Department of Climate Change, Energy, the Environment and Water

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DRAFT: Hydrologic analysis of options for the Western Regional Water Strategy

Regional Water Strategies Program

May 2024

Acknowledgement of Country

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

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Executive Summary

The NSW Government is developing 12 regional water strategies that bring together the best and latest climate evidence, with a wide range of tools and solutions to plan and manage each region's water needs over the next 20 to 40 years. The Western Regional Water Strategy is one of 12 strategies being developed across NSW to meet this commitment.

The draft Western Regional Water Strategy, including a long list of options, was released in June 2022.[1]

This report provides the outcomes of hydrological assessment that was undertaken to understand the impact of options on existing water supply risks to water users in the catchment, as well as to feed into the economic assessment of options.

Assessment of water security and changes in flow regime in the Barwon-Darling valley were undertaken for two climatic regimes:

- historic climate – this data includes both observed streamflow data and simulated rainfall runoff data from (1895 – 2020)
- instrumental climate – this data includes the period of available instrumental meteorological recordings for the catchment (1895–2020)

Assessment of changes in flows regime in the Lower Darling valley were undertaken for the historic climate period of 1895 - 2020.

Stage 1 of the modelling program for the Barwon-Darling River system and the major regulated tributary rivers investigated a base case and a number of preliminary analyses to understand the scale of potential benefits of key measures such as restrictions to water access and additional releases from storages in the regulated tributary rivers. These preliminary analyses are described in Table 1 below.

Stage 2 of the modelling program investigated a range of options identified as part of the Western Regional Water Strategy. For the Barwon-Darling, four options were modelled. Two additional options were assessed by modelling alternate scenarios. For the Lower Darling four options and a base case were modelled (Table 1). All hydrologic and water security assessment modelling was undertaken using the Barwon-Darling Integrated Quantity Quality Model (IQQM), and the Source Murray Model (which includes the Lower Darling River system). The

[1] The draft Western Regional Water Strategy and long list of options can be viewed at, https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/what-we-heard/western-regional-water-strategy

Department of Planning & Environment – Water's IQQM and Source models were developed as a tool for planning and evaluating water resource management policies at the river basin scale (base case model versions are listed in Attachment 1). The end-of-system flow from the IQQM model is used as an input to the Source Murray Model (developed by the MDBA) at the Menindee Lakes.

Table 1. Options assessed using hydrologic modelling for the Western Regional Water Strategy

Category	Description
Base case	Current conditions with floodplain harvesting entitlements[2] in place and held environmental water diverted[3] in regulated rivers in a similar pattern to consumptive water users (as per NSW pre-Basin Plan scenarios).
Barwon-Darling Stage 1 - preliminary analysis	Preliminary analysis to explore potential benefits and impacts of actions to improve connectivity and implement the North-West Unregulated Flow Management Plan. Modelling undertaken using historic climate datasets over periods available for each model.
Stage 1A – preliminary "bookend" analysis	Preliminary modelling analysis to understand the upper limit of possible connectivity benefits from imposing water restrictions in the Barwon-Darling and upstream regulated tributary rivers. This identifies years where restrictions would have resulted in flows reaching key thresholds. • Scenario 1: Suspension of all supplementary access in the regulated tributaries, and A, B, and C Class access in the Barwon-Darling. • Scenario 2: Suspension of all non-exempt[4] floodplain harvesting. • Scenario 3: Suspension of all supplementary access and non-exempt floodplain harvesting in the regulated tributaries, and A, B, and C class access and non-exempt floodplain harvesting in the Barwon-Darling River system.

[2] For the Barwon-Darling Valley the Current Conditions model scenario was used as the Valley Scale Compliance scenario was not completed until after December 2021. However, the licensing of floodplain harvesting is not intended to reduce access as modelling indicates there is no growth in water use.

[3] For the Barwon-Darling Valley the held environmental water (HEW) is not modelled as being pumped, and water use has been removed at the irrigation sites in the model where the HEW was purchased.

[4] Rainfall-runoff harvesting from areas developed for irrigation that is exempted from licensing requirements under the NSW Floodplain Harvesting Policy has not been suspended.

Category	Description
Stage 1B – preliminary analysis of the use of general security entitlements	Preliminary modelling to understand the potential connectivity benefits from the use of general security entitlements in the regulated tributary rivers.
Stage 1C – preliminary "perfect forecasting" analysis for algal suppression and fish migration	Preliminary modelling to understand the potential benefits and impacts in the Barwon-Darling and upstream regulated tributary rivers from targeted restrictions to achieve algal suppression and fish migration flow targets. These scenarios assume that years where opportunities to meet target flows could be operationally forecasted to avoid restrictions that would not have resulted in successfully meeting target flows.
Stage 2 – options analysis: Barwon-Darling and Lower Darling	Analysis of options for shortlisting in the Western Regional Water Strategy. Instrumental climate datasets used over a standardised period from 1895 – 2020 across all models.
Stage 2A – Option 5: Targeted restrictions for North -West Flow Plan algal and fish outcomes	The Stage 1A bookend and Stage 1C targeted restrictions scenarios were remodelled using instrumental inflows (simulated by rainfall-runoff models with instrumental climate) and an extended climate sequence up to 2020 to include the most recent drought (excl. Macquarie Valley). Two new scenarios were produced: • Option 3: restrictions targeting additional years where the proposed alternate algal dispersal flow event was achieved, • Option 8: restrictions targeting additional years where either of the existing fish passage events at Brewarrina and Bourke were achieved.
Stage 2B – Option 6: Targeted restrictions for critical Menindee storage volumes	Restrictions to B and C Class and upstream supplementary access during critical dry periods, with restrictions linked to water storage levels at Menindee Lakes. Three options were modelled with Menindee Lakes storage triggers for commencing / ceasing restrictions to Barwon-Darling and upstream supplementary access. • Option 6: 195 GL/ 250 GL active storage in upper lakes (Wetherell and Pamamaroo) • Option 6b: 480 GL/640 GL active storage in upper lakes (Wetherell and Pamamaroo) • Option 6c: 195 GL/ 250 GL total storage across all lakes

Category	Description
Stage 2C – Option 46: Replenishment releases from major storages	Modelling of “replenishment” releases from storages in the NSW Border Rivers, Gwydir and Namoi regulated rivers to reduce periods of very low or no flows. The modelled commencement of restrictions in the Barwon-Darling valley under the existing “resumption of flow rule” was used as a trigger for a release of water from the storages, with a release of 20 GL targeted over a three-week period in each valley.
Stage 2D - Continuous flow in the Barwon-Darling	Target releases from storages in Namoi, Gwydir, and Border Rivers to achieve 500 ML/day at Bourke.
Stage 2E - Replenishment releases and Border Rivers inland diversions	Modelling of a combined connectivity option and an option for inland diversions to the Border Rivers that was investigated as part of the NSW Border Rivers Regional Water Strategy. The Border Rivers replenishments scenario (under Option 46) was extended to include a 50 GL/year diversion from the Clarence River (coastal) catchment to the Mole River (Border Rivers tributary).
Stage 2F – Option 47: Changes to Barwon-Darling water access flow thresholds	This option investigates the impacts of changing flow thresholds in the Barwon-Darling River system for B Class and C Class licences to align with the small freshes and large freshes flow classes defined in the Barwon-Darling Long-Term Water Plan.
Lower Darling	
Option 52 – Review how the Menindee Lakes are operated	This option investigates the impacts of applying the 480/640 rule of the Murray Darling Basin Agreement to active storage available to the lower Darling, rather than total storage in the Menindee Lakes.
Option 30 – Review the environmental water allowance for the Lower Darling water source	A desk-top study was undertaken for this option to examine the viability of providing environmental flows to provide mixing of pools in the Lower Darling, thus preventing water column stratification and blue-green algae outbreaks. Under present arrangements such additional flushing flows are not available when the Menindee Lakes are under NSW control per the 480/640 rule.
Option 50 – Deliver water down the Great Darling Anabranch	This option investigates the water resource implications of releasing water from Lake Cawndilla to the Great Darling Anabranch, and hence towards the Murray River, after Lake Cawndilla water levels drop too low to gravitate back to Lake Menindee. One objective of this option is to allow native fish stock to exit the stranded lake prior to desiccation.

Category	Description
Option 50 and Option 6	Option 50 (Deliver water down the Great Darling Anabranch) above, together with Option 6 (Option 6: 195 GL/ 250 GL active storage in upper lakes (Wetherell and Pamamaroo)

1.Introduction

This report outlines the hydrologic modelling undertaken to understand the water supply risks posed by management rule options on water users in the Barwon-Darling and Lower Darling river systems. Hydrologic modelling for the Barwon-Darling unregulated river system was undertaken using the Barwon-Darling Integrated Quantity Quality Model (IQQM) developed by the NSW Department of Planning and Environment - Water, and modelling for Menindee Lakes and the Lower Darling regulated river system was undertaken using the Source Murray Model (SMM) developed by the Murray-Darling Basin Authority.

Hydrological modelling is a key input to the development of the final Western Regional Water Strategy. The modelling provides part of the evidence for the final list of actions included in the Western Regional Water Strategy[5].

Thirteen options and a base case were modelled, five targeting outcomes in the Barwon-Darling and three at Menindee Lakes, four for the Lower Darling, and one for the Border Rivers (inland diversion). A number of initial modelling scenarios (Barwon-Darling stage 1 modelling in Table 2) were used to understand potential benefits and impacts of restrictions to water use and were later used to support the options modelling. Modelling results for each option and scenario are presented in Sections 4 to 16 of this report.

[5] The Western Regional Water Strategy can be accessed at Western Regional Water Strategy | Water (nsw.gov.au)

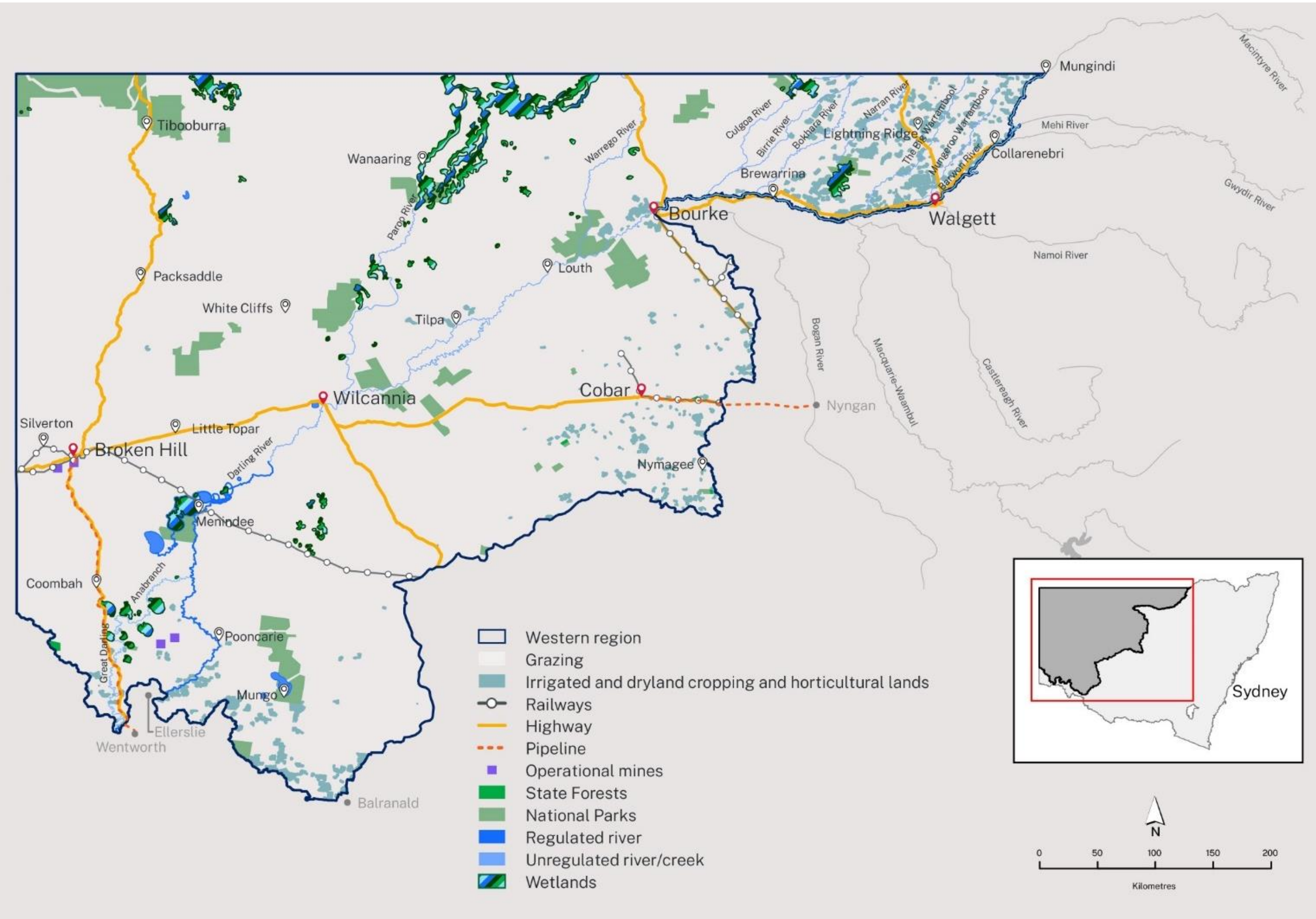
2. Background

Western region

The Western Regional Water Strategy region (Figure 1) is in the far west of NSW and includes the catchments of the Barwon–Darling and Lower Darling rivers, as well as the Intersecting Streams. The region is bounded by the Queensland border to the north, the South Australian border to the west, the catchments of the Border Rivers, Gwydir, Namoi, Macquarie–Castlereagh, Lachlan and Murrumbidgee to the east and the Murray River catchment to the south. The region is vast, flat and low-lying, making up about one-third of the land mass of NSW and covering 275,000 km^2.

The region is home to a small and dispersed population of over 36,600 people. The largest towns are Broken Hill (17,800 people) and Cobar (4,800 people).

Figure 1. Map of the Western Regional Water Strategy area



Water resources in the region

The Western region has significant water features, including multiple interconnected rivers, creeks, lakes, groundwater aquifers and wetlands.

The main river system is the Barwon–Darling River and its tributaries. The Barwon–Darling is one of the most significant unregulated river systems in NSW. The Barwon–Darling River connects the northern and southern parts of the Murray–Darling Basin and receives over 90% of inflows from upstream catchments. This means that the climate, development and water extraction in upstream catchments impacts on the amount of water flowing into the Western region.

The Menindee Lakes storage system consists of 5 main lakes: Wetherell, Tandure, Pamamaroo, Menindee, and Cawndilla (Figure 2). These lakes are the only large public water storage in the Western region and are a critical ecological system for fish breeding and bird life.

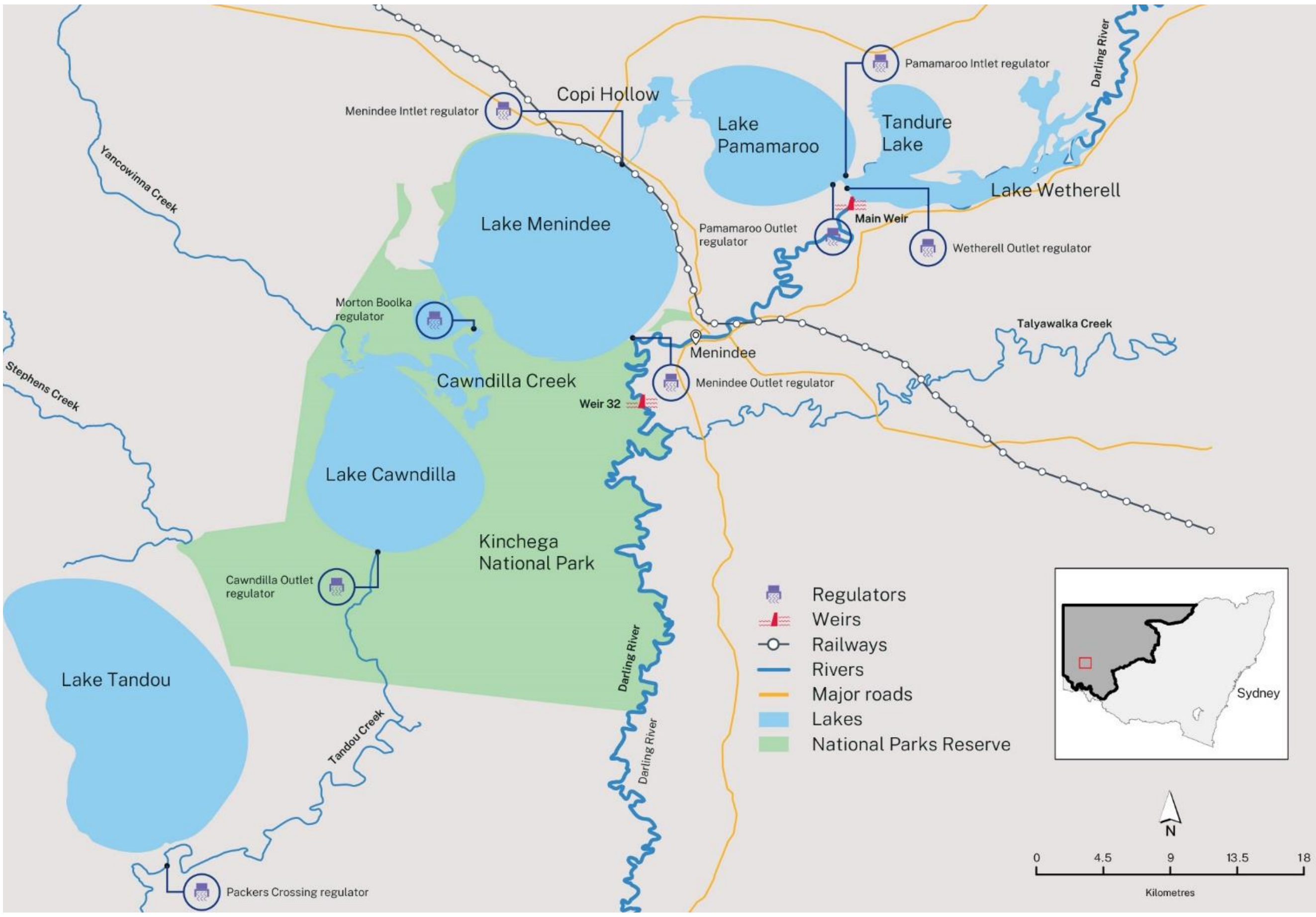
Flows into Barwon-Darling and Menindee Lakes often occur in large pulses, after flooding rain in the upper catchments. Large floods usually occur after late summer rains in Queensland or after late winter rains in NSW tributaries.

Ensuring there is enough water in the Barwon–Darling River for critical needs during summer can be a challenge. Evaporation in the region is high and the length of the river system (extending over 1,900 km) means that it can take one to 4 months for water to flow from the northern valleys to Menindee Lakes.

The Intersecting Streams system includes the Narran, Bokhara, Culgoa, Warrego, and Paroo rivers, which flow south across the Queensland–NSW border and into the Barwon River. The system contains many tributaries, distributaries and anabranches and an extensive network of ephemeral wetlands and hypersaline lakes. The system is unique and has some of the largest natural free-flowing and high environmental value systems in the Murray–Darling Basin.

Other water resources in the region are the arid catchments in the region's north-west, private on-farm storages, floodplain harvesting and small volumes of recycled water.

Figure 2. Menindee Lakes system



Managing water in the Western region

Water in NSW is managed and shared under the *Water Management Act 2000*, with specific water sharing rules set out in water sharing plans.

The Murray-Darling Basin Plan sets the limit on the amount of water that can be extracted from water sources in the Western region, based on long-term models of the river system. The current estimate of the annual sustainable diversion limits for surface water are: 178 GL for the Barwon–Darling Unregulated River, 37 GL for the Lower Darling, and 17 GL for the Intersecting Streams.

Surface water extractions in the Western region are managed so that they remain within these limits, irrespective of the licensed entitlement volume. These limits are implemented through water sharing plans.

- Barwon–Darling Unregulated River Water Source 2012
- Intersecting Streams Unregulated River Sources 2011,
- NSW Murray and Lower Darling Regulated Rivers Water Sources 2016
- Lower Murray–Darling Unregulated River Water Source 2011

The Water Management Act sets out how we prioritise water sharing during normal operations, with the highest priority being for the environment, followed by basic landholder rights. During extreme events, such as prolonged droughts, the priority changes. Basic landholder rights and essential town water services (authorised by an access licence) become the highest priority in the Murray-Darling Basin, followed by the environment. This change in priorities is triggered when a water sharing plan (or part of a plan) is suspended. The aim is to operate within the plan rules for as long as possible, as they provide clarity for all users of these water sources.

The Barwon-Darling River system is categorised as an unregulated water source as it does not receive flows from major storages to supply licensed water users, although it does receive outflows from tributary rivers that are categorised as regulated rivers. Licensed water users along the Barwon-Darling River between Mungindi in the north and Menindee Lakes in the south may take water if flows are available, subject to commence-to-pump thresholds for each licence category set out in the *Water sharing Plan for the Barwon-Darling Unregulated River Water Source 2012*.

