any time of the year at Wilby Wilby on the Narran River (outer floodplain) (frequency results shown as the average period in years between events)	8	10	5.3	13.8	12.2	11.0	9.1	9.1	11.0	10.0	11.0	11.0	9.9
NL 4	154 GL inflow over 90 days any time of the year at Wilby Wilby on the Narran River (waterbird breeding) (frequency results shown as the average period in years between events)	4	5	2.6	8.3	7.2	6.7	6.3	6.3	7.2	6.3	6.7	6.7	6.3
BD 01	6,000 ML/d for 14 days any time of the year at Bourke on the Darling River (small fresh) (frequency results shown as percent of years with at least one event)	90	80	96	66	78	80	80	80	82	82	82	75	82
BD 04	10,000 ML/d for 14 days between Aug and May at Bourke on the Darling River (large fresh – fish movement) (frequency results shown as percent of years with at least one event)	80	60	89	54	59	59	59	58	59	59	59	57	60
BD05	Two events of 10,000 ML/d for 20 days between Aug and May at Bourke on the Darling River (large fresh – fish breeding) (frequency results shown as percent of years with at least one event)	35	25	42	20	23	22	23	22	22	23	22	22	22

SFI ID	Flow event	Low uncertainty target range	High uncertainty target range	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
BD 08	30,000 ML/d for 24 days any time of the year at Bourke on the Darling River (riparian zone)	2	3	1.8	4.1	3.9	3.8	3.9	3.9	3.9	3.8	3.8	3.9	3.8
BD09	45,000 ML/d for 22 days any time of the year at Bourke on the Darling River (inner floodplain)	3.5	4	3.4	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
BD 10	65,000 ML/d for 24 days any time of the year at Bourke on the Darling River (middle floodplain)	6	8	5.6	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
BD 02	6,000 ML/d for 20 days between Aug and May at Louth on the Darling River (small fresh – long duration) (frequency results shown as percent of years with at least one event)	70	70	91	58	61	61	63	62	63	63	63	63	63
BD 06	21,000 ML/d for 20 days between Aug and May at Louth on the Darling River (large fresh – long duration) (frequency results shown as percent of years with at least one event)	40	40	54	32	32	32	32	32	32	32	32	32	32
BD03	6,000 ML/d for 7 days any time of the year at Wilcannia on the Darling River (small fresh - short duration) (frequency results shown as percent of years with at least one event)	60	45	77	42	46	46	46	48	49	46	48	49	50
BD 07	20,000 ML/d for 7 days any time of the year at Wilcannia on the Darling River (large fresh – short duration) (frequency results shown as percent of years with at least one event)	60	45	70	39	42	45	45	45	45	45	45	44	45
BD 11	Annual flow volume of 2,350 GL measured when flow is above 30,000 ML/d at Wilcannia on the Darling River (outer floodplain) (frequency results shown as percent of years with at least one event)	10	7	11	7	7	7	7	7	7	7	7	7	7
BR 1	4,000 ML/d for 5 days between Oct and Dec at Mungindi on the Barwon River (fresh – fish breeding) (frequency results shown as percent of years with at least one event)	31	23	39	17	18	22	20	20	22	22	22	22	22
BR 2	4,000 ML/d for 5 days between Oct and March at Mungindi on the	59	44	74	33	35	37	37	37	39	38	38	36	39

SFI ID	Flow event	Low uncertainty target range	High uncertainty target range	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
	Barwon River (fresh – fish breeding longer season) (frequency results shown as percent of years with at least one event)													
BR 3	Two 4,000 ML/d for 11 days events any time of the year at Mungindi on the Barwon River (fresh – productivity) (frequency results shown as percent of years with at least one event)	34	25	42	14	14	17	15	79	16	16	18	18	18
G1	150 ML/d for 45 days between Oct and Jan at Yarraman Bridge on the Gwydir River (baseflow – fish movement and breeding) (frequency results shown as percent of years with at least one event)	85	85	38	81	79	79	80	84	79	80	80	77	80
G2	1,000 ML/d for 2 days between Oct and Jan at Yarraman Bridge on the Gwydir River (fresh – cue for fish movement and breeding) (frequency results shown as percent of years with at least one event)	85	85	89	85	84	84	84	82	84	84	84	85	84
G3	45 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (frequency results shown as percent of years with at least one event)	85	85	64	83	82	82	82	75	82	82	82	81	82
G4	60 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (frequency results shown as percent of years with at least one event)	90	80	67	70	75	75	75	61	75	75	75	74	75
G5	80 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (frequency results shown as percent of years with at least one event)	70	60	57	63	62	62	62	47	61	61	61	62	60
G6	150 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (frequency results shown as percent of years with at least one event)	50	40	50	46	46	46	47	25	47	47	47	46	46