Managing water in the Menindee Lakes and Lower-Darling regulated region

The Menindee Lakes and Lower Darling River are categorized as a regulated water source, and releases are made from Menindee Lakes to supply licensed water users along the Lower Darling River, including the townships of Menindee and Pooncarie.

The Menindee Lakes and the Lower Darling River have specific water management arrangements defined by the Murray-Darling Basin Agreement (Schedule 1 of the Water Act, 2007, Commonwealth). When the volume of water in storage exceeds 640 GL, inflows to the lakes are shared 50:50 between NSW and Victoria (with the exception that Victoria cedes 4.17 GL of its share of inflow to NSW each month), and the release of water from the lakes is directed by the Murray Darling Basin Authority (MDBA). Clause 95 of the Agreement provides that if the volume in storage in lakes drops below 480 GL, control of the lakes transfers to NSW until the volume in storage next exceeds 640 GL. When the volume reaches 640 GL the MDBA retakes direction of operations, and the difference in shares of water in store of NSW and Victoria that existed when the volume dropped below 480 GL is re-instated. This effectively means that all inflows to the Menindee Lakes when they are under NSW control are assigned to NSW.

When the Menindee Lakes are under NSW control, NSW may use water from the lakes to supply its demands in the Lower Darling system and the Murray River downstream of the confluence with the Darling River. When under MDBA control releases from Menindee Lakes supply the Lower Darling, and NSW, South Australian and Victorian demands, and environmental flows. Releases to the Great Darling Anabranch for environmental requirements are made from time to time via the Cawndilla outlet regulator and Tandou Creek. Releases are also made during periods of high flows and flooding.

3. Assessment framework

Modelling objectives

Hydrologic modelling has been undertaken to support wider objectives of the regional water strategies program. In recognition that river flows in the western region predominantly rise in other regions, connectivity of flows to the western region have been a focus of the hydrologic investigations. This work investigated three existing policy initiatives:

- the Interim Unregulated Flow Management Plan for the North-West[6] (North-West Flow Plan),
- the resumption of flow rules[7] set out in the water sharing plan for the unregulated Barwon-Darling water source, and
- the critical dry conditions triggers (protect the first flush of water after extended dry period)

A set of over-arching connectivity objectives have been used to review both the potential implementation or extension of existing approaches, and new options that would improve connectivity between the Barwon-Darling River system and the regulated tributary river systems in northern NSW (Border Rivers, Gwydir, Namoi and Macquarie).

Over-arching connectivity objectives are to:

- reduce the impact of cease to flow periods and improve low flow connectivity
- protect the first flush of water after an extended dry period
- support water quality and reduce risk of algal blooms forming
- support fish migration.

Potential actions to improve connectivity

To achieve these objectives, the following broad actions have been investigated in the Barwon-Darling and upstream regulated river systems (NSW Border Rivers, Gwydir, Namoi, and Macquarie):

- restrictions to water use by Barwon-Darling B and C Class licences, floodplain harvesting, and supplementary access licences.
- use of water from major headworks storages in the regulated tributary rivers

[6] Interim Unregulated Flow Plan for the North-West 1992 can be accessed at: The North-West Flow Plan - Water in New South Wales (nsw.gov.au)

[7] See s.50 of Water Sharing Plan for the Barwon-Darling Unregulated River Water Source 2012 Barwon, Darling and West region | Water (nsw.gov.au)

    - storage reserves or allowances in regulated tributary systems
    - use of existing water access licences

Hydrologic modelling has been undertaken in a two-stage approach:

- Stage 1: Preliminary analysis to explore potential benefits and impacts of broad actions to improve connectivity to support critical human and environmental needs, minimise extreme conditions and implement existing or alternative rules. In this stage of the analysis the aim is to understand when it would be useful to target s324 restrictions and or an extension of the resumption of flow rule as an alternative to the riparian targets in the North-West Flow Plan something about algal suppression and fish migration.
- Stage 2: Based on the results of Stage 1, apply targeted actions to further explore the potential benefits and impacts of applying actions to help address connectivity needs.

The Menindee Lakes and Lower Darling

The inflows to the Menindee Lakes in the Source Murray Model are end of system flows from the IQQM Barwon-Darling model. In most cases the base case results were used, but on occasion one of the Barwon-Darling options was used to allow assessment of impacts combining a Barwon-Darling option with a Menindee/Lower Darling option.

The focus of the modelling of the Menindee Lakes/Lower Darling was on improving water supply reliability and environmental outcomes.

Climate datasets

Historic climate

The historic climate refers to the period of available observed inflow data (in-filled with simulated inflow data where there are gaps in the observed data) that are used as input to the river system model. This period spans July 1895 to June 2020.

Instrumental climate

The instrumental climate refers to the period of available instrumental meteorological recordings (1895–2020) that are used as input into the rainfall–runoff models, required to simulate inflows to the river system models and as direct climate input to river system model simulations. For options assessment, fourteen replicates of 40-year periods were sampled from this data to provide a preliminary basis to evaluate options for shortlisting for portfolios.

This climate data is referred to as 'instrumental' throughout this report. It is the building block for incorporating long-term and climate change data. This dataset was used for all of the hydrologic modelling of options in this report.

Long-term historic climate projections (stochastic data)

The long-term historic climate projections (stochastic data) refers to the 10,000 years of stochastically-generated climate (developed using paleo climatic information by The University of Adelaide, Australia) that are used to evaluate the final viability of portfolios as well as define the base case. For option assessment, a thousand replicates of 40-year periods were sampled from this data to provide a comprehensive assessment of outcomes across many possible climate realisations.

This climate data set is referred to as 'stochastic' and will be used in subsequent modelling work for the Barwon-Darling and Lower Darling Rivers.

Dry climate change scenario (NARCliM modelling)

The 'dry climate change scenario (NARCliM modelling)' refers to the stochastic climate data generated by multiplying the stochastic time-series of 10,000 years with average monthly scaling factors derived from NSW and ACT Regional Climate Modelling (NARCliM) climate projections for 2060–2079 compared to the baseline period of 1990–2009 for each climate timeseries for every climate station used in the modelling. The average monthly scaling factors represent the mean of three regional climate models of CSIRO-MK3 GCM used in NARCliM 1.0.

This set of stochastic data with climate projections are used in conjunction with the stochastic data to evaluate the final viability of options, as well as to define future base cases. For options assessment, 1,000 replicates of 40-year periods were sampled from this data to provide a comprehensive assessment of outcomes across many possible climate realisations.

This is source of data is referred to as 'stochastic+NARCliM' and will be used in subsequent modelling work for the Barwon-Darling and Lower Darling Rivers.

Base case model scenario

A base case scenario is important for comparison with modelling of the various options that has been undertaken. It is intended that the base case represents current conditions, including any policies or initiatives that have been agreed or are currently in the process of being implemented.

For each NSW valley, the latest current conditions model scenario available[8] with the latest irrigation infrastructure and management rules is the modelling developed for the Healthy Floodplains program, and the licensing of floodplain harvesting. This scenario has been documented in the relevant Healthy Floodplains Project Scenario reports for each valley[9] published on DPE

[8] As at December 2021 when the modelling analysis commenced. Model versions are listed at Attachment 1.

[9] For example: Floodplain harvesting entitlements for the Gwydir Valley regulated river system – Scenarios report

Water website and is referred to as the Valley Scale Compliance scenario[10]. For the Barwon-Darling Valley the Current Conditions model scenario was used as the Valley Scale Compliance scenario was not completed when modelling commenced (December 2021). However, the licensing of floodplain harvesting is not intended to reduce access as modelling indicates there is no growth in water use.

For the Namoi Valley, a preliminary version of the Valley Scale Compliance scenario in the new Source model has been used. Subsequent to this connectivity modelling, the Namoi Source model has been upgraded and recalibrated, and is described in the reports released in November 2022.[11]

For the Murray and Lower Darling river system, the Source Murray Model developed by the MDBA has been used.

These base case models also include water entitlements held by government for environmental purposes (known as held environmental water) which are represented as irrigation nodes in the model that extract water from the river[12]. This is the model setup used for “pre-Basin Plan” modelling undertaken by NSW for the development of water resource plans, which was a representation of the “current conditions” in each valley at that time[13]. The use from these licences has been included in the diversion totals reported, unless otherwise indicated.

Further work has been undertaken for the regional water strategy program in the Gwydir and Macquarie valleys to represent the contemporary use of held environmental water for environmental purposes. However, this was not used in the base case modelling to better understand the changes to the flow regime produced by subsequent scenarios that explore the use of water entitlements to improve connectivity.

Modelled options

Table 2 lists the options and scenarios modelled for the draft Western Regional Water Strategy.

Each of the options in Table 2 were initially modelled using historic climate datasets. Those options that passed the rapid cost-benefit analysis were selected for further investigation and modelled using the instrumental climate datasets, and may be subsequently modelled using the extended climate (stochastic) and climate change (NARCliM) datasets.

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[10] For the Barwon-Darling Valley the Current Conditions model scenario was used as the Valley Scale Compliance scenario was not completed until after December 2021. However, the licensing of floodplain harvesting is not intended to reduce access as modelling indicates there is no growth in water use.

[11] https://www.industry.nsw.gov.au/water/plans-programs/healthy-floodplains-project/water-sharing-plan-rules/namoi-valley

[12] For the Barwon-Darling Valley the HEW is not modelled as being pumped, and water use has been removed at the irrigation sites in the model where the HEW was purchased.

[13] Pre-Basin Plan modelling reports are included as Attachment B to Schedule F of NSW Water Resource Plans.

Table 2. Options assessed using hydrologic modelling for the draft Western Regional Water Strategy

Category	Description
Base case	Current conditions with Floodplain harvesting entitlements[14] in place and Held Environmental Water diverted[15] in regulated rivers in a similar pattern to consumptive water users (as per NSW Pre-Basin Plan scenarios).
Barwon-Darling Stage 1 - preliminary analysis	Preliminary analysis to explore potential benefits and impacts of actions to improve connectivity and implement the North-West Unregulated Flow Management Plan. Modelling undertaken using historic climate datasets over periods available for each model.
Stage 1A – preliminary "bookend" analysis	Preliminary modelling analysis to understand the upper limit of possible connectivity benefits from imposing water restrictions in the Barwon-Darling and upstream regulated tributary rivers. This identifies years where restrictions would have resulted in flows reaching key thresholds. • Scenario 1: Suspension of all supplementary access in the regulated tributaries, and A, B, and C Class access in the Barwon-Darling. • Scenario 2: Suspension of all non-exempt[16] floodplain harvesting. • Scenario 3: Suspension of all supplementary access and non-exempt floodplain harvesting in the regulated tributaries, and A, B, and C class access and non-exempt floodplain harvesting in the Barwon-Darling River system.
Stage 1B – preliminary analysis of the use of general security entitlements	Preliminary modelling to understand the potential connectivity benefits from the use of general security entitlements in the regulated tributary rivers.

[14] For the Barwon-Darling Valley the Current Conditions model scenario was used as the Valley Scale Compliance scenario was not completed until after December 2021. However, the licensing of floodplain harvesting is not intended to reduce access as modelling indicates there is no growth in water use.

[15] For the Barwon-Darling Valley the held environmental water (HEW) is not modelled as being pumped, and water use has been removed at the irrigation sites in the model where the HEW was purchased.

[16] Rainfall-runoff harvesting from areas developed for irrigation that is exempted from licensing requirements under the NSW Floodplain harvesting policy has not been suspended.

Category	Description
Stage 1C – preliminary "perfect forecasting" analysis for algal suppression and fish migration	Preliminary modelling to understand the potential benefits and impacts in the Barwon-Darling and upstream regulated tributary rivers from targeted restrictions to supplementary and B/C class licences to achieve algal suppression and fish migration flow targets. These scenarios assume that years where opportunities to meet target flows could be operationally forecasted to avoid restrictions that would not have resulted in successfully meeting target flows.
Stage 2 – options analysis: Barwon-Darling and Lower Darling	Analysis of options for shortlisting in the Western Regional Water Strategy. Instrumental climate datasets used over a standardised period from 1895 – 2020 across all models.
Stage 2A – Option 5: Targeted restrictions for North -West Flow Plan algal and fish outcomes	The Stage 1A bookend scenario and Stage 1C targeted restrictions scenario were re-modelled using instrumental inflows (simulated by rainfall-runoff models with instrumental climate) and an extended climate sequence up to 2020 to include the most recent drought (excl. Macquarie Valley). Two new scenarios were produced: • Option 3: restrictions targeting additional years where the proposed alternate algal dispersal flow event was achieved, and • Option 8: restrictions targeting additional years where either of the existing fish passage events at Brewarrina and Bourke were achieved.
Stage 2B – Option 6: Targeted restrictions for critical Menindee storage volumes	Restrictions to B and C Class and upstream supplementary access during critical dry periods, with restrictions linked to water storage levels at Menindee Lakes. Three options were modelled with Menindee Lakes storage triggers for commencing / ceasing restrictions to Barwon-Darling and upstream supplementary access. • Option 6: 195 GL/ 250 GL active storage in upper lakes (Wetherell and Pamamaroo) • Option 6b: 480 GL/640 GL active storage in upper lakes (Wetherell and Pamamaroo) • Option 6c: 195 GL/ 250 GL total storage across all lakes.

Category	Description
Stage 2C – Option 46: Replenishment releases from major storages	Modelling of "replenishment" releases from storages in the NSW Border Rivers, Gwydir and Namoi regulated rivers to reduce periods of very low or no flows. The modelled commencement of restrictions in the Barwon-Darling valley under the existing "resumption of flow rule" was used as a trigger for a release of water from the storages, with a release of 20 GL targeted over a three-week period in each valley.
Stage 2D - Continuous flow in the Barwon-Darling	Target releases from storages in Namoi, Gwydir, and Border Rivers to achieve 500 ML/day at Bourke.
Stage 2E - Replenishment releases and Border Rivers inland diversions	Modelling of a combined connectivity option and an option for inland diversions to the Border Rivers that was investigated as part of the NSW Border Rivers Regional Water Strategy. The Border Rivers replenishments scenario (under Option 46) was extended to include a 50 GL/year diversion from the Clarence River (coastal) catchment to the Mole River (Border Rivers tributary).
Stage 2F – Option 47: Changes to Barwon-Darling water access flow thresholds	This option investigates the impacts of changing flow thresholds in the Barwon-Darling River system for B Class and C Class licences to align with the small freshes and large freshes flow classes defined in the Barwon-Darling Long-Term Water Plan.
Lower Darling	
Option 52 – Review how the Menindee Lakes are operated	This option investigates the impacts of applying the 480/640 rule of the Murray Darling Basin Agreement to active storage available to the lower Darling, rather than total storage in the Lakes.
Option 30 – Review the environmental water allowance for the Lower Darling water source	A desk-top study was undertaken to assess the viability of providing environmental flows to provide mixing of pools in the Lower Darling, thus preventing water column stratification and blue-green algae outbreaks. Under present arrangements such additional flushing flows are not available when the Lakes are under NSW control per the 480/640 rule.
Option 50 – Review the environmental water allowance for the Lower Darling water source	This option looks at the water resource implications of releasing water from Lake Cawndilla to the Great Darling Anabranch, and hence towards the River Murray, after Lake Cawndilla water levels drop too low to gravitate back to Lake Menindee. One objective of this option is to allow native fish stock to exit the stranded lake prior to desiccation.

Category	Description
Option 50 and Option 6	Option 50 (Deliver water down the Great Darling Anabranch) above, together with Option 6 (Option 6: 195 GL/ 250 GL active storage in upper lakes (Wetherell and Pamamaroo).

Outputs for option assessment

The performance metrics presented in Table 3 were used to interpret the performance of each option. Streamflow locations were selected to represent the alterations in the flow regime at the end of each river system, as shown in Table 3.

Table 3. Performance metrics

Category	Component
Mean annual diversions	• General security • High security • Supplementary • Floodplain harvesting • Rainfall harvesting • Local water utility • Unregulated A, B, and C Class diversions (Barwon-Darling)[17]
Allocations (selected options only)	• General security average effective allocation 30 September • General security effective allocation 30 June
Storage behaviour (selected options only)	• Daily storage volume exceedance distribution (ranked plots) • Time series of storage volumes during important periods (e.g. 2017-2020 drought period)

[17] These are the only categories of diversions modelled in the Barwon-Darling Valley, and local water utilities are not represented in the model.

<table>
<tr><th>Category</th><th>Component</th></tr>
<tr><td>Mean annual streamflow</td><td>Tributary end of system flows:
Macintyre River at Mungindi (GS 416001)
Mehi River at Collarenebri (GS 418055) and Gil Gil Creek at Galloway (GS 416052)
Namoi River at Walgett (GS 419091)
Macquarie River at Carinda (GS 421012)</td></tr>
<tr><td rowspan="2">North-West Flow targets</td><td>Riparian flow targets
Mungindi: 850 ML/day
Collarenebri: 760 ML/day
Walgett: 700 ML/day
Brewarrina: 550 ML/day
Bourke: 390 ML/day
Louth: 280 ML/day
Wilcannia: 150 ML/day</td></tr>
<tr><td>Algal suppression targets
Current targets:
2,000 ML/d at Wilcannia for 5 days October - April
At least once in the previous three months.
Proposed targets:
3,000 ML/day for 7 days, unless flows have remained above:
- Walgett – 250 ML/d
- Brewarrina – 510 ML/d
- Bourke – 450 ML/d Bourke – 450 ML/d
- Wilcannia – 350 ML/d</td></tr>
</table>

Category	Component
	Fish migration targets Current targets: • 14,000 ML/d at Brewarrina and/or • 10,000 ML/d at Bourke • for 5 days Sep - Feb, unless 2 such flows have already occurred. Proposed targets: • 15,000 ML/d for 15 days at Bourke July - September (dispersal and condition) • 15,000 ML/d for 15 days at Bourke October - April (spawning) • 14,000 ML/d for 15 days at Brewarrina October - April (migration)
Long-term water plan flow categories	Flow classes below, as defined in the long-term water plans for each valley • very low and cease to flow • base flows • small freshes

4. Stage 1A: preliminary "bookend" analysis

Analysis description

Several initial model scenarios were undertaken where the lower priority forms of water take in the upstream regulated tributaries and the unregulated Barwon-Darling were suspended completely.

- Scenario 1: Suspension of all supplementary access in the regulated tributaries, and A, B, and C Class access in the Barwon-Darling.
- Scenario 2: Suspension of all non-exempt[18] floodplain harvesting.
- Scenario 3: Suspension of all supplementary access and non-exempt floodplain harvesting in the regulated tributaries, and A, B, and C class access and non-exempt floodplain harvesting in the Barwon-Darling River system.

The purpose of these scenarios was to test the upper limit of downstream connectivity benefits that might be possible, and when restrictions might provide the most benefits for the connectivity objectives. Whilst these model scenarios assume that water users will continue to operate in a similar way to the base case, it should be recognised that this is not intended to be a realistic representation of how they would likely operate with such severe reductions in water access.

This modelling was undertaken using the historic inflow dataset that was initially available for each valley model.

The suspension of access was implemented in each tributary valley model, and the results of the tributary model scenarios were then used as input to the Barwon-Darling model.

The base case and scenario modelling undertaken in Stage 1A used the maximum period of climate available for the Barwon-Darling model, which was the shortest of the valley models at the commencement of this work (1895 - 2014).

Suspending water access

Suspensions to water access were undertaken in the model as described below:

[18] Rainfall-runoff harvesting from areas developed for irrigation that is exempted from licensing requirements under the NSW Floodplain harvesting policy has not been suspended.

- Supplementary access was suspended in the model by reducing supplementary access entitlements to zero.
- Floodplain harvesting was suspended by setting the water accounts associated with the new floodplain harvesting licences to zero[19].
- Access to water by A[20], B, and C Class licences in the Barwon-Darling was suspended by setting pump capacities to zero.

Representation of floodplain harvesting restrictions

Implementing restrictions

Two components of floodplain harvesting are simulated in all valley models: the harvesting of flows that breakout of the river banks and flow across the floodplain, and the generally smaller harvesting of runoff generated by local rainfall on the farm and (in some cases) surrounding local areas. The restriction of the overbank flow harvesting component was undertaken by setting licence accounts to zero, or river pump capacities to zero (for the Barwon-Darling). However, this does not restrict the generally smaller volumes of rainfall runoff harvesting from occurring. Restricting this second component of floodplain harvesting required more detailed modifications to the model, and timeframes did not permit pursuing this.

Return flows

Floodplain harvesting has been configured in the regulated tributary models by representing the net volumes of water that break out of the channel in most river reaches where floodplain harvesting occurs, and individually representing properties that are able to capture some of that water. The net volume of water leaving the river channel is simulated, rather than the total volume of water that leaves the river and then the return of some proportion of that water that is not taken or lost on the floodplain. This approach recognises that in most cases it is not possible to directly measure the volumes of water flowing out of the river channel, and the volume of water subsequently returning to the channel.

When the modelled harvesting of water from the floodplain is altered in the tributary models, the model configuration described above does not produce any changes to the modelled flows in the river. In some cases, this may be appropriate, but it is expected that in others it is not representative of what would happen. The department has initiated a research program to investigate the potential for representation of the total flows onto the floodplain and those that return to the river. However,

[19] For stage 1A only, due to model limitations.

[20] For Stage 1A only, due to model limitations.

this work will not be completed until after the development of the Western Regional Water Strategy.

To provide an initial estimate of increases in river flows as a result of suspending floodplain harvesting, the volumes of water harvested[21] in the base case scenario were added back to the modelled river flows at the end of each tributary river. Though for the Macquarie River system, the additional flows were added back to the river upstream of the Macquarie Marshes. This outcome would be unlikely to occur in practice, and the increase in river flows that might arise would only be a proportion of the reduction in floodplain harvesting. However, this approach provides a conservative upper estimate of possible return flows to the river if floodplain harvesting was restricted.

For the Barwon-Darling model, no additional effluent streams have been configured to represent floodplain breakouts explicitly. This is because many of the overbank flow breakouts in the Barwon-Darling remain close to the river itself and usually rejoin the main river system. Where this occurs, the flow breakout is not separately simulated and the model simulates the total flow, and floodplain harvesting access by water users is simulated via use of higher flow thresholds. Unlike the tributary river system models, when the modelled harvesting of water from the floodplain is restricted in the Barwon-Darling model, the model configuration does simulate changes in the modelled river flows.

Modelling results

Modelling results are shown for the base case and the “bookend” scenarios with suspension of supplementary access and A, B, and C Class access (Scenario 1), suspension of floodplain harvesting (Scenario 2) and the combined suspension of supplementary, A, B, and C Class access, and floodplain harvesting (Scenario 3).

Tributary flows to the Barwon-Darling

The suspension to supplementary, A, B, and C Class, and floodplain harvesting access resulted in increased flows from each regulated tributary river and along the Barwon-Darling River. Changes in the tributary end of system flows and flows along the Barwon-Darling River resulting from the suspension of water access are summarised in Table 4.

[21] Both the overbank flow harvesting and the rainfall runoff harvesting components of floodplain harvesting were included.

Table 4. Comparison of the end of tributary valley mean annual flows (1895 - 2014)

River Valley	Base case Current conditions (GL/y)	Scenario 1 Supplementary and A/B/C class access suspended (GL/y)	Scenario 2 FPH access suspended (GL/y)	Scenario 3 Combination of Scenarios 1 and 2 (GL/y)
Border Rivers Macintyre River at Mungindi	591	625 (+6%)	619 (+5%)	652 (+11%)
Gwydir Valley Mehi River @ Collarenebri + Gil Gil Creek @ Galloway	148	193 (31%)	215 (+45%)	261 (+76%)
Namoi Valley Namoi River at Walgett	542	571 (+5.4%)	566 (+4.5%)	596 (+10%)
Macquarie Valley Macquarie River at Carinda	123	126 (+3%)	135 (+10%)	134 (+9%)

Barwon-Darling River flows

Model results were reviewed to understand the changes in different flows classes that would occur when water access was restricted. The changes in the proportion of time that flows exceed the thresholds for the flow classes set out in the Barwon-Darling Long-Term Water Plan are shown in Table 5. Overall, complete suspension of these types of access to water resulted in:

- little improvement to the proportion of time flows were above thresholds for base flows at Bourke, and modest improvements at Wilcannia,
- significant improvements for small freshes at both locations, mainly from scenario 1 (suspension of supplementary access and A, B, and C Class access), and
- modest improvements to large freshes.

Baseflows are unlikely to be significantly improved by restricting these types of diversions as the effect of the current water sharing plans across the northern valleys is to protect (to varying degrees) lower flows before supplementary access and Barwon Darling access is announced.

Table 5: Proportion of time that Barwon-Darling flows exceed long-term water plan flow thresholds

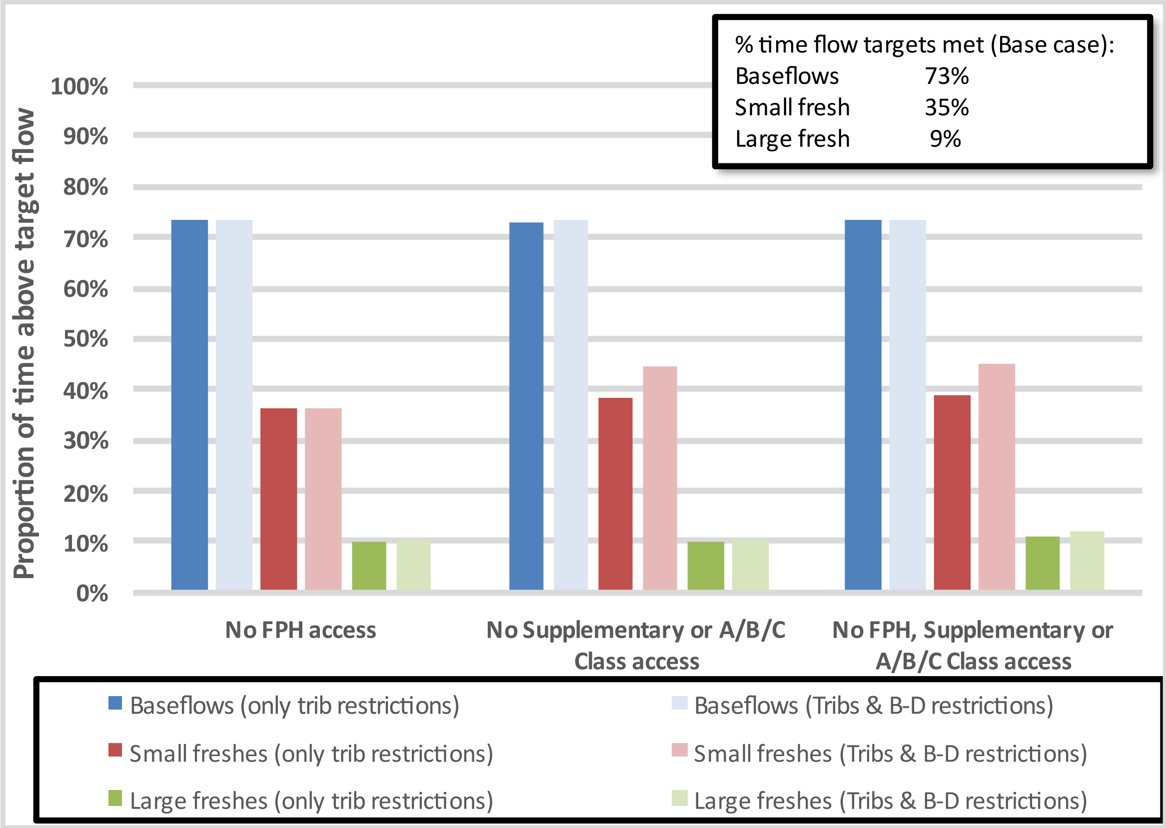
Barwon-Darling Long -Term Water Plan commencing flow class thresholds	Base case Current conditions	Scenario 1 Supplementary and A/B/C class access suspended	Scenario 2 FPH access suspended	Scenario 3 Combination of Scenarios 1 and 2
Darling River at Bourke				
Baseflows (500 ML/day)	73%	+0.4%	+0.2%	+0.6%
Small freshes (1,550) ML/day	35%	+9.3%	+1.2%	+9.8%
Large freshes (15,000 ML/day)	9%	+1.9%	+1.8%	+3.6%
Darling River at Wilcannia				
Baseflows (350 ML/day)	69%	+1.9%	+2.3%	+4.3%
Small freshes (1,400) ML/day	35%	+9.5%	+4.0%	+12.5%
Large freshes (14,000 ML/day)	9%	+2.1%	+2.5%	+4.4%

Note: Lower threshold for each flow class has been used.

The results for flows at Bourke are shown in Figure 3. For comparison the changes from suspending A, B, and C Class access in the Barwon-Darling system only (no suspensions in tributary valleys) are also shown. This shows that:

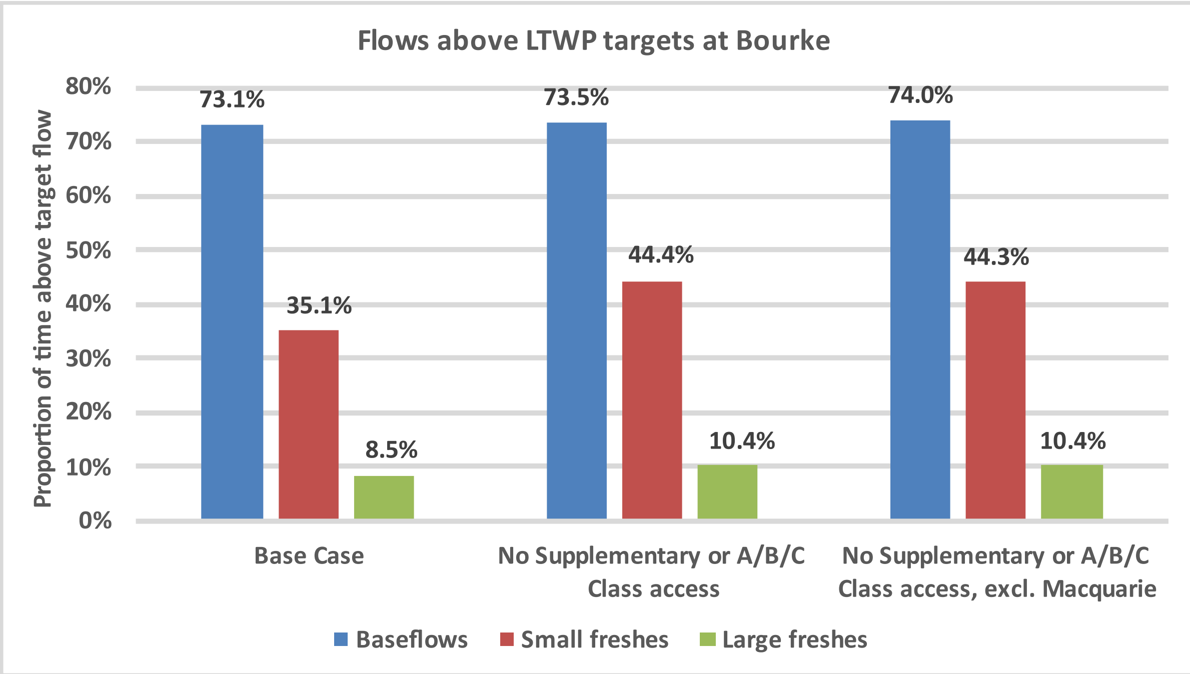
- there is little difference in the proportion of time that flows are above the baseflows threshold across all the scenarios consistent with expectations that the forms of water take being suspended are occurring higher in the flow regime. This result indicates that removing or altering low reliability forms of water take is not an effective way to manipulate baseflow outcomes,
- for small freshes, suspending supplementary and A, B, and C Class access has more impact than suspending floodplain harvesting access in the regulated tributary valleys, although suspending both provides the most improvement. This result is consistent with our understanding that floodplain harvesting is not common at the small fresh flow range, however access to small fresh events is common for supplementary entitlement holders and A, B and C class entitlements,
- none of the diversion categories suspended had a significant impact on the proportion of time flows are above the threshold for large freshes. This is consistent with our expectation that existing limits on pump sizes act to prevent these forms of water take having a large effect on flows at this scale.

Figure 3: Changes in flows above Barwon-Darling Long-Term Water Plan flow thresholds at Bourke from suspension of floodplain harvesting and supplementary and A, B, and C Class access



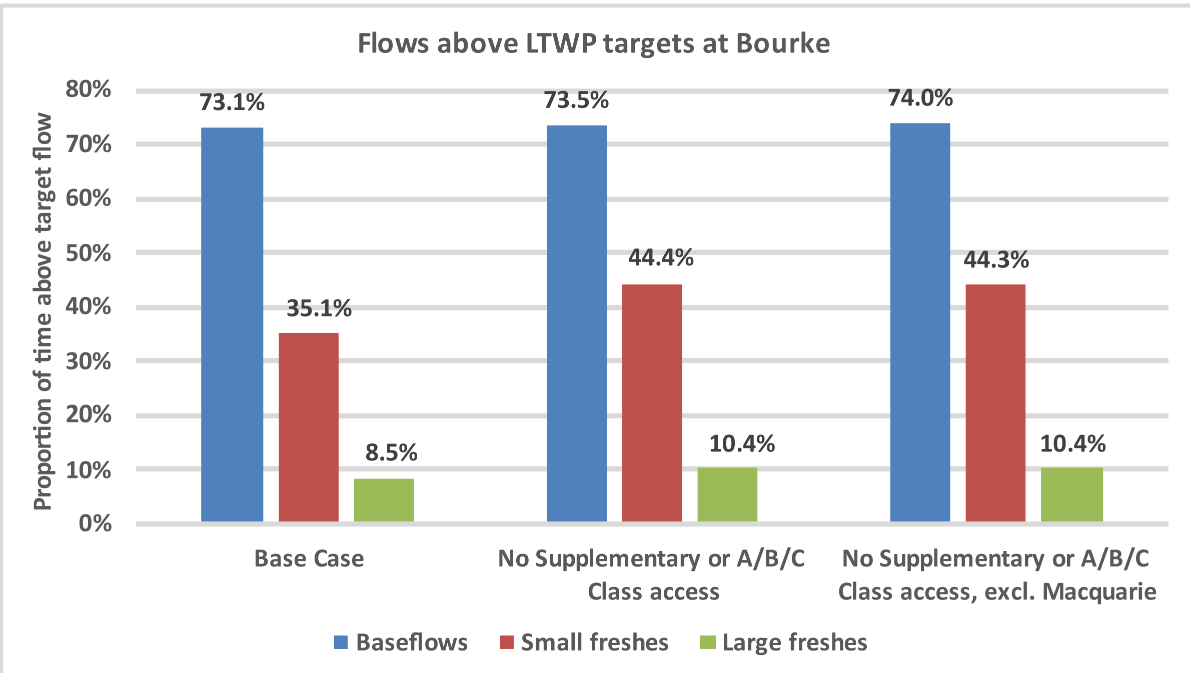
The comparison between the changes in long-term average end of system flows (Table 4) and the reductions in diversions (refer to Table 6 in the section on water diversions below) indicates that the suspensions to water access in the Macquarie Valley led to a proportionally smaller improvement in end of system flows from that valley to the Barwon-Darling River system when compared with the other regulated tributary rivers. This is largely due to the relatively small amount of supplementary and floodplain harvesting access in the Macquarie Valley, and the presence of the Macquarie Mashes which retain most of the flows below the regulated river in that valley.

To demonstrate the relative lack of benefits from Macquarie Valley suspensions on water use for the Barwon-Darling River system, a further model scenario was tested with the suspension of supplementary access in the NSW Border Rivers and the Gwydir and Namoi valleys only. The results of this scenario were then compared with suspension of supplementary access and A, B, and C Class access in all valleys, are shown in



. When considered together with the end of system flows shown in Table 4, these results indicate that there is little benefit to connectivity with the Barwon-Darling River system from restrictions to supplementary access in the Macquarie Valley. Consequently, restrictions in the Macquarie Valley to improve flow outcomes in the Barwon-Darling were not considered in subsequent stages of modelling.

Figure 4: Changes in flows above long-term water plan thresholds at Bourke with and without suspension of supplementary access in the Macquarie Valley



North-West Flow Plan flow targets

Model results were also reviewed to understand the improvements in meeting the riparian, algal suppression and fish passage flow targets set by the North-West Flow Plan that would occur when water access was restricted.

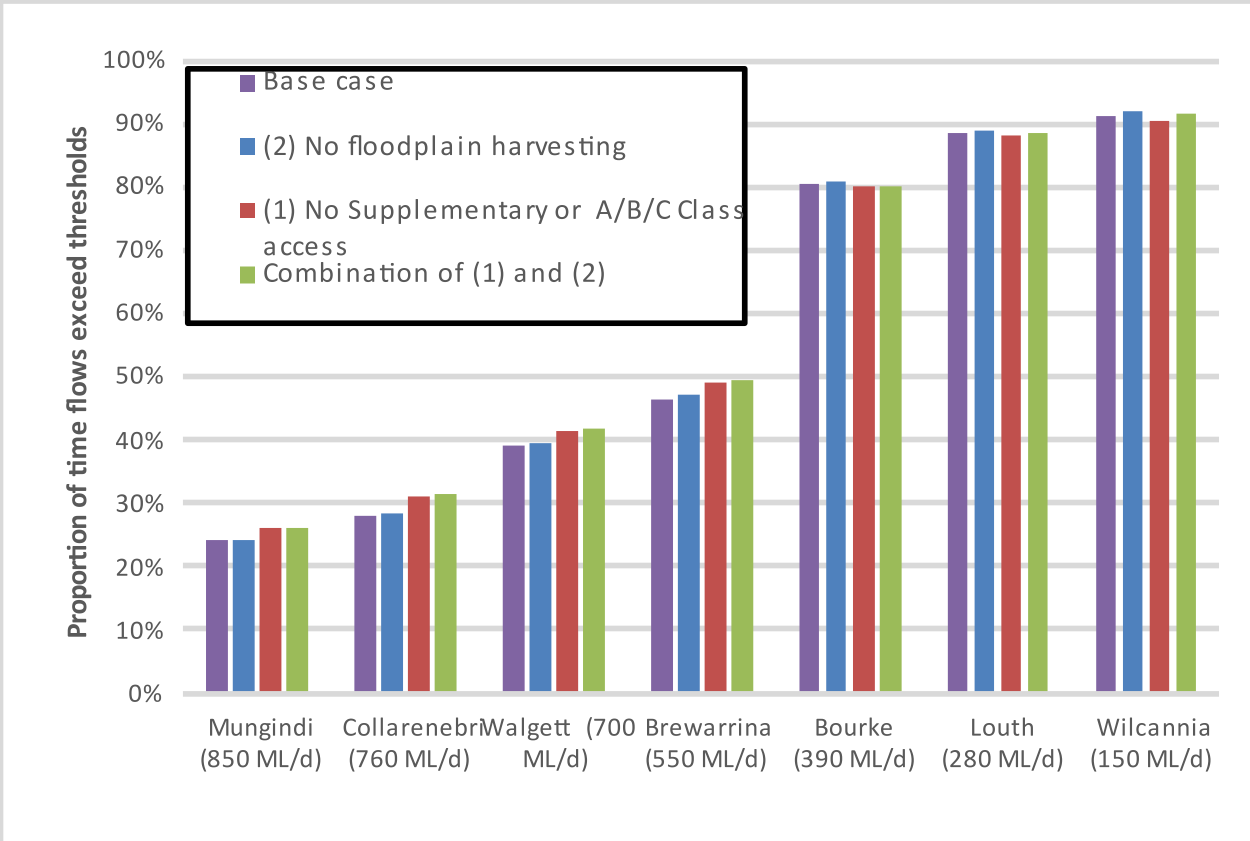
Riparian flow thresholds

The North-West Flow Plan sets a riparian flow threshold at major flow gauging stations along the Barwon-Darling River to ensure stock and domestic access.

The riparian flow targets set by the North-West Flow plan (see Error! Reference source not found.) are much higher in the upper reaches of the system, as they were intended to be sufficient to provide a riparian flow down to Wilcannia. These targets do not account for inflows from downstream tributaries that may occur in particular events. Consequently, it can be seen in Error! Reference source not found. that flows do not exceed the riparian targets in the upper reaches as often. However, these upper reach target flows are higher than the riparian requirements for that reach.