SFI ID	Flow event	Low uncertainty target range	High uncertainty target range	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
G7	250 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (frequency results shown as percent of years with at least one event)	30	20	29	20	25	25	25	14	25	25	25	25	25
G8	5.4 GL inflow over 120 days between Feb and Mar and between Aug and Sep at the Mallowa Creek regulator – targeting 50 ML/d during these periods (riparian veg) (frequency results shown as percent of years with at least one event)	12	12	14	11	14	14	14	79	14	15	15	14	15
G9	4.5 GL inflow over 92 days between Nov and Jan at the Mallowa Creek regulator – targeting 50 ML/d during this periods (riparian vegetation) (frequency results shown as percent of years with at least one event)	91	91	17	83	84	84	84	87	87	86	86	84	85
N1	500 ML/d for 75 days (events with min duration of 25 days included) any time of the year at Bugilbone on the Namoi River (baseflow) (frequency results shown as percent of years with at least one event)	50	40	15	1	50	50	50	49	49	50	50	51	49
N2	1,800 ML/d for 60 days (events with min duration of 6 days included) any time of the year at Bugilbone on the Namoi River (freshes) (frequency results shown as percent of years with at least one event)	55	41	69	33	40	45	45	45	46	46	46	43	45
N3	4,000 ML/d for 45 days (events with min duration of 7 days included) any time of the year at Bugilbone on the Namoi River (riparian veg) (frequency results shown as percent of years with at least one event)	39	29	49	30	32	32	32	32	32	32	32	31	32
M1	100 GL inflow over 5 months between Jun and Apr at Marebone Break on the Macquarie River River (wetlands) (frequency results shown as percent of years with at least one event)	25	22	32	16	19	22	22	22	22	22	22	23	22

SFI ID	Flow event	Low uncertainty target range	High uncertainty target range	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
M2	250 GL inflow over 5 months between June and Apr at Marebone Break on the Macquarie River (wetlands) (frequency results shown as percent of years with at least one event)	85	80	91	80	85	85	84	82	85	85	85	85	86
M3	400 GL inflow over 7 months between June and Apr at Marebone Break on the Macquarie River (wetlands) (frequency results shown as percent of years with at least one event)	50	40	66	35	48	48	51	46	46	48	48	49	50
M4	700 GL inflow over 8 months between Jun and May at Marebone Break on the Macquarie River (wetlands) (frequency results shown as percent of years with at least one event)	40	30	48	27	37	37	38	34	37	37	37	40	39

Appendix E — Site-specific flow indicator spells analysis

Table 30: Number of events over the 114 year modelled period. Note not all indicators have been analysed using this technique.