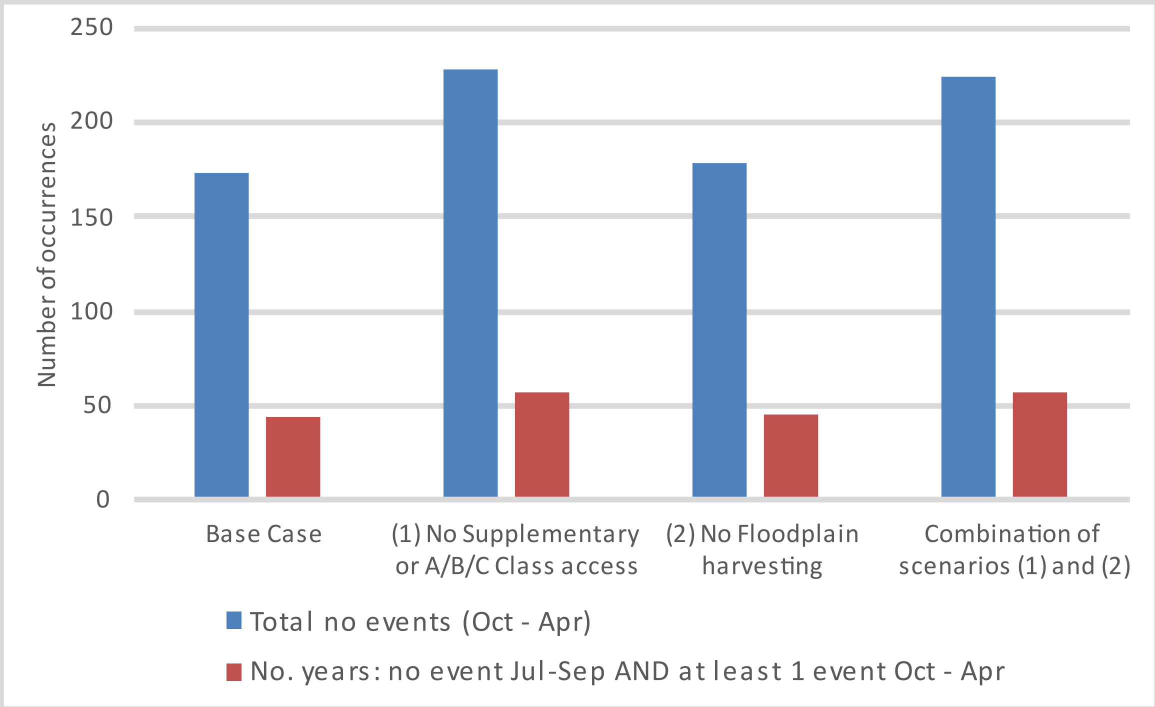
Regardless of the differences in riparian flow targets between river reaches, Error! Reference source not found. shows that the complete suspension of Barwon-Darling A, B, and C Class and tributary supplementary access and floodplain harvesting resulted in little improvement in the proportion of time that flows were above the riparian flow targets. This result is consistent with our conceptual understanding that these forms of take are operating higher in the flow regime and hence removing or altering low reliability forms of water take is not an effective way to manipulate riparian flow outcomes.

Figure 5: Flows above North-West Flow Plan riparian target flows – impact of suspension of floodplain harvesting, supplementary access and A, B, and C Class access



Algal suppression targets

The North-West Flow Plan includes a flow event target at Wilcannia that was expected to disperse algal blooms. This target event was at least 2,000 ML/day for a five-day period during the period of October to April, if there had not been such an event in the preceding July to September period. The modelling results for base case and bookend scenarios are shown in

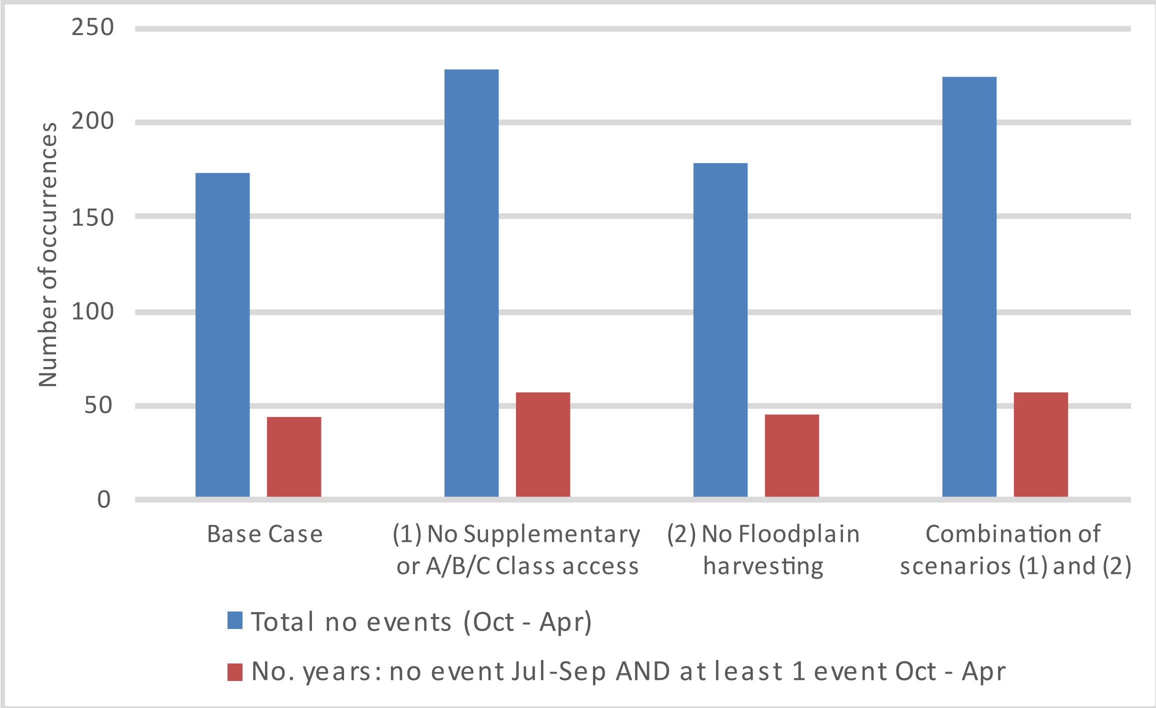


and indicate that the broad bookend suspensions of access significantly increased the number of events across the 119 years of model simulation, with the restrictions to supplementary access having the greatest effect. However, increases in the number of years without an event in July to September, and with more events during October to February were much smaller (+11% of years), indicating that suspending floodplain harvesting access is mainly resulting in additional events in years where events are already being achieved.

It can also be seen that suspension of floodplain harvesting did not result in any additional years meeting the improvement criteria above that achieved by the suspension of supplementary access. This likely to be due to additional flows occurring in years where events are already being achieved.

These results indicate that altering access for supplementary or A, B, and C class entitlements can have an influence on algae suppression flows, but floodplain harvesting take is generally not occurring from events that are important to this outcome.

Figure 6: Modelled North-West Flow Plan existing algal dispersion events at Wilcannia (2 GL/day for 5 days) – impact of suspension of floodplain harvesting, supplementary and A, B, and C Class access



Fish passage targets

The North-West Flow Plan sets two target flow events that are intended to ensure fish passage along the Barwon-Darling River:

- 14,000 ML/day at Brewarrina for five days, and
- 10,000 ML/day Bourke for five days.

The number of years that these events are achieved in the base case and bookend scenarios for Brewarrina is shown in Figure 7, and for Bourke in Figure 8. The combination bookend scenario provided a small overall increase in years with events (+6% of years), although this was only marginally higher[22] than with suspension of supplementary and A, B, and C Class access only. The combination bookend scenario resulted in a modest increase in the number of years with more than one event, but a slight reduction in years with only one event, indicating that additional events were occurring in some years where an event had already occurred.

[22] 3 additional years over the 119 years of simulation.

Figure 7: Existing North-West Flow Plan Fish passage threshold - Brewarrina (14 GL/day for 5 days) – impact of suspension of floodplain harvesting, supplementary and A, B, and C Class access over 119 years of model simulation

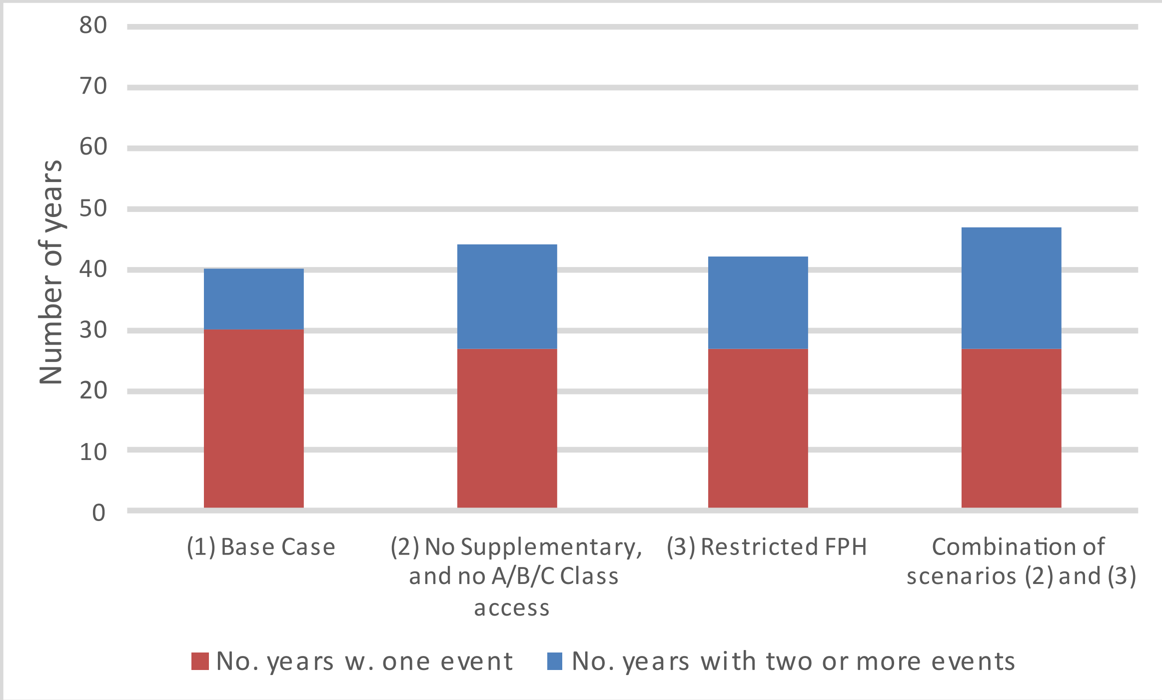
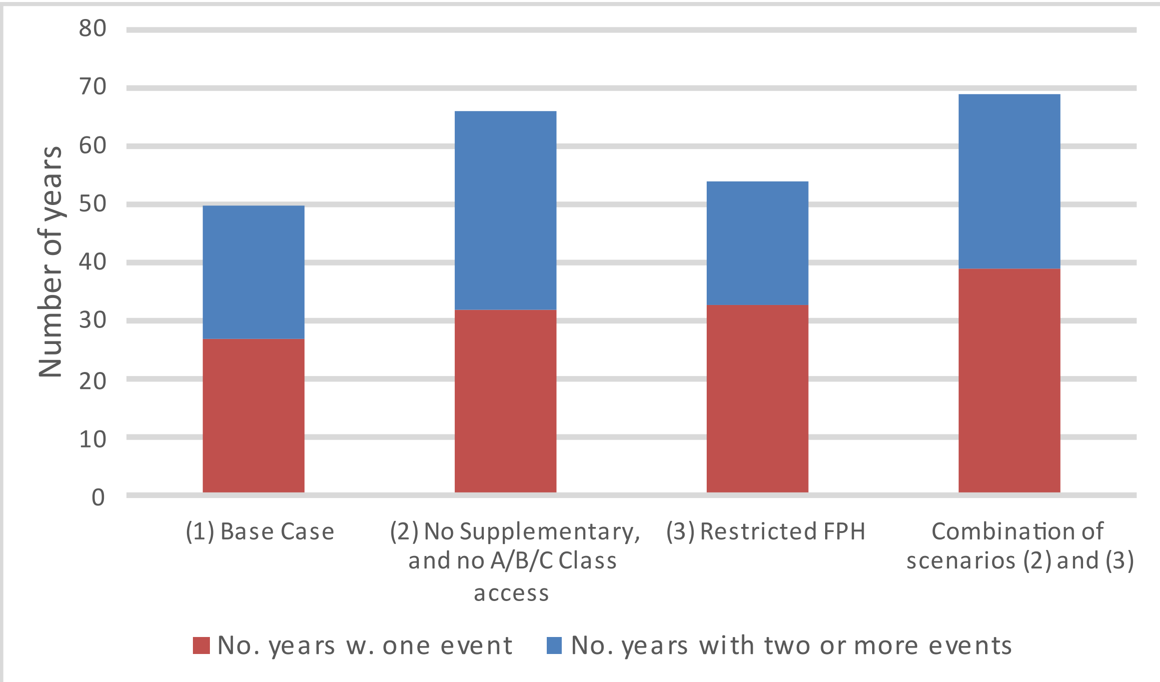


Figure 8: Existing North-West Flow Plan Fish passage targets - Bourke (10 GL/day for 5 days) – impact of suspension of floodplain harvesting, supplementary and A, B, and C Class access over 119 years of model simulation



Floodplain harvesting restrictions were not considered further in subsequent analyses, as the analysis above for the existing North-West Flow Plan events indicated that even the most unlikely scenario, where all restrictions to such harvesting were assumed to fully return to the end of each tributary river system, did not result in achieving many additional years with events.

These results indicate that altering access for supplementary or A, B, and C Class entitlements can have an influence on algae suppression flows, but floodplain harvesting take is generally not occurring from events that are important to this outcome.

Proposed alternate algal and fish flow event targets

In 2021[23] a review was undertaken of the earlier North-West Flow Plan algal suppression flow targets against contemporary science. As a result of this review, alternate proposals were recommended for algal suppression and dispersal. Results of the bookend scenario 1 (suspension of supplementary and A, B, and C Class access) were reviewed to understand the upper limit to improvements for these proposed alternate flow event targets.

Proposed alternate algal suppression and dispersal flows

The review of the North-West Flow Plan recommended that the flow target for an algal dispersal event be increased to 3,000 ML/d for seven days at Wilcannia unless flows have remained above the following flow suppression thresholds throughout the spring/summer period:

- Walgett – 250 ML/day
- Brewarrina – 510 ML/day
- Bourke – 450 ML/day
- Wilcannia – 350 ML/day

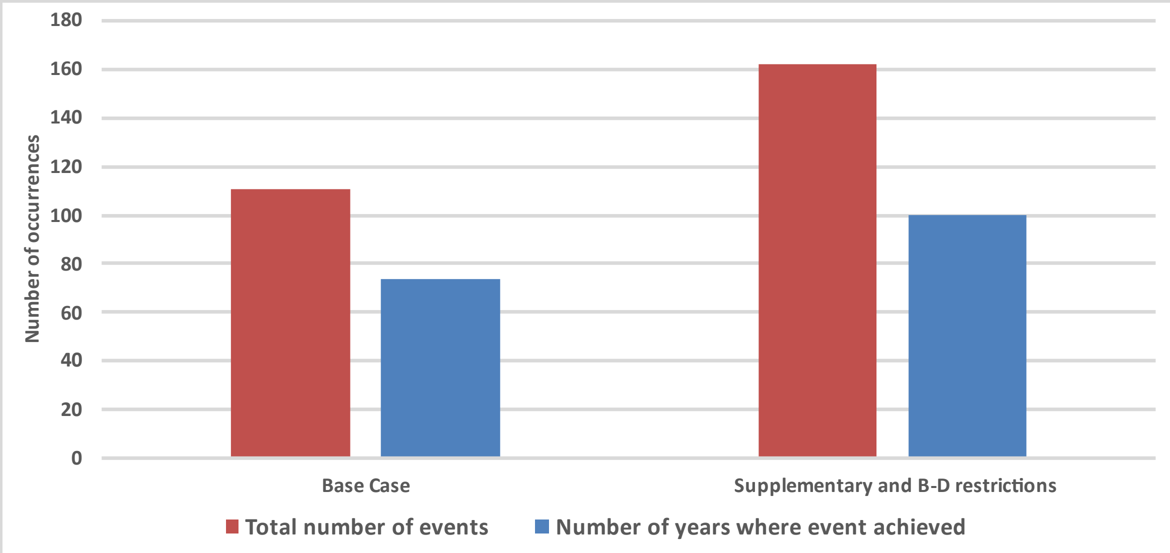
Modelling results for the proposed alternate algal targets were examined for the base case and Bookend Scenario 2 (no supplementary and A, B, and C Class access) across spring and summer (September – February). The modelling results indicated that:

- flows only remained above all four of these proposed algal suppression thresholds for the spring-summer period in 4% of years under the base case, and 6% of years for Bookend Scenario 1 (supplementary and A, B, and C Class access suspended), with all other years having at least some period of time below the thresholds at one or more of the four indicator sites.
- flows would remain above one or more of the proposed algal suppression thresholds for this spring-summer period in 44% of years under the base case, and 40% of years for Bookend Scenario 1. The decrease in the number of years appears to be due to changes in modelled demand patterns for general security use (increased general security use outside of the restriction periods) because of the restrictions to supplementary access restrictions. The four

[23] Alluvium, 2021, Review of the Interim Unregulated Flow Management Plan for the North-West, Final report prepared by Alluvium Consulting Australia for DPIE Water, NSW

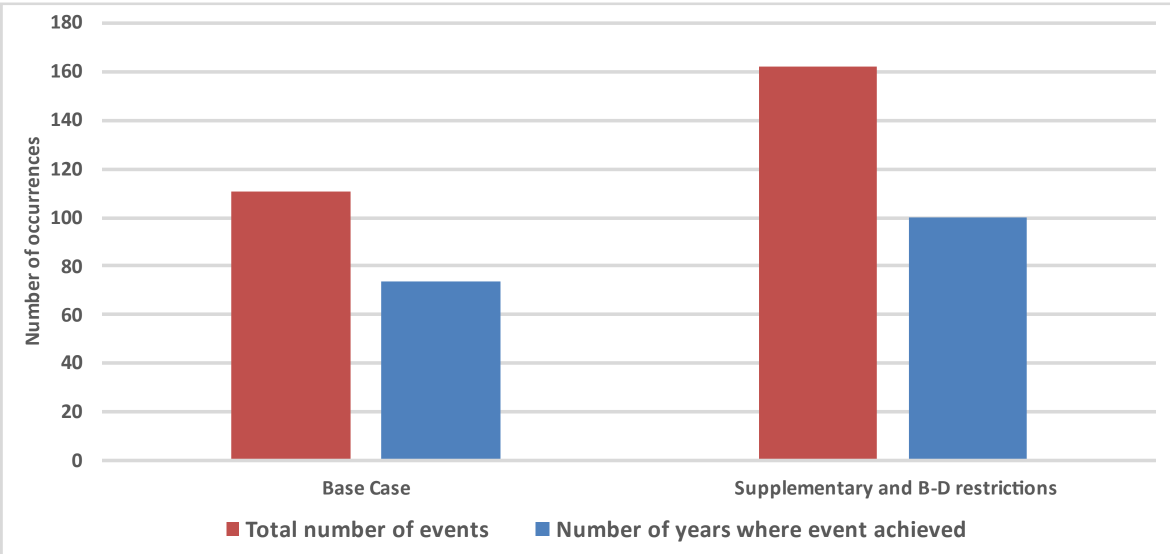
flow thresholds are reasonably low, and likely to be sensitive to small changes in modelled flows.

The modelling results shown in



indicate that suspension of supplementary and A, B, and C Class access can significantly improve the number of algal dispersal events and a smaller increase in the number of years where events are achieved (+ 22%).

Figure 9: Proposed alternate algal dispersion events at Wilcannia (3,000 ML/day for 7 days) - impact of suspension of supplementary and A, B, and C Class access



Proposed alternate flow targets for native fish passage

As a result of a review undertaken in 2021[24] to review the earlier North-West Flow Plan targets against contemporary science, an alternate proposal for fish passage was developed. This review

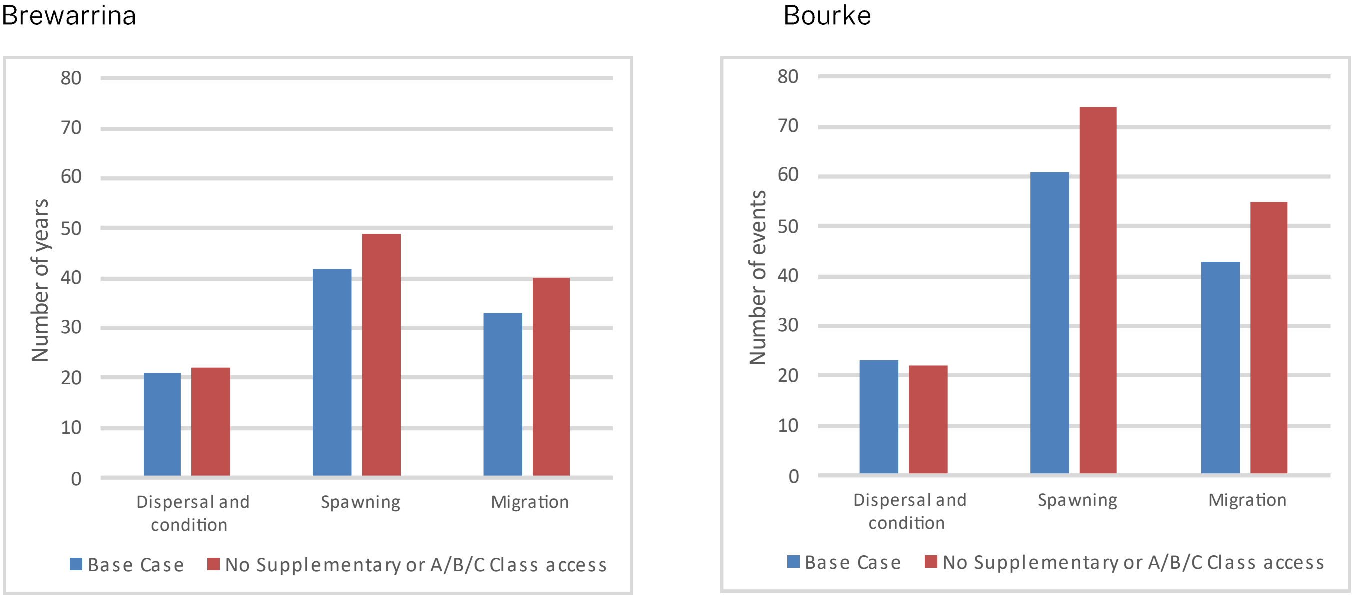
[24] Alluvium, 2021, Review of the Interim Unregulated Flow Management Plan for the North-West, Final report prepared by Alluvium Consulting Australia for DPIE Water, NSW

recommended that, to achieve the native fish outcomes, flow targets should include flows that promote migration, spawning, and dispersal and condition to enhance the effectiveness of fish migration targets. Therefore, the review recommended flow targets at Bourke and Brewarrina as follows:

- 15,000 ML/d for 15 days at Bourke between July and September (dispersal and condition)
- 15,000 ML/d for 15 days at Bourke between October and April (spawning)
- 14,000 ML/d for 15 days at Brewarrina between October and April (migration).