SFI ID	Flow event	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
CB 3	1,000 ML/d for 7 days any time of the year at Brenda on the Culgoa River (small fresh)	336	185	185	188	188	186	186	186	186	186	188
CB 4	1,700 ML/d for 14 days between Aug and May at Wilby Wilby on the Narran River (large fresh)	105	41	48	58	63	63	62	62	62	62	63
CB 5	3,500 ML/d for 14 days between Aug and May at Brenda on the Culgoa River (large fresh)	125	45	62	64	67	64	66	60	68	68	69
CB 6	9,200 ML/d for 12 days any time of the year at Brenda on the Culgoa River (riparian zone)	83	19	24	24	29	28	28	30	31	31	32
CB 7	15,000 ML/d for 10 days any time of the year at Brenda on the Culgoa River (inner floodplain)	57	15	17	17	17	17	17	18	20	20	20
CB 8	24,500 ML/d for 7 days any time of the year at Brenda on the Culgoa River (middle floodplain)	31	12	14	14	13	15	14	13	14	14	14
CB 9	38,000 ML/d for 6 days any time of the year at Brenda on the Culgoa River (outer floodplain)	11	3	2	2	4	4	3	4	5	5	6
NL 1	25 GL inflow over 60 days any time of the year at Wilby Wilby on the Narran River (waterbird breeding habitat)	129	71	79	88	90	89	88	88	89	89	92
NL 2	50 GL inflow over 90 days any time of the year at Wilby Wilby on the Narran River (waterbird breeding and foraging habitat)	102	48	57	63	68	68	65	68	68	68	68
NL 3	250 GL inflow over 180 days any time of the year at Wilby Wilby on the Narran River (outer floodplain)	19	7	8	9	11	11	9	10	9	9	10
BD 08	30,000 ML/d for 24 days any time of the year at Bourke on the Darling River (riparian zone)	58	26	27	28	27	27	27	28	28	27	28
BD09	45,000 ML/d for 22 days any time of the year at Bourke on the Darling River (inner floodplain)	31	21	21	21	21	21	21	21	21	21	21
BD 10	65,000 ML/d for 24 days any time of the year at Bourke on the Darling River (middle floodplain)	19	12	12	12	12	12	12	12	12	12	12

Table 31: Maximum dry period over the 114 year modelled period. Note not all indicators have been analysed using this technique

SFI ID	Flow event	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
CB 1	2 ML/d for 1 day any time of the year at Weilmoringle on the Culgoa River (refuges) (days)	397	712	685	685	NA	NA	684	685	685	685	685
CB 2	2 ML/d for 1 day any time of the year at Narran Park on the Narran River (refuges) (days)	624	866	862	781	NA	NA	738	854	858	858	
CB 3	1,000 ML/d for 7 days any time of the year at Brenda on the Culgoa River (small fresh) (years)	1.7	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
CB 4	1,700 ML/d for 14 days between Aug and May at Wilby Wilby on the Narran River (large fresh) (years)	5.7	12.7	10.1	10.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0
CB 5	3,500 ML/d for 14 days between Aug and May at Brenda on the Culgoa River (large fresh) (years)	4.4	10.8	10.1	8.0	7.6	10.1	8.0	10.1	7.7	7.7	7.7
CB 6	9,200 ML/d for 12 days any time of the year at Brenda on the Culgoa River (riparian zone) (years)	5.3	28.5	28.5	28.5	19.2	19.2	28.5	19.2	19.2	19.2	19.2
CB 7	15,000 ML/d for 10 days any time of the year at Brenda on the Culgoa River (inner floodplain) (years)	8.9	55.1	55.1	55.1	55.1	55.1	55.1	55.1	28.5	28.5	28.5
CB 8	24,500 ML/d for 7 days any time of the year at Brenda on the Culgoa River (middle floodplain) (years)	10.9	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1
CB 9	38,000 ML/d for 6 days any time of the year at Brenda on the Culgoa River (outer floodplain) (years)	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1
NL 1	25 GL inflow over 60 days any time of the year at Wilby Wilby on the Narran River (waterbird breeding habitat) (years)	3.1	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
NL 2	50 GL inflow over 90 days any time of the year at Wilby Wilby on the Narran River (waterbird breeding and foraging habitat) (years)	3.2	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
NL 3	250 GL inflow over 180 days any time of the year at Wilby Wilby on the Narran River (outer floodplain) (years)	54.7	54.7	54.7	54.7	54.7	54.7	54.7	54.7	54.7	54.7	54.7
NL 4	154 GL inflow over 90 days any time of the year at Wilby Wilby on the Narran River (waterbird breeding) (years)	10.9	29.7	29.7	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2
BD 01	6,000 ML/d for 14 days any time of the year at Bourke on the Darling River (small fresh) (years)	1	2	2	2	2	2	2	2	2	2	2
BD 04	10,000 ML/d for 14 days between Aug and May at Bourke on the Darling River (large fresh – fish movement) (years)	2	5	3	3	3	3	3	3	3	5	3

SFI ID	Flow event	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
BD05	Two events of 10,000 ML/d for 20 days between Aug and May at Bourke on the Darling River (large fresh – fish breeding) (years)	6	11	9	9	9	9	9	9	9	9	9
BD 08	30,000 ML/d for 24 days any time of the year at Bourke on the Darling River (riparian zone) (years)	9.4	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
BD09	45,000 ML/d for 22 days any time of the year at Bourke on the Darling River (inner floodplain) (years)	14.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6
BD 10	65,000 ML/d for 24 days any time of the year at Bourke on the Darling River (middle floodplain) (years)	18.7	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9
BD 02	6,000 ML/d for 20 days between Aug and May at Louth on the Darling River (small fresh – long duration) (years)	1	3	3	3	3	3	3	3	3	3	3
BD 06	21,000 ML/d for 20 days between Aug and May at Louth on the Darling River (large fresh – long duration) (years)	4	11	11	10	10	10	10	10	10	10	11
BD03	6,000 ML/d for 7 days any time of the year at Wilcannia on the Darling River (small fresh - short duration) (years)	4	7	7	7	7	7	7	7	7	5	5
BD 07	20,000 ML/d for 7 days any time of the year at Wilcannia on the Darling River (large fresh – short duration) (years)	3	7	7	7	7	7	7	7	7	7	7
BD 11	Annual flow volume of 2,350 GL measured when flow is above 30,000 ML/d at Wilcannia on the Darling River (outer floodplain) (years)	28	28	28	28	28	28	28	28	28	28	28
BR 1	4,000 ML/d for 5 days between Oct and Dec at Mungindi on the Barwon River (fresh – fish breeding) (years)	6	13	13	13	13	13	13	13	13	13	13
BR 2	4,000 ML/d for 5 days between Oct and March at Mungindi on the Barwon River (fresh – fish breeding longer season) (years)	5	7	7	7	6	NA	7	6	7	7	5
BR 3	Two 4,000 ML/d for 11 days events any time of the year at Mungindi on the Barwon River (fresh – productivity) (years)	7	28	28	28	28	NA	21	21	21	15	21
G1	150 ML/d for 45 days between Oct and Jan at Yarraman Bridge on the Gwydir River (baseflow – fish movement and breeding) (years)	11	4	4	4	4	4	4	4	4	4	4
G2	1,000 ML/d for 2 days between Oct and Jan at Yarraman Bridge on the Gwydir River (fresh – cue for fish movement and breeding) (years)	2	3	3	3	3	3	3	3	3	3	3

Environmental Outcomes of the Northern Basin Review

SFI ID	Flow event	Without Dev.	B/L	278 GL	320 GL A	320 GL B	320 GL C	345 GL	350 GL	390 GL A	390 GL B	415 GL
G3	45 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (years)	6	4	4	4	4	4	4	4	4	4	4
G4	60 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (years)	6	5	4	4	4	4	7	4	4	7	4
G5	80 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (years)	6	8	7	7	7	7	7	7	7	7	7
G6	150 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (years)	11	12	12	12	12	12	12	12	12	12	12
G7	250 GL inflow over 60 days between Oct and Mar at Yarraman Bridge on the Gwydir River (wetlands) (years)	29	32	32	32	32	32	32	31	31	32	31
N1	500 ML/d for 75 days (events with min duration of 25 days included) any time of the year at Bugilbone on the Namoi River (baseflow) (years)	8	13	8	8	8	8	8	8	8	8	8
N2	1,800 ML/d for 60 days (events with min duration of 6 days included) any time of the year at Bugilbone on the Namoi River (freshes) (years)	8	12	12	12	12	12	12	12	12	12	12
N3	4,000 ML/d for 45 days (events with min duration of 7 days included) any time of the year at Bugilbone on the Namoi River (riparian veg) (years)	10	17	14	14	14	14	14	14	14	14	14
M1	100 GL inflow over 5 months between Jun and Apr at Marebone Break on the Macquarie River River (wetlands) (years)	1	2	2	2	2	2	2	2	2	2	2
M2	250 GL inflow over 5 months between June and Apr at Marebone Break on the Macquarie River (wetlands) (years)	3	8	8	8	7	NA	8	8	8	7	8
M3	400 GL inflow over 7 months between June and Apr at Marebone Break on the Macquarie River (wetlands) (years)	7	15	11	11	10		11	11	11	8	10
M4	700 GL inflow over 8 months between Jun and May at Marebone Break on the Macquarie River (wetlands) (years)	21	21	21	21	21	21	21	21	21	21	21