The modelling indicates that the bookend scenarios only result in a minor increase in the number of events that are achieved (**Error! Reference source not found.**).

Figure 10: Proposed alternate flow events at Brewarrina and Bourke for fish outcomes (additional events and years) – impact of suspension of supplementary and A, B, and C Class access over 119 years of model simulation



Water diversions

The objective of these scenarios was to explore potential flow benefits. These “bookend” scenarios also result in significant reductions in water use, as expected. These significant impacts to diversions are shown in Table 6.

Table 6. Stage 1A bookend scenario – Valley total annual average diversions - impact of suspension of floodplain harvesting, supplementary and A, B, and C Class access

Water diversions	Base case Current conditions (GL/y)	Scenario 1 Supplementary, and A/B/C Class access suspended (GL/y)	Scenario 2 FPH access suspended (GL/y)	Scenario 3 Supplementary, A/B/C Class, and FPH access suspended (GL/y)
NSW Border Rivers	209.19	159.15	176.31	124.90
Gwydir	445.96	368.72	365.81	290.85
Namoi	237.12	197.24	209.34	166.78
Macquarie	348.10	340.67	311.56	326.26
Barwon-Darling	165.41	49.16	145.79	5.74

Note: The small Barwon-Darling diversions still occurring in option 3 are the rainfall-runoff harvesting that was not readily able to be restricted with the existing model configurations.

5. Stage 1B – Regulated releases (use of general security)

Analysis description

Flows connecting river systems in the northern NSW portion of the Murray-Darling Basin could be improved by making releases of water for this purpose from the regulated tributary river systems. Modelling was undertaken to explore the potential benefits of supplying water from the major storages in the NSW Border Rivers, Gwydir, Namoi, and Macquarie regulated river systems.

In recognition that additional releases from major storages for connectivity purposes will have impacts to water users in the tributary valleys, this modelling tests the benefits and impacts of a limited release of water, based on a general security entitlement equivalent to the volume of general security entitlement that is held by environmental water managers (also referred to as held environmental water) in the valley. This approach also provides an initial upper bound estimate of the improvements in flows to the Barwon-Darling River system that could be achieved with the held environmental water.

Model configuration and assumptions

For this initial test, an additional irrigation node was placed at the end of each tributary river system and provided with the held environmental water for that valley (Table 7).

This irrigation node at the end of each tributary river ordered water using a summer irrigation pattern, but did not take the water, which instead flowed downstream to the end of the valley model. A summer crop demand was used to order the water such that the utilisation of the held environmental water licences remained similar to the average utilisation of other water users in the model.

It is not intended that Barwon-Darling water users would be able to divert any additional inflows under this scenario. However, there is no facility in the Barwon-Darling model to easily simulate a restriction to the additional inflows. Two options were tested – one with suspension of all Barwon-Darling A, B, and C Class access, and another without any additional restrictions on water use in the Barwon-Darling. The option without any additional restrictions on access in the Barwon-Darling indicated that there was only a small increase in Barwon-Darling diversions because of the additional inflows (see Table 8). This is largely due to the additional flows being provided to the

Barwon-Darling system being below B Class access thresholds, which prevented additional diversions much of the time. The results presented in this report are from the scenario without restrictions on Barwon-Darling water use, except Error! Reference source not found. where both scenarios are presented.

Table 7: Held environmental water entitlements configured in the use of general security scenario

Valley	Held environmental water entitlement (GL)	Location used in model
NSW Border Rivers	2.6	Mungindi
Gwydir	89.5	Mehi River near Collarenebri
Namoi	13.6	Walgett
Macquarie	126.0	Marebone Weir

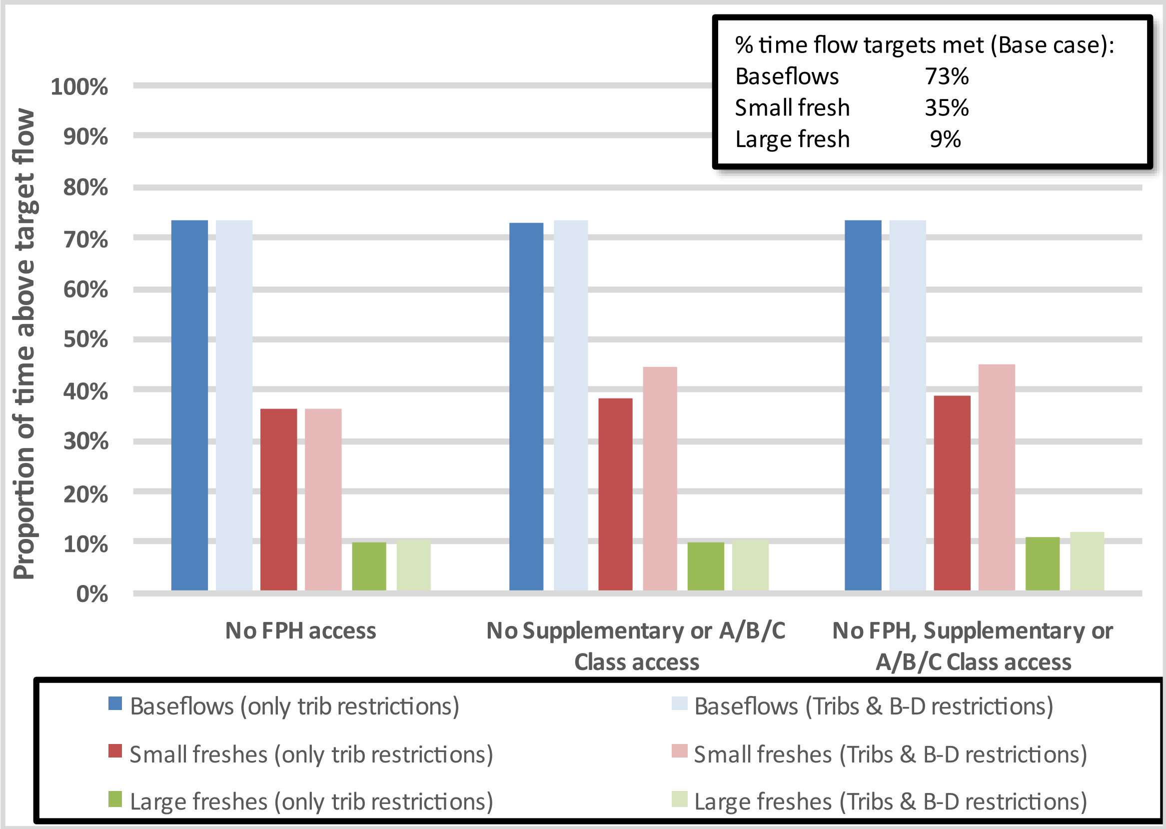
Modelling results

River flows

The modelling results for the regulated releases scenario and selected bookend scenarios are shown in **Error! Reference source not found.** to Figure 18 for selected flow metrics, including the existing North-West Flow Plan flow targets and proposed alternate algal and fish targets. The results generally show that the regulated releases (general security) provide more improvement in riparian flows and long-term water plan base flows at the end of the tributary rivers and along the Barwon-Darling than supplementary access restrictions. However, the regulated releases at lower rates tested in this scenario provided less improvement for small and large freshes and North-West Flow Plan target events.

Figure 12 shows that significant increases in the proportion of time that the end of system flows exceed the long-term water plan baseflow threshold. This is because the water ordered to the end of system is generally during lower flow periods.

Error! Reference source not found. to Figure 18 are a repeat of



, 6, 7, 8, 9 and 10 in Section 4, with the use of general security scenario results added for comparison. These show that regulated releases were better at improving base flows at the end of each tributary and along the Barwon-Darling than suspending floodplain harvesting, supplementary, and A, B, and C Class access (Figure 13 and Figure 14) . However, whilst regulated releases did improve the number of algal and fish targets, this improvement was less than that achieved by suspending floodplain harvesting, supplementary, and A, B, and C Class access (Figure 14 to Figure 18).

Figure 11: Tributary end of system flow increases for bookend (suspension of floodplain harvesting, supplementary, and A, B, and C Class access) and regulated releases scenarios

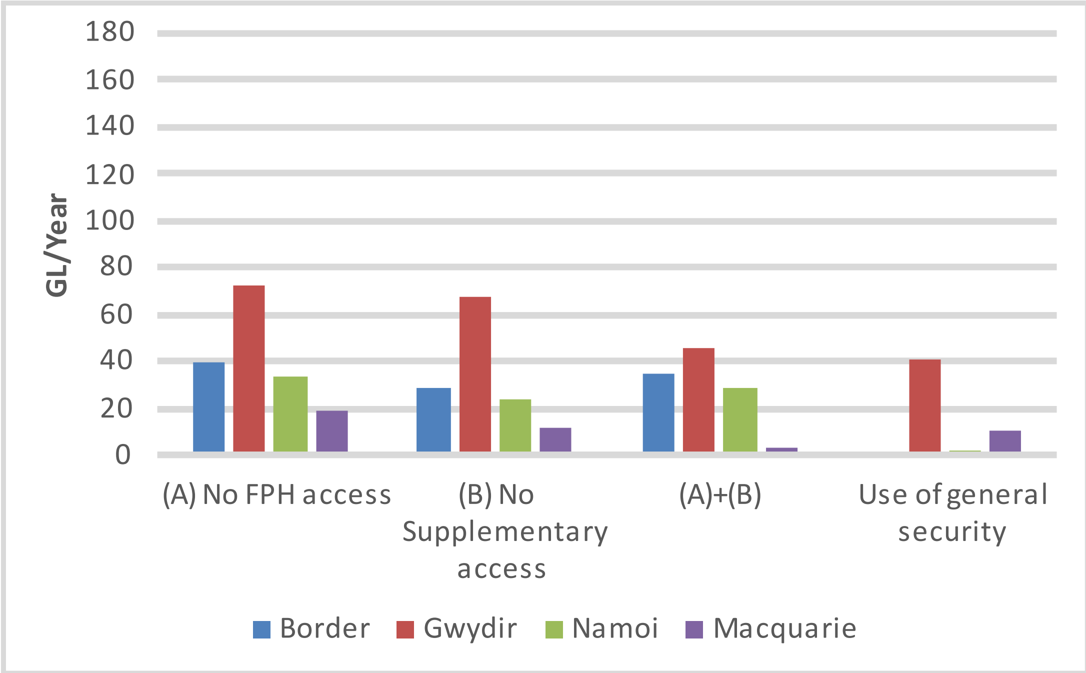


Figure 12: Improvements in the proportion of time that bookend (suspension of supplementary, and A, B, and C Class access) and regulated releases scenarios exceed the long-term water plan baseflow threshold at the end of tributary river systems

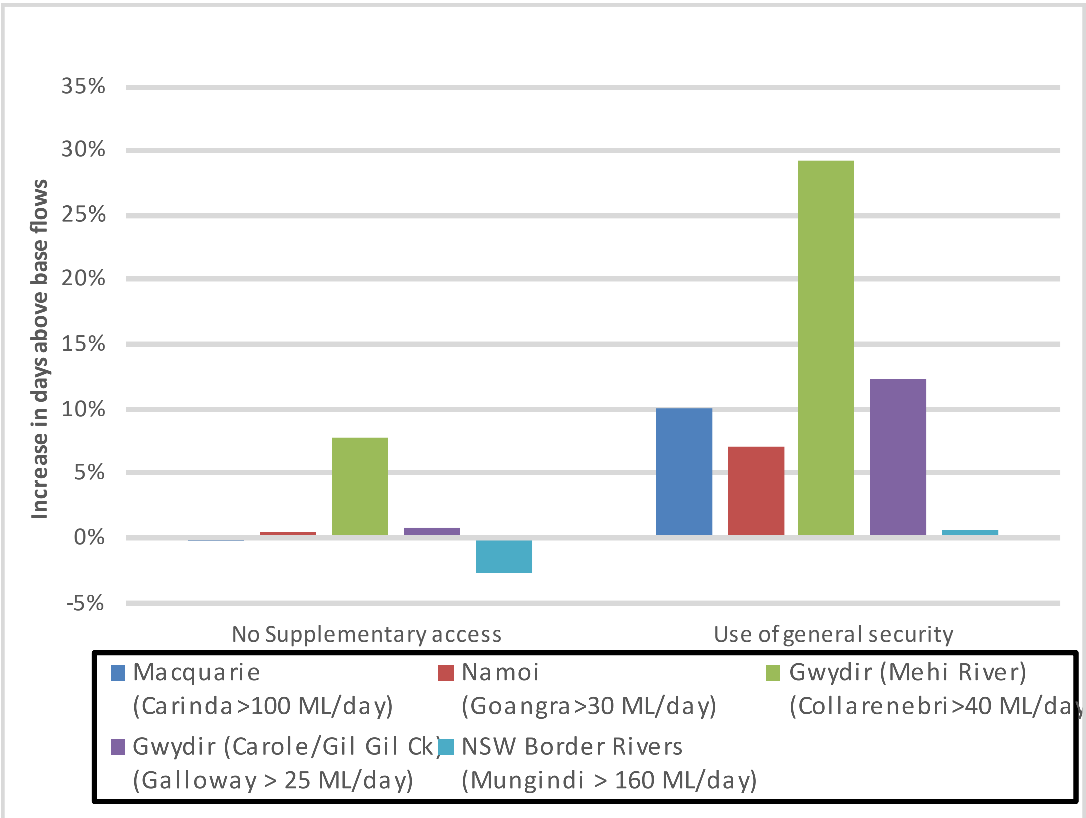


Figure 13: Change in Barwon-Darling Long-Term Water Plan flow classes at Bourke for bookend (suspension of floodplain harvesting, supplementary, and A, B, and C Class access) and regulated release scenarios

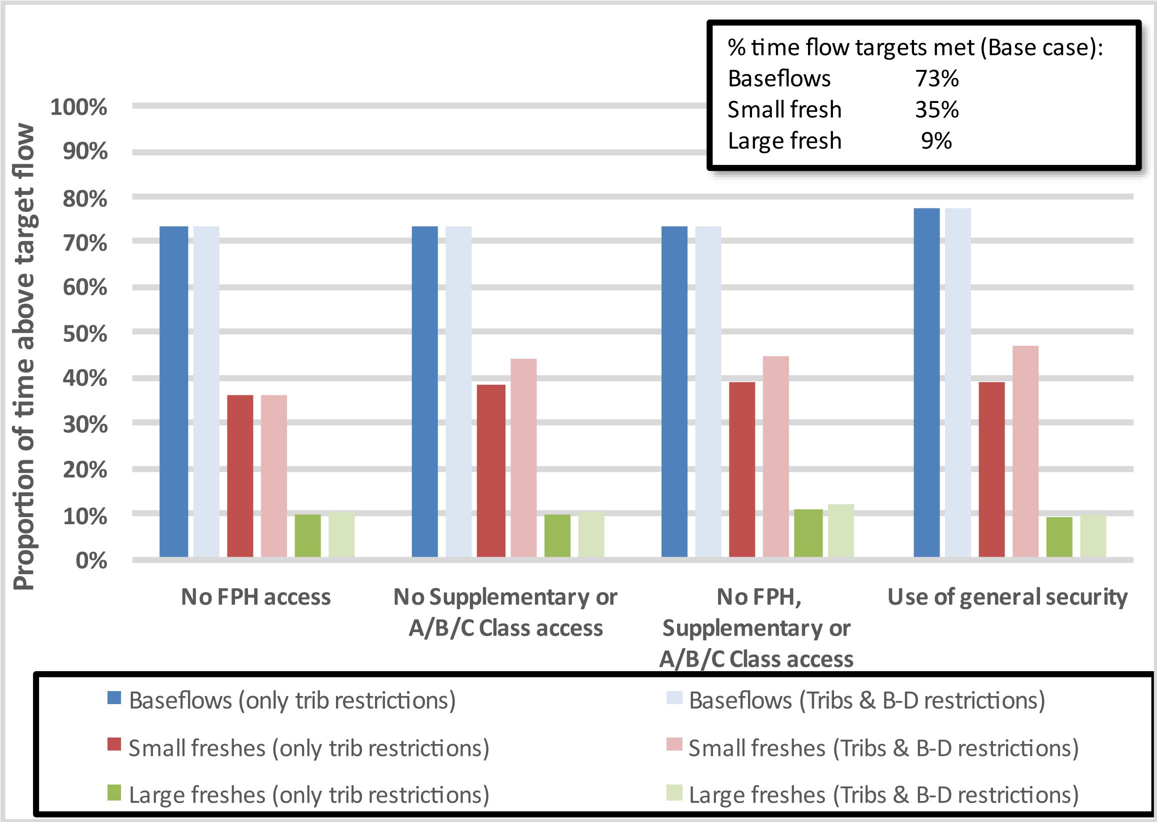


Figure 14: Modelled North-West Flow Plan algal dispersal events at Wilcannia (2 GL/day for 5 days) – for bookend (suspension of floodplain harvesting, supplementary, and A, B, and C Class access) and regulated releases scenarios

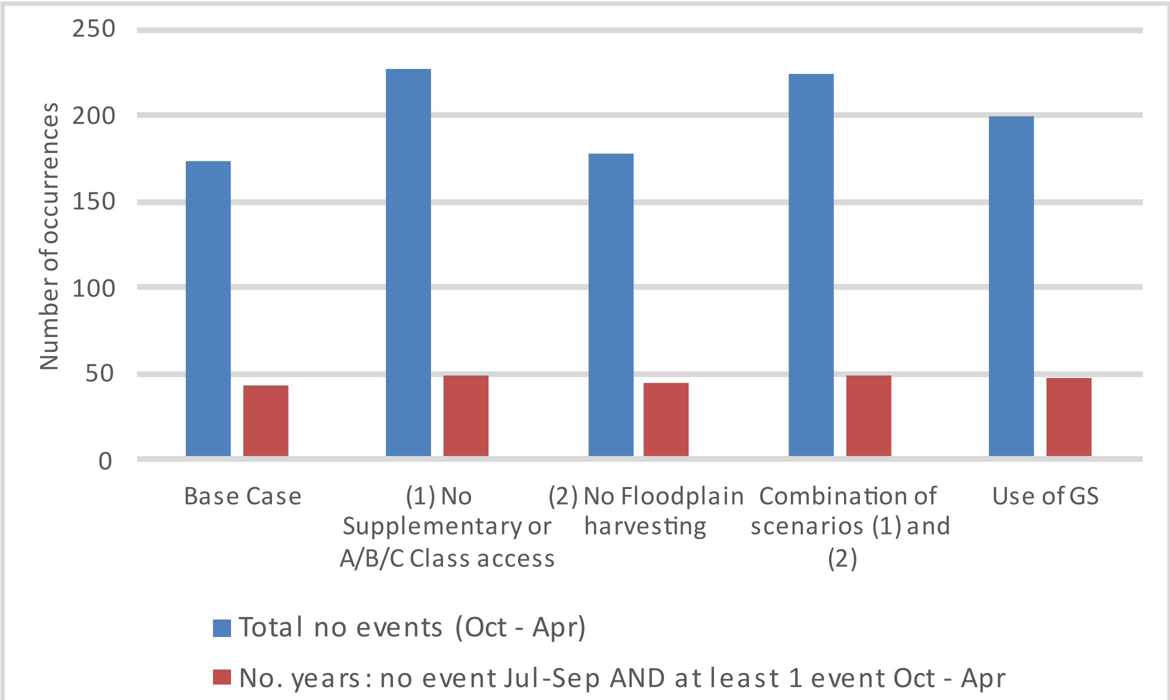


Figure 15: Modelled North-West Flow Plan fish passage events at Brewarrina for bookend (suspension of floodplain harvesting, supplementary, and A, B, and C Class access) and regulated releases scenarios over 119 years of model simulation

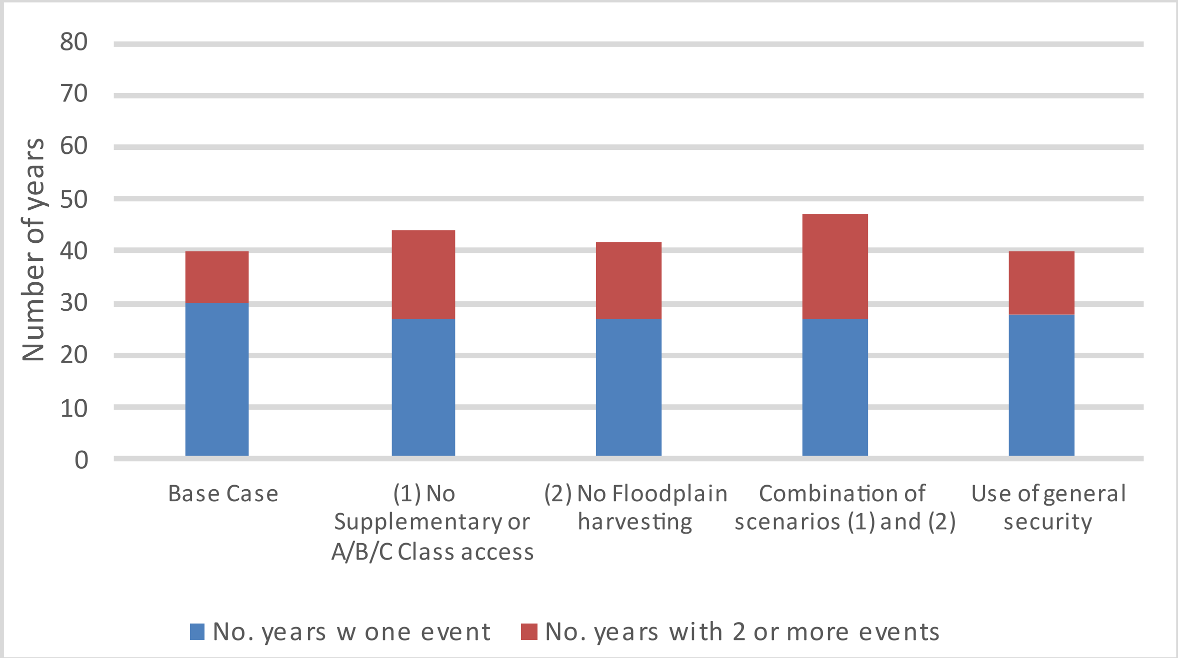


Figure 16: Modelled North-West Flow Plan fish passage events at Bourke for bookend (suspension of floodplain harvesting, supplementary, and A, B, and C Class access) and regulated releases scenarios over 119 years of model simulation

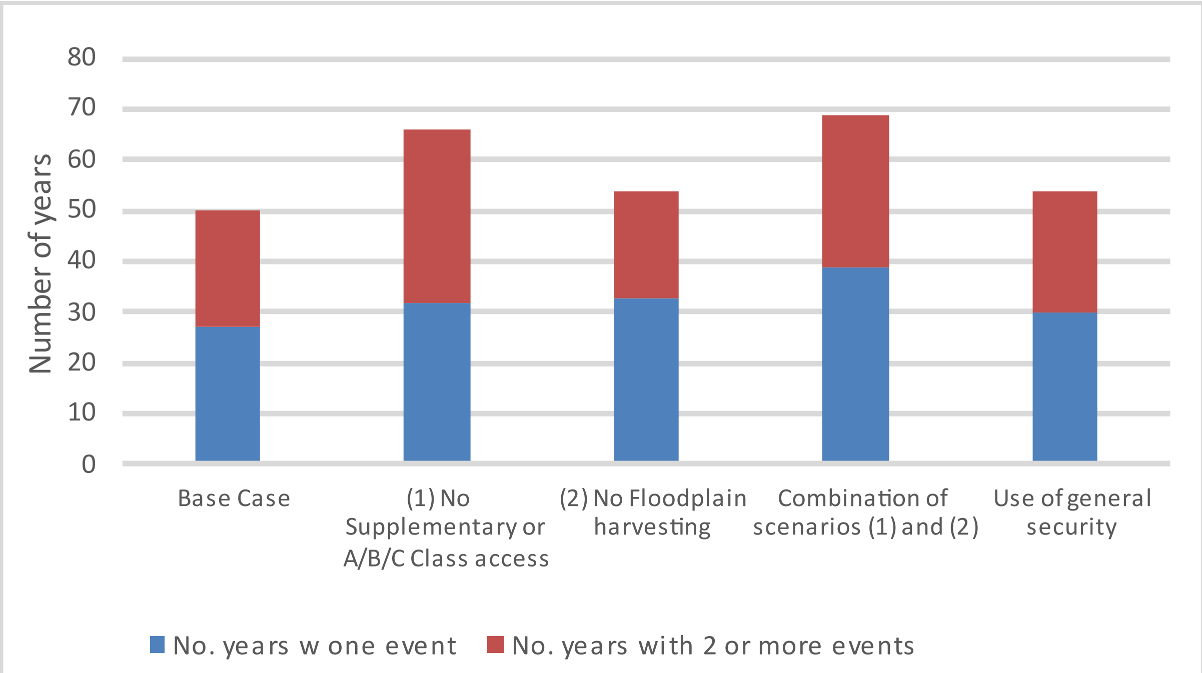


Figure 17: Proposed alternate algal dispersal events for bookend (suspension of supplementary, and A, B, and C Class access) and regulated releases scenarios over 119 years of model simulation

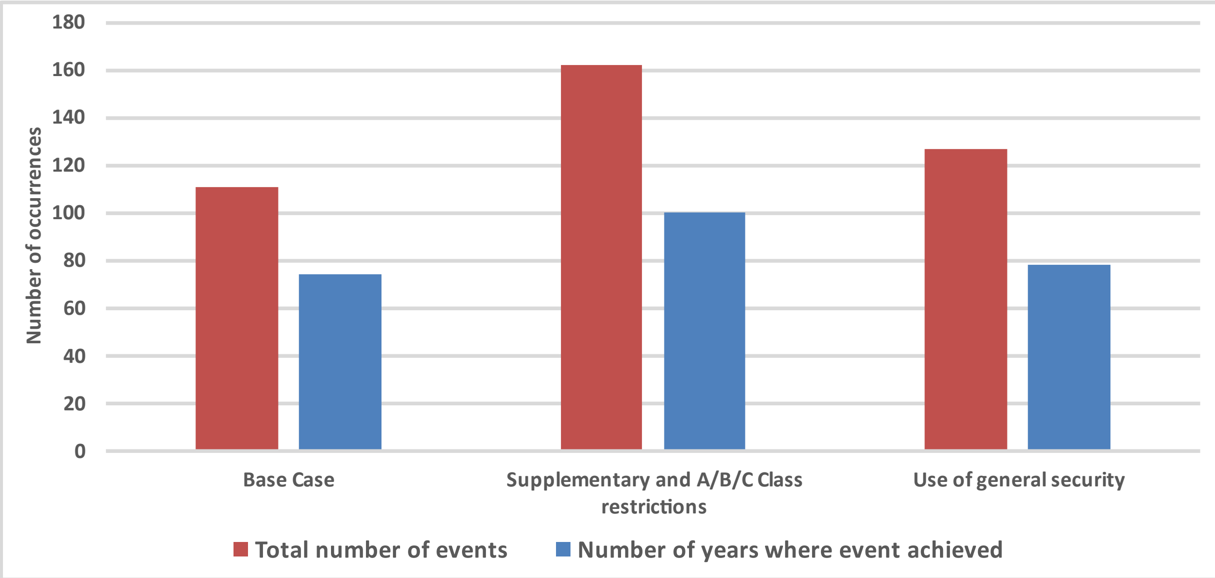
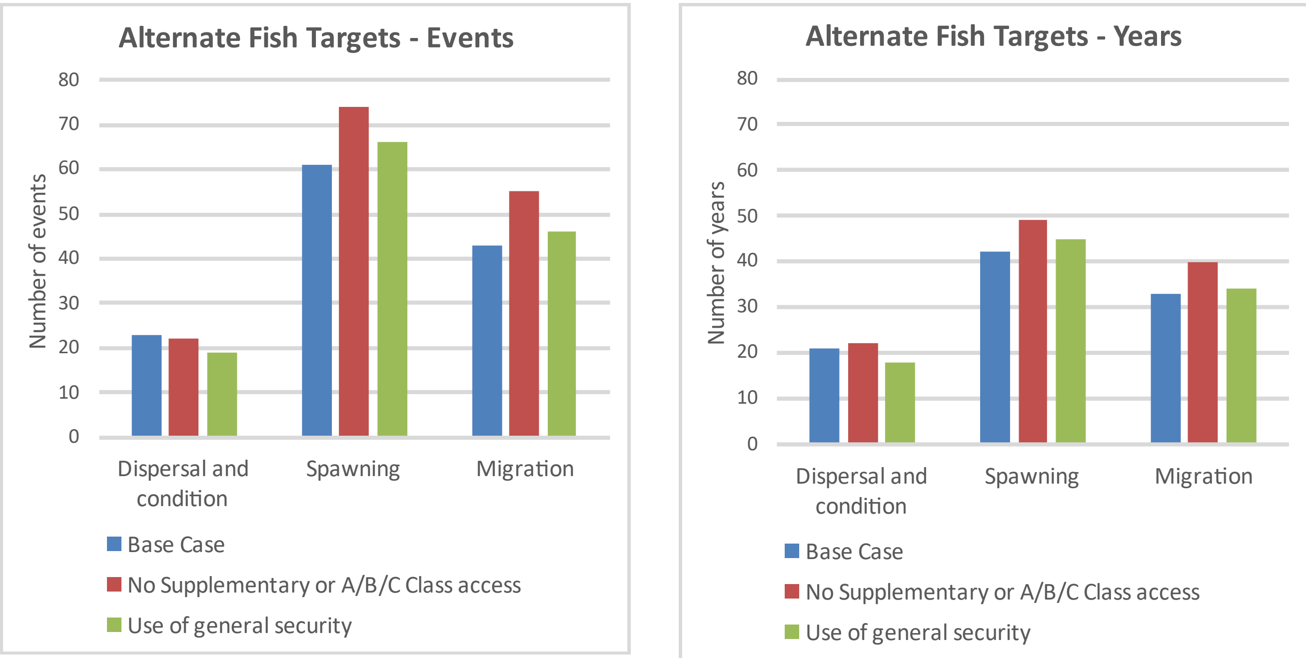


Figure 18: Proposed alternate fish target events for selected bookend (suspension of supplementary, and A, B, and C Class access) and regulated releases scenarios over 119 years of model simulation



Water diversions

In the base case model for each valley, held environmental water is represented as a water user and extracts water from the river. This use has been included in water use totals reported in Table 8 below. The results show that overall diversions are slightly lower than the base case. The delivery of significant volumes of general security water to the end of the regulated river systems has an impact on overall diversions, mainly as a result of the additional transmission losses incurred in delivery of the water to the end of the river system. There may also be small differences in the utilisation of held environmental water in the base case (configured to be similar to the water users from which the water was recovered) and the use of that water to the end of the regulated river systems (configured to be similar to typical utilisations in the valley).

Table 8: Impacts to water user diversions when general security held environmental water (HEW) is modelling as being used as the end of the system

Valley	Base case total diversions (GL/y)	Total diversions when HEW general security is delivered to end of system (GL/y)	Change to total diversions %	HEW general security delivered to end of system (GL/y)
NSW Border Rivers	209.2	208.2	-0.5%	1.4
Gwydir	446.0	435.9	-2.3%	35.7
Namoi	237.1	232.5	-1.9%	7.3
Macquarie	348.1	335.9	-3.5%	65.5
Barwon-Darling	165.4	168.4	+1.8%	N/A

6. Stage 1C – preliminary targeted restrictions analysis

Analysis description

Stage 1A modelling indicated that restrictions to supplementary, floodplain harvesting, and Barwon-Darling (A, B, and C Class) access provided no significant benefit to achieving North-West Flow Plan riparian flow targets or improving the proportion of time that flows exceeded the long-term water plan baseflow thresholds along the Barwon-Darling (Figure 3 and Figure 5). However, some improvement was observed in the number of times where the original North-West Flow Plan algal dispersal and fish passage events were achieved (Figure 6 to Figure 9).

Stage 1A modelling also underlined that applying restrictions to water access would produce very high impacts to water users without some ability to focus the restrictions to periods where they would help achieve more targeted flow events. In practice, operational forecasting to identify flow events where restrictions to water access would create an algal dispersal or fish passage event (where it would not otherwise be achieved) has so far proved too difficult to do.

However, to investigate what could be possible if sufficient improvements in operational forecasting could be achieved, another stage of modelling was undertaken. Where the Stage 1A modelling indicated that there were potential improvements in the algal and fish flow events, further modelling was undertaken to investigate the benefits that might be possible from a more targeted approach to the restriction of access to water than the broad suspension of access across the whole period of model simulation.

This work was undertaken for both the existing North-West Flow Plan targets for algal and fish outcomes, and the proposed alternate algal and fish targets arising from the 2021 review of the plan.

Model configuration and assumptions

A time series of restriction periods was prepared that identified with hindsight the periods where additional flow events or targets were achieved in Bookend Scenario 2 (no supplementary and A, B, and C Class access) compared to the base case. This process was initially undertaken to identify additional flow events that met the existing North-West Flow Plan algal dispersal and fish passage targets, and subsequently also for the proposed alternate algal dispersal and fish targets.

For both the original North-West Flow Plan targets and proposed alternate algal and fish targets, two options were investigated for identifying when to suspend supplementary and B, and C Class access:

- for each year in Bookend Scenario 2 where there were additional algal suppression or fish migration events compared to the base case (referred to as the “extra events” objective),
- for each year in Bookend Scenario 2 where there were algal suppression or fish migration events where there were none in the base case (referred to as the “extra years” objective).

In each year where suspended access was targeted, a simplified approach was taken to suspend supplementary and B and C Class access from September to February for all tributary valleys. Targeting suspension of access to particular events across four tributary valleys was found to be too time consuming. However, this could be undertaken in future work.

Due to the existing model configurations, changes to modelled floodplain harvesting results in changes to modelled river flows in the Barwon-Darling and not in the models for the regulated tributary river systems. This means that restricting access to floodplain harvesting in the regulated tributary river system models does not result in any improvement in the modelled river flows. In addition, targeted (time-varying) restrictions to floodplain harvesting were not possible with existing model configurations and were not able to be implemented in this stage of modelling.

Restrictions to access were implemented in the models for the regulated tributary rivers by increasing the supplementary access flows thresholds. For the Barwon-Darling, the previous method of reducing pump capacities to zero could not be applied for specific periods within the model simulation period (1895 – 2014, later extended to 2020). The Barwon-Darling model has an existing input time series of restrictions that are applied to ensure supply of water for critical needs in the Lower Darling. This time series input only applies to B and C Class licences, and restrictions to the much smaller A Class licences[25] were not pursued.

Similarly, to Stage 1A modelling, the base case and scenario modelling undertaken in Stage 1C used the maximum period of climate that was initially available for each model. However, the Barwon-Daring valley model had the shortest period of climate available (1895-2014), and the tributary model simulation period was adjusted to align with the period of the time series of restrictions generated in the Barwon-Darling model.

[25] There are approximately 9 GL of A Class water entitlement. Although use is generally not metered, the base case model simulates an average annual use of around 5.5 GL/year based on irrigator surveys undertaken as part of a broader project to establish irrigation infrastructure and behaviour (the Development History Project) in 2001.

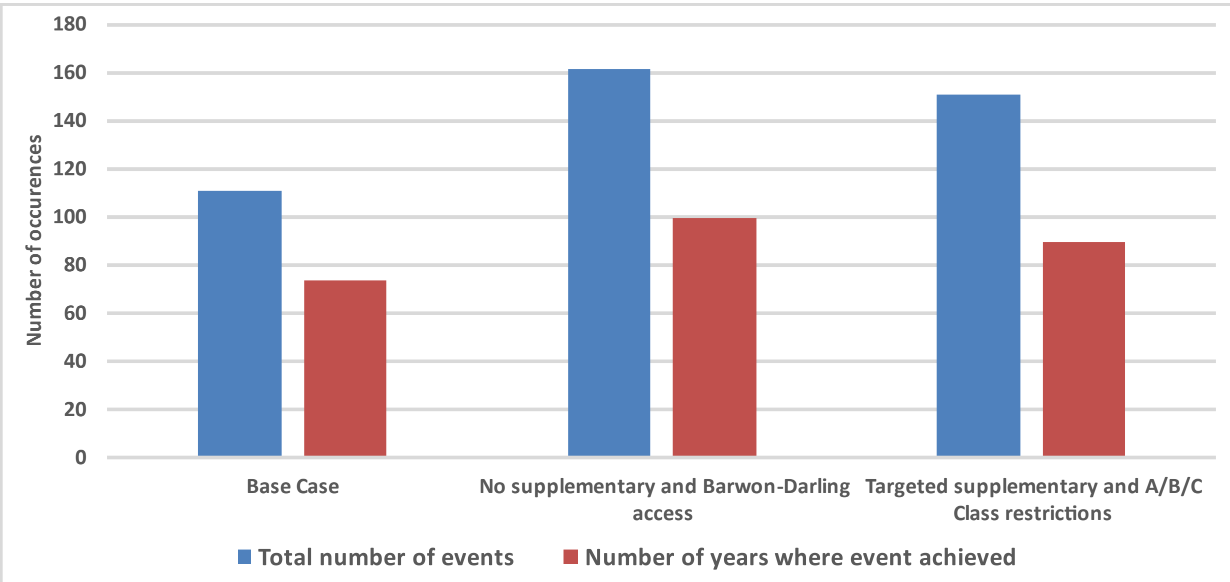
Modelling results

River flows

Algal suppression

Error! Reference source not found. and Figure 20 compare the results of the targeted restrictions for supplementary and B and C Class access to the bookend restrictions modelled in Stage 1A, for the existing and proposed alternate algal suppression targets. They show that for suspending access (Stage 1A) and targeted restrictions (Stage 1C) there is a significant increase in the number of algal suppression events that occur, and a more modest increase in the number of years with events occurring. This suggests that the restrictions often increase the number of events in years where at least one event is already occurring.

In **Error! Reference source not found.**, the targeted restrictions are not quite as effective as complete suspension for achieving the total number of events, as the targeting of restrictions was focused on only those years where there was no event between July and September and at least one event between October and April.



Fish migration

Figure 21 to Figure 23 compare the results of the targeted restrictions for supplementary and B and C Class access to the bookend restrictions modelled in Stage 1A, for the existing and proposed alternate fish passage targets. They show that for suspending access (Stage 1A) and targeted restrictions (Stage 1C) makes very little improvement to the high flow targets set for fish passage in the North-West Flow Plan at Brewarrina, and a modest improvement at Bourke. For the proposed new fish flow targets, these restrictions provided no improvement to the dispersal and condition flow events and only modest improvements to the spawning and migration target flow events.

Figure 21: Comparison of existing North-West Flow Plan fish passage threshold - Brewarrina (14 GL/day for 5 days) achieved by Bookend Scenario 2 (suspension of all supplementary and A, B, and C Class access) and targeted restrictions to supplementary and B/C Class access over 119 years of model simulation

shows that the targeted restrictions do not quite produce improvements in the same number of years as the suspensions, as the targeting of restrictions was based on the North-West Flow Plan targets rather than the proposed alternate algal targets.

Figure 19: Comparison of existing North-West Flow Plan algal suppression events at Wilcannia (2 GL/day for 5 days) achieved by Bookend Scenario 2 (suspension of all supplementary and A, B, and C Class access) and targeted restrictions to supplementary and B and C Class access

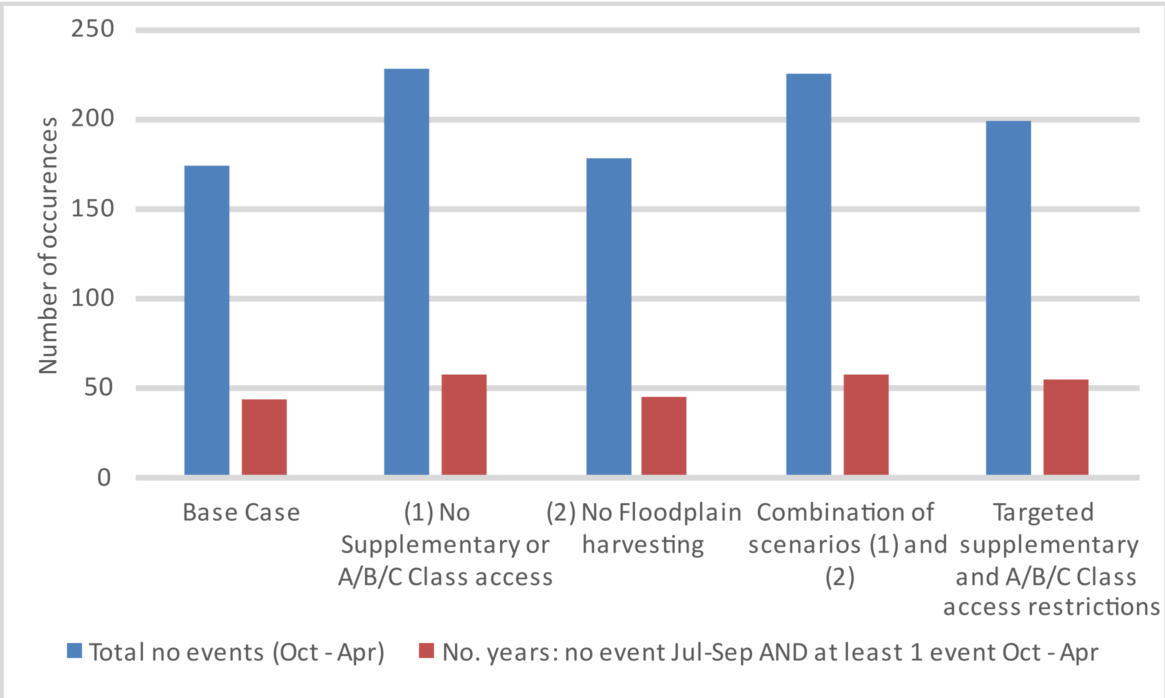
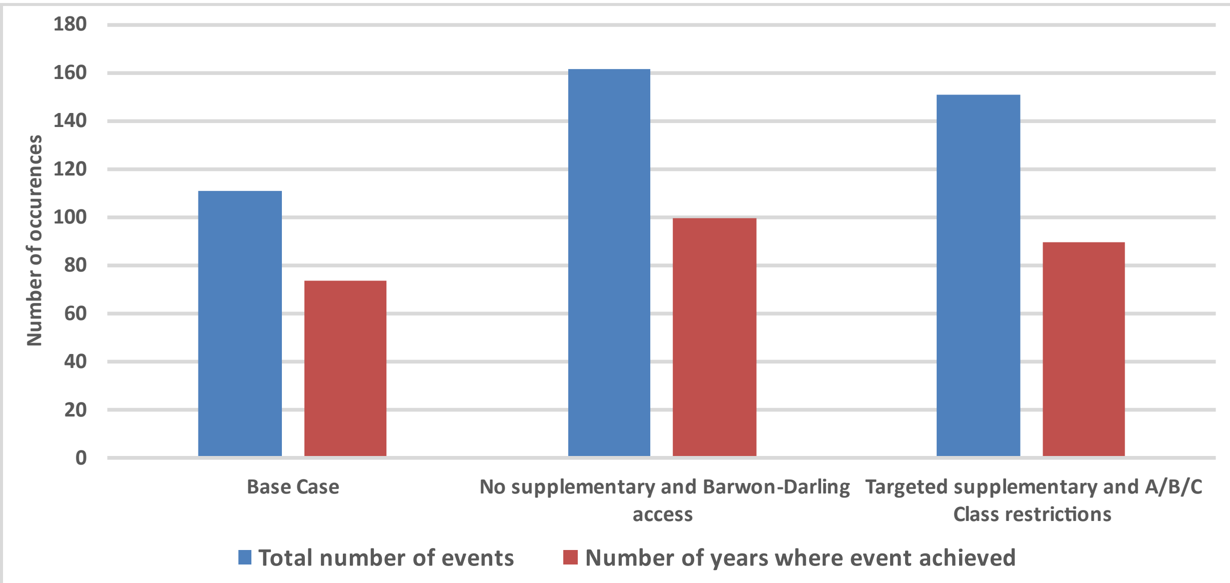


Figure 20: Comparison of proposed alternate algal dispersal events (3,000 ML/day for at least 7 days) achieved by Bookend Scenario 2 (suspension of all supplementary and A, B, and C Class access) and targeted restrictions to supplementary and B and C Class access over 119 years of model simulation



Fish migration

Figure 21 to Figure 23 compare the results of the targeted restrictions for supplementary and B and C Class access to the bookend restrictions modelled in Stage 1A, for the existing and proposed alternate fish passage targets. They show that for suspending access (Stage 1A) and targeted restrictions (Stage 1C) makes very little improvement to the high flow targets set for fish passage in the North-West Flow Plan at Brewarrina, and a modest improvement at Bourke. For the proposed new fish flow targets, these restrictions provided no improvement to the dispersal and condition flow events and only modest improvements to the spawning and migration target flow events.

Figure 21: Comparison of existing North-West Flow Plan fish passage threshold - Brewarrina (14 GL/day for 5 days) achieved by Bookend Scenario 2 (suspension of all supplementary and A, B, and C Class access) and targeted restrictions to supplementary and B/C Class access over 119 years of model simulation

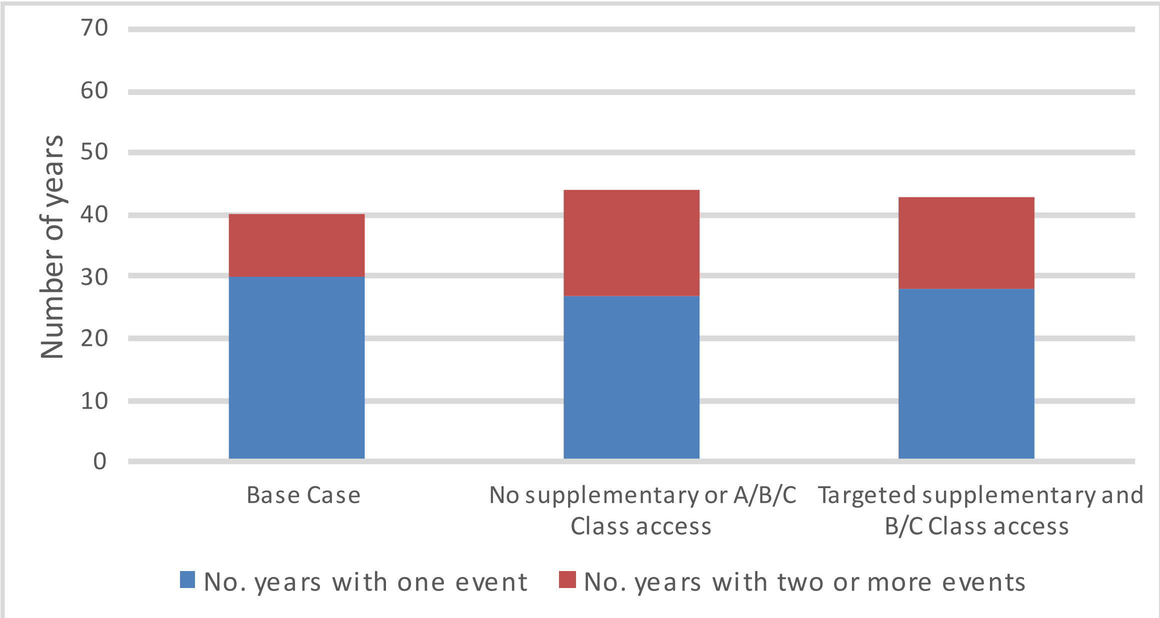


Figure 22: Comparison of existing North-West Flow Plan fish passage threshold – Bourke (10 GL/day for 5 days) achieved by Bookend Scenario 2 (suspension of all supplementary and A, B, and C Class access) and targeted restrictions to supplementary and B/C Class access over 119 years of model simulation

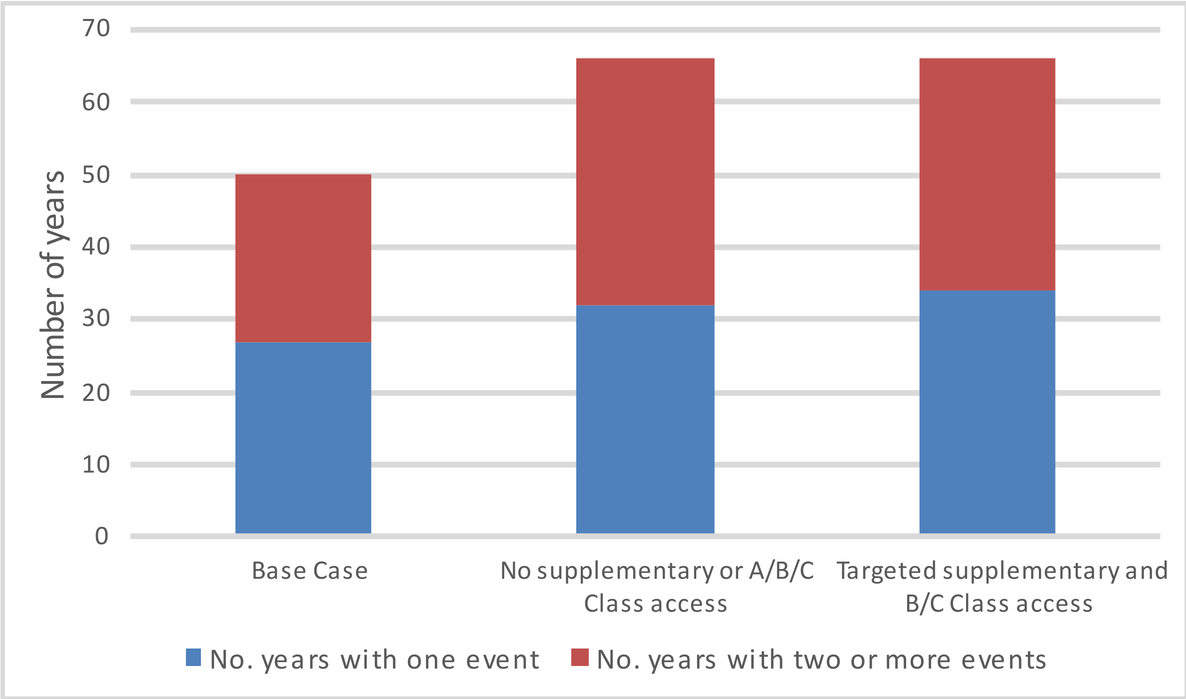
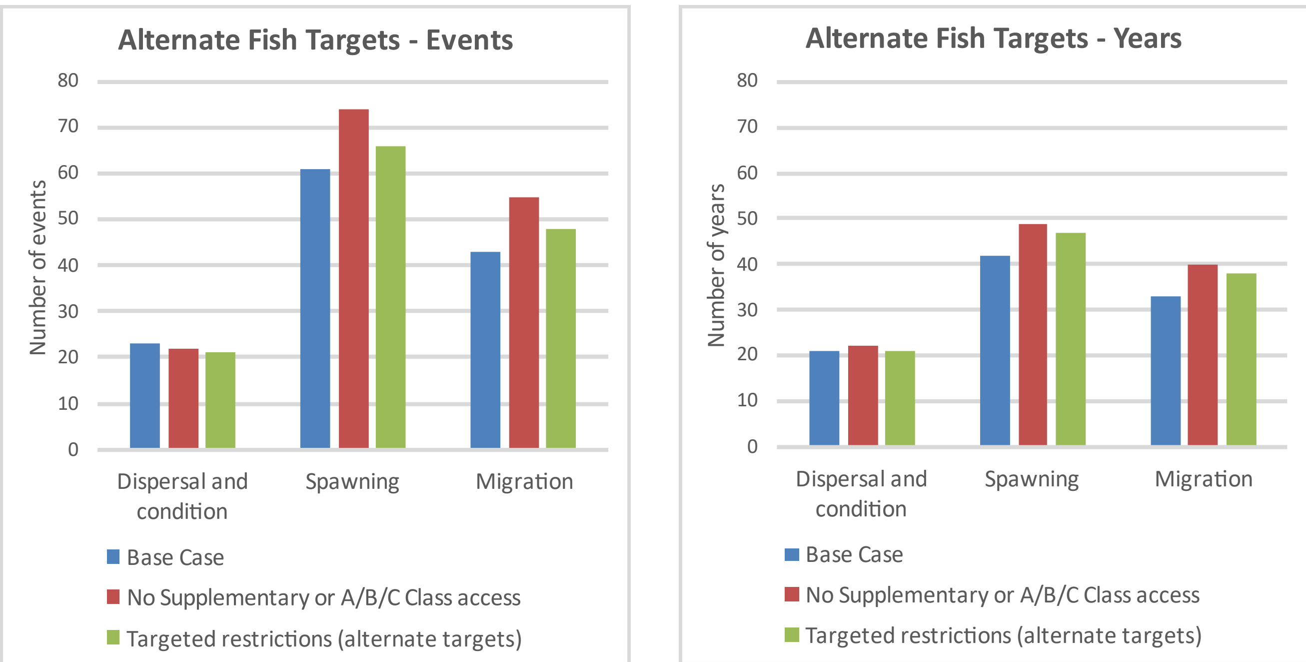


Figure 23: Comparison of proposed alternate fish target events achieved by Bookend Scenario 2 (suspension of all supplementary and A, B, and C Class access) and targeted restrictions to supplementary and B/C Class access over 119 years of model simulation



Water diversions

Changes in long-term average diversions are shown in Table 9, indicating that there are modest impacts to water users, although some valleys are more impacted than others. There are fewer impacts in the Macquarie regulated river system as supplementary access is a much smaller proportion of the overall water use in that valley.

Table 9: Long-term average diversions - targeted restrictions scenarios (North-West Flow Plan and proposed alternate algal and fish flow events)

Valley	Base case (GL/y)	Targeted restrictions for North-West Flow targets (GL/y)	Change	Targeted restrictions for alternate targets (GL/y)	Change
NSW Border Rivers	209.4	203.1	-3.0%	201.5	-3.8%
Gwydir	448.2	442.3	-1.3%	436.0	-2.7%
Namoi	241.9	236.8	-2.1%	234.8	-2.9%
Macquarie	343.1	342.7	-0.1%	342.5	-0.2%
Barwon-Darling	165.4	164.5	-0.6%	166.5	0.7%

Note 1: no targeted restrictions to floodplain harvesting have been modelled.

Note 2: Base case diversions vary slightly from earlier tables, as tributary models have been used a shorter period of climate records (1895-2014) to be consistent with the period of record available for the Barwon-Darling model.

7. Stage 2A – North-West Flow Plan: targeted restrictions for algal and fish flow targets

Option description

The proposed alternate algal flow targets and the existing North-West Flow Plan fish flow targets with the assumption of perfect forecasting have been investigated further as options for the Western Regional Water Strategy.

The two options modelled with the instrumental climate and inflows dataset were:

- Western Regional Water Strategy Option 3: restrictions targeting additional years where the proposed alternate algal dispersal flow event was achieved, and
- Western Regional Water Strategy Option 8: restrictions targeting additional years where either of the existing North-West Flow Plan fish passage events at Brewarrina and Bourke were achieved.

Model configuration and assumptions

For Stage 2 modelling, the base case has been remodelled using an instrumental climate data set extended from the previous 1895 to 2014 period to cover the 1895 to 2020 period, which incorporates the most recent drought in the northern Murray-Darling Basin. This extended climate data set has been used for modelling of all Stage 2 options. Use of the instrumental climate and inflows data sets allows comparison to modelling with the extended climate datasets[26].

The Stage 1C targeted restrictions scenarios were remodelled using the instrumental climate and inflow datasets for each valley for the period 1895 to 2020. This involved re-simulating the base case and the Stage 1A bookend scenario with suspension of supplementary and Barwon-Darling access, and then rederiving the time series of restriction periods that identified those periods where additional flow events or targets were achieved in the revised bookend scenario compared to the revised base case.

[26] Modelling using extended climate data sets will be published in a subsequent report.

The same general approach to placing restrictions on upstream access has been used as described in Section 6 (Stage 1C preliminary targeted restrictions analysis), with a time series of restriction periods applied where additional flow alternate algal flow events or targets were achieved in Bookend Scenario 2 (no supplementary and A, B, and C Class access) compared to the base case.

All Stage 2 modelling is based on the same methodology as Stage 1C, which includes:

- restrictions to supplementary access, B and C Class access
- no simulation of variations to water returning to the river from the floodplain in response to changes in floodplain harvesting (model limitation), and
- no time-varying restrictions to floodplain harvesting (model limitation).

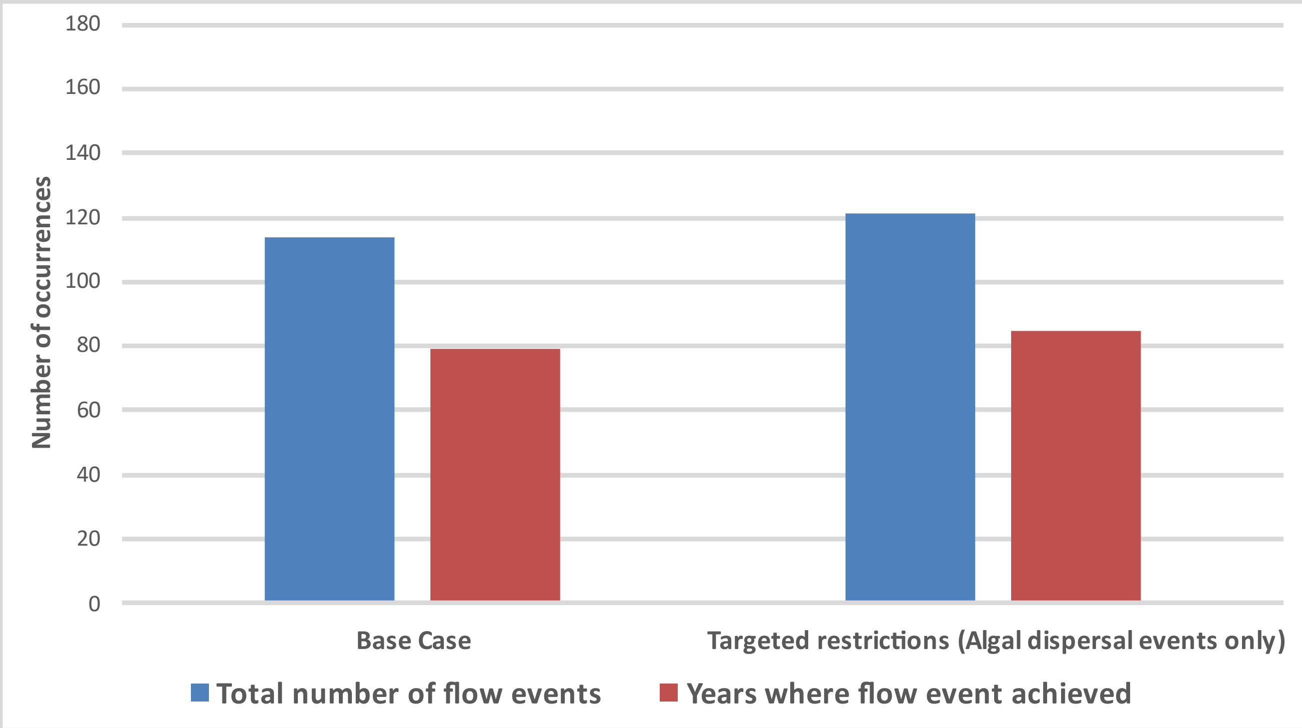
Modelling results

River flows

Modelling results for the proposed alternate algal targets were examined for the base case and Option 3 across spring and summer (September – February). The modelling results indicate that flows only remained above all four of the proposed algal suppression thresholds for the spring-summer period (as described in Section 4) in 4% of years under the base case, with all other years having at least some period of time below the thresholds.

The modelling results shown in Figure 24 indicate that targeted suspension of supplementary and B/C Class access can make a small improvement in the number of algal dispersal events and in the number of years with an algal dispersal event (+ 7%).

Figure 24: Targeted restrictions to supplementary and B/C Class access to achieve proposed alternate algal dispersion events (3,000 ML/day at Wilcannia for 7 days) over 125 years of model simulation



The proportion of time that flows occur in each of the flow classes defined in the long-term watering plan[27] for each of the regulated tributary valleys is shown in

[27] Long-term water plans can be accessed at: Long term water plans | NSW Environment and Heritage

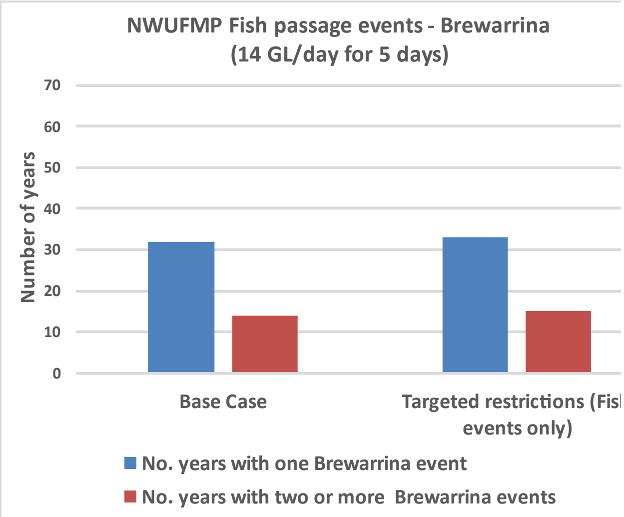
Table 10. The model results indicate that the targeted restrictions to supplementary access to achieve algal dispersal events do not significantly change the distribution of flows between the flow classes. Most changes are less than 1%, and there is generally a trend towards reduction in time that flows are in the baseflow or very low flows categories.

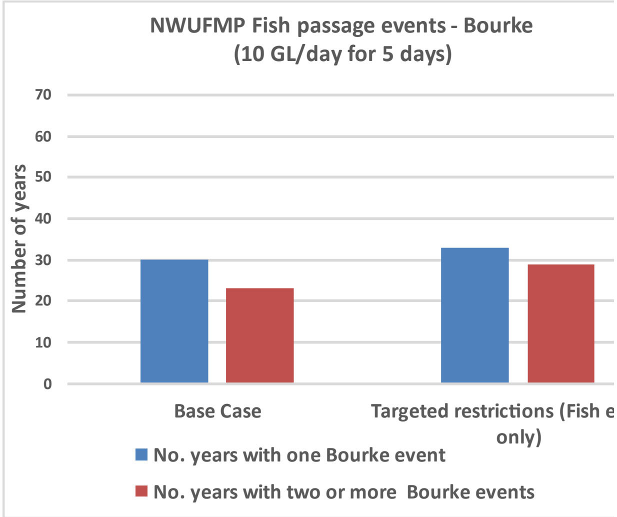
Table 10: Proportion of time in long-term water plan flow classes: Western Regional Water Strategy Option 3 - targeted restrictions to supplementary and B/C Class access to achieve algal dispersal events

Valley	Base case	Option 3: Targeted restrictions for algal dispersal	Change
NSW Border Rivers at Mungindi			
Very low or no flows (<160 ML/day)	42.3%	42.3%	0.0%
Baseflows (160-550 ML/day)	25.9%	25.8%	-0.1%
Small freshes (550-5400 ML/day)	28.1%	28.2%	0.1%
Large freshes / floods (>5,400 ML/day)	3.7%	3.7%	0.0%
(Gwydir) Mehi River at Collarenebri			
Very low or no flows (<40 ML/day)	56.6%	56.0%	-0.6%
Baseflows (40-90 ML/day)	15.9%	16.1%	0.2%
Small freshes (90-900 ML/day)	20.6%	20.9%	0.3%
Large freshes / floods (>900 ML/day)	6.9%	7.1%	0.2%
(Gwydir) Gil Gil Creek at Galloway			
Very low or no flows (<40 ML/day)	56.8%	56.7%	-0.1%
Baseflows (40-90 ML/day)	10.1%	10.3%	0.1%
Small freshes (90-900 ML/day)	29.5%	29.4%	-0.1%
Large freshes / floods (>900 ML/day)	3.6%	3.6%	0.0%
Namoi River at Walgett			
Very low or no flows (<30 ML/day)	42.4%	42.4%	-0.1%
Baseflows (30-200 ML/day)	27.4%	27.5%	0.0%
Small freshes (200-2,250 ML/day)	19.0%	19.0%	-0.1%
Large freshes / floods (>2,250 ML/day)	11.1%	11.2%	0.1%

Figure 25 shows the results of the Western Regional Water Strategy Option 8 (existing North-West Flow Plan fish flow targets), indicating that only very small improvements in either the number of events or the number of years with events would occur.

Figure 25: Western Regional Water Strategy Option 8: targeted restrictions to supplementary and B/C Class access to achieve North-West Flow Plan fish passage events over 125 years of model simulation





The proportion of time that flows occur in each of the flow classes defined in the long-term water plan for each of the regulated tributary valleys is shown in

Table 11. As was the case with algal dispersal events, the model results indicate that the targeted restrictions to supplementary access to achieve North-West Flow Plan fish passage events do not significantly change the distribution of flows between the flow classes. Most changes are less than 1%, and there is generally a trend towards reduction in time that flows are in the baseflow or very low flows categories.

Table 11: Proportion of time in long-term flow plan river flow classes: Western Regional Water Strategy Option 8 - targeted restrictions to supplementary and B and C Class access to achieve North-West Flow Plan fish passage events

Valley	Base case	Option 8: Targeted restrictions for fish passage	Change
NSW Border Rivers at Mungindi			
Very low or no flows (<160 ML/day)	42.3%	42.4%	0.1%
Baseflows (160-550 ML/day)	25.9%	25.8%	0.0%
Small freshes (550-5400 ML/day)	28.1%	28.0%	-0.2%
Large freshes / floods (>5,400 ML/day)	3.7%	3.8%	0.1%
(Gwydir) Mehi River at Collarenebri			
Very low or no flows (<40 ML/day)	56.6%	56.0%	-0.6%
Baseflows (40-90 ML/day)	15.9%	16.1%	0.2%
Small freshes (90-900 ML/day)	20.6%	20.5%	-0.1%
Large freshes / floods (>900 ML/day)	6.9%	7.4%	0.5%
(Gwydir) Gil Gil Creek at Galloway			
Very low or no flows (<40 ML/day)	56.8%	56.8%	0.1%
Baseflows (40-90 ML/day)	10.1%	10.1%	-0.1%
Small freshes (90-900 ML/day)	29.5%	29.4%	-0.1%
Large freshes / floods (>900 ML/day)	3.6%	3.7%	0.1%
Namoi River at Walgett			
Very low or no flows (<30 ML/day)	42.4%	42.5%	0.1%
Baseflows (30-200 ML/day)	27.4%	27.3%	-0.1%
Small freshes (200-2,250 ML/day)	19.0%	18.9%	-0.1%
Large freshes / floods (>2,250 ML/day)	11.1%	11.2%	0.1%

Water diversions

The results in Table 12 show that there are impacts to upstream water users from targeted restrictions to achieve algal dispersal and fish passage events.

Table 12: Long-term average diversions – targeted supplementary and B and C Class access restrictions to achieve Western Regional Water Strategy option 3 (proposed alternate algal dispersal events), and option 8 (North-West Flow Plan fish passage events)

Valley	Base case total diversions (GL/y)	Targeted restrictions: algal dispersal events (GL/y)	Change	Targeted restrictions: fish passage events (GL/y)	Change
NSW Border Rivers	206.4	204.5	-0.9%	199.9	-3.1%
Gwydir	449.5	446.8	-0.6%	441.5	-1.8%
Namoi	226.9	225.7	-0.5%	222.1	-2.1%
Barwon-Darling	161.8	161.3	-0.3%	159.9	-1.2%

Note: no targeted restrictions to floodplain harvesting have been modelled.

8. Stage 2B – Menindee critical storage target

Option description

Storage volumes at Menindee Lakes have fallen to critically low levels four times over the last 20 years, with the most recent period between 2017 and 2020 being the lowest on record. An initial investigation was undertaken to consider the potential for restrictions to upstream water use to improve water storage levels at Menindee Lakes during critical dry periods, similarly to the perfect forecasting scenarios discussed in Section 6 (Stage 1C modelling).

For this modelling, a Menindee Lakes storage trigger has been set for commencing and ceasing restrictions to B and C Class Barwon-Darling and upstream supplementary access.

Three different Western Regional Water Strategy options have been modelled, as described in Table 13, where the first volume listed for each option (195 or 480) is the storage volume that (when reached) triggers the commencement of upstream restrictions, and the second volume (250 or 640) is the volume that triggers the cessation of upstream restrictions. The volume of 195 GL has been assessed as the volume in Lakes Wetherell and Pamamaroo (the upper lakes) required to maintain releases to the Lower Darling over a 12 month period without any inflows to the Menindee Lakes. A volume of 250 GL for cessation of upstream restrictions allows for 12 months of releases and an additional volume (assessed as approximately 60 GL) to make an initial flushing flow to mitigate poor water quality.

Table 13: Menindee critical storage trigger – Western Regional Water Strategy options modelled

Option	Storages considered	Restriction start trigger	Restriction end trigger
Option 6: 195/250 top two lakes	Active storage in Lakes Wetherell and Pamamaroo[28]	195	250
Option 6b: 480/640 across Menindee Lakes	Active storage across all lakes	480	640

[28] This includes Lake Tandure and Copi Hollow

Option	Storages considered	Restriction start trigger	Restriction end trigger
Option 6c: 195/250 across Menindee Lakes	Total storage across all lakes	195	250

Model configuration and assumptions

The same approach to placing restrictions on upstream access has been used as described in Section 6 (Stage 1C preliminary targeted restrictions analysis), with a time series of restriction periods developed from the base case model results whenever the modelled storage volume Menindee Lakes was below the critical storage threshold volumes.

The scenarios have no forecasting of Menindee inflows that are in transit through upstream valleys over the previous few months, and do not anticipate Menindee Lakes storage volumes falling below or rising above, the specified thresholds. To simplify the initial modelling, restrictions are placed and then lifted at the same time across all upstream valleys.

Suspending modelled water access in upstream valleys will alter the volume of water in Menindee Lakes compared to the base case scenario, which could then lead to changes in the time series input restrictions used in the Barwon-Darling model. This could be addressed by undertaking iterations of the modelling scenarios until the time series of restrictions for upstream valleys matched closely with the period that the Menindee Lakes storage volumes were below the thresholds. No iterations between the upstream models and the Lower Darling model were undertaken to address these effects in this preliminary modelling, and this could be considered further in future work.

When considering the modelling results for this scenario, the following should be noted:

- Hydrologic models (and the Barwon-Darling IQQM in particular) tend to over-simulate low flows, and therefore over-simulate Menindee storage for the lower storage volumes. However, this happens for both the base case and scenarios, and this issue is not as significant for comparisons between model results.
- No restrictions have been applied in the model to Lower Darling and NSW Murray water users.
- All Stage 2 modelling is based on the same methodology as Stage 1C, which includes:
    - no simulation of variations to water returning to the river from the floodplain in response to changes in floodplain harvesting (model limitation), and
    - no time-varying restrictions to floodplain harvesting (model limitation).

Modelling results

Menindee storage volumes

The exceedance charts (modelled daily storage volumes ranked from highest to lowest) in

and Figure 27 show that the restrictions improved the storage volumes at Menindee Lakes at the mid to lower storage volumes. The proportion of time that the storage volumes were below the triggers compared to the base case for each scenario are shown in Table 14.

Figure 26: Percentage of time Menindee Lakes storage* volumes are exceeded for Western Regional Water Strategy Options 6 (195/250 top 2 lakes), 6b (480/640 all lakes), and 6c (195/250 all lakes) (1895 – 2020)

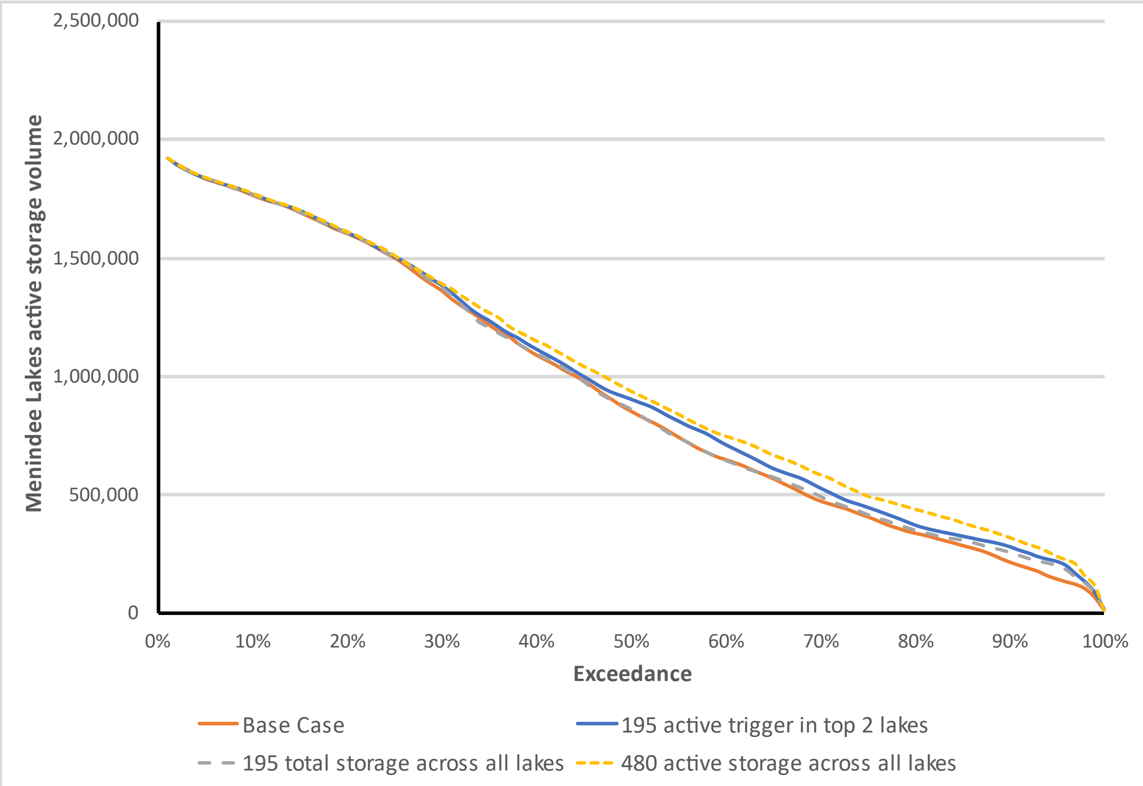
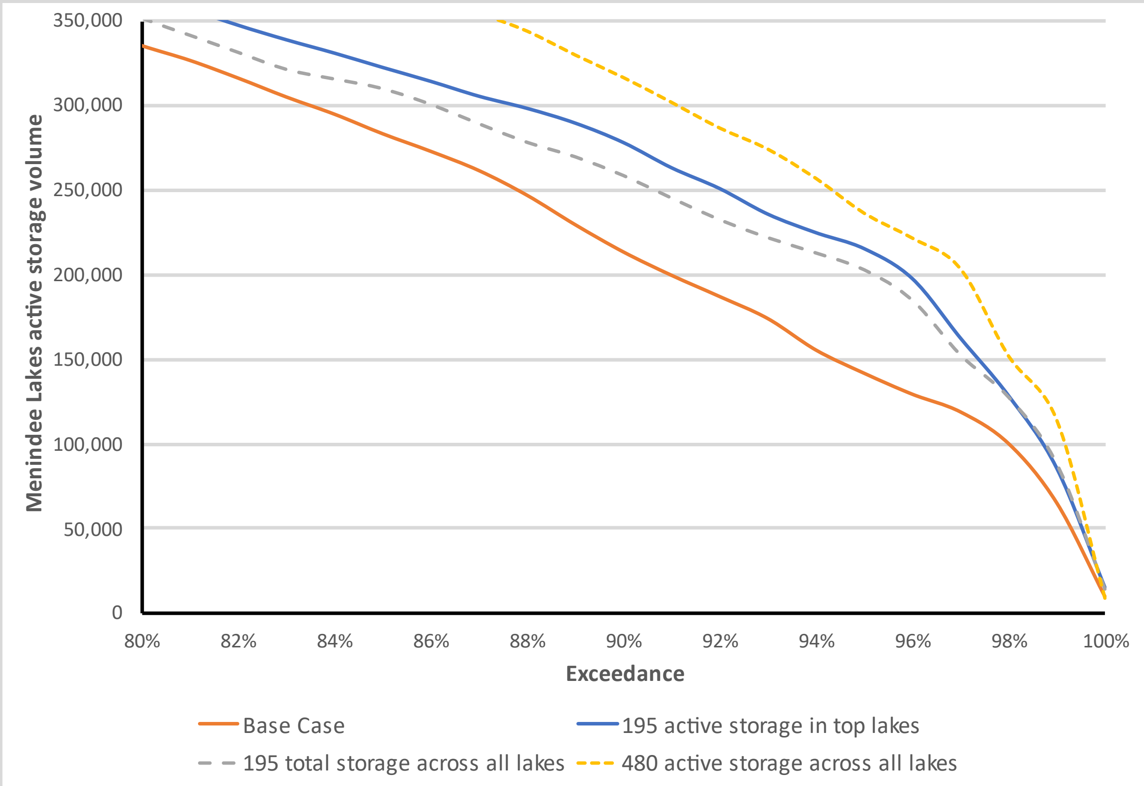


Figure 27: (Lower right portion of Figure 26) Percentage of time Menindee Lakes storage volumes* are exceeded for Western Regional Water Strategy Options 6 (195/250 top 2 lakes), 6b (480/640 all lakes), and 6c (195/250 all lakes)



*Excludes the small volumes in Copi Hollow and Lake Speculation

Table 14: Change in proportion of time Menindee Lakes is below storage triggers

	Proportion of time below storage thresholds		
	Option 6 (195/250 GL active storage top lakes)	Option 6b (480/640 GL active storage - all lakes)	Option 6c (195/250 GL total storage - all lakes)
Base Case	21%	31%	7%
Scenario	15%	24%	5%

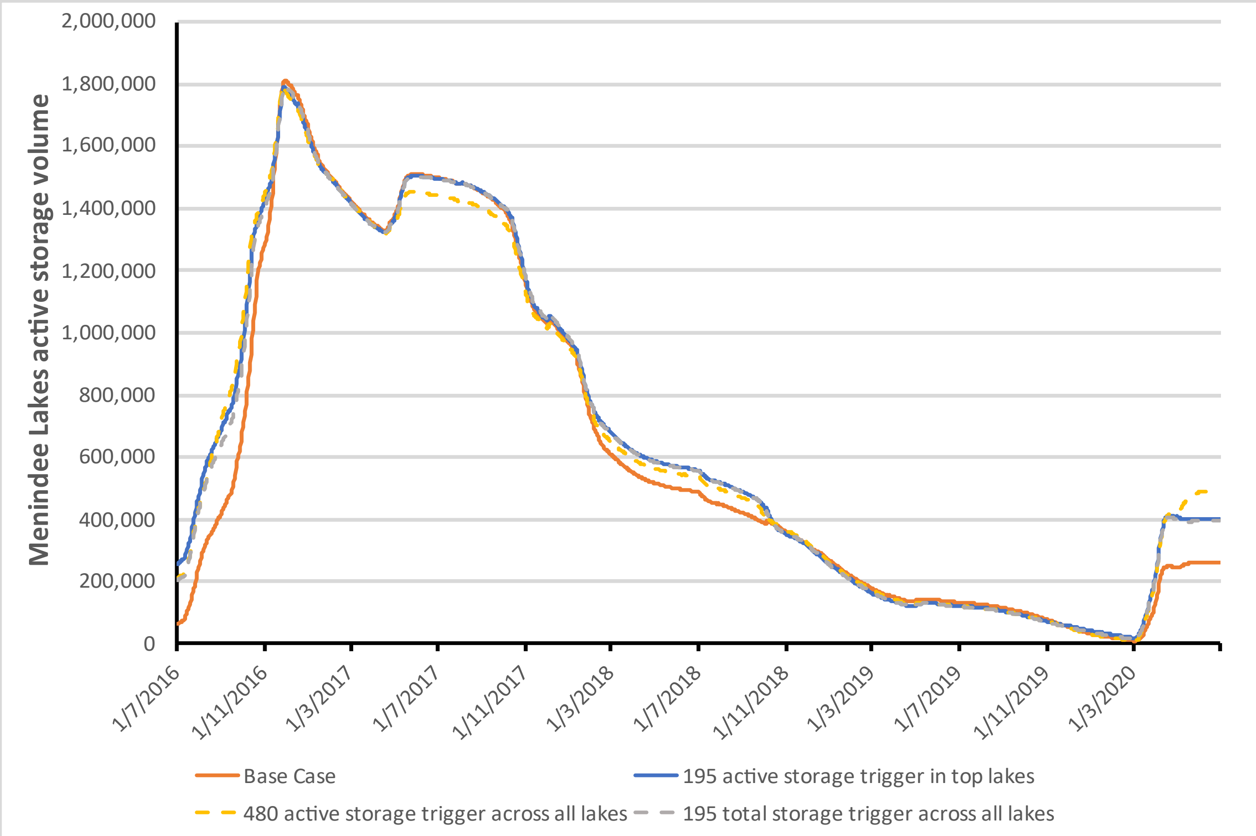
Note: Each base case proportion is different as it relates to the different threshold for each scenario.

For each of the storage trigger options, the modelled volume of water in Menindee Lakes during the recent drought is shown in Figure 28 below. This shows that there would have been little difference in the outcomes at Menindee Lakes under the various options, although it can be seen that Option 6b (480/640 GL across all lakes) results in more improvement at Menindee Lakes in 2020 for the smaller flow event.

The number of days of restriction modelled for each of the options was found to largely over-lap, as expected. However, there was an increase in the number of days of restriction between Option 6

(195/250 GL in top lakes) and Option 6b (480 GL across all lakes) from 20% of days to 25% of days over the 125 years of model simulation.

Figure 28: Menindee Lakes observed and modelled storage volumes* 2016-2020: Options 6 (195/250 top 2 lakes), 6b (480/640 all lakes), and 6c (195/250 all lakes)



*Excludes the small volumes in Copi Hollow and Lake Speculation

River flows

The proportion of time that flows occur in each of the flow classes defined in the long-term water plan for each of the regulated tributary valleys is shown in Table 15. The model results indicate that the targeted restrictions to supplementary access when the storage volume at Menindee Lakes falls below the trigger volumes in each scenario do not significantly change the distribution of flows between the flow classes. Most changes are less than 1%, and there is generally a trend towards reduction in time that flows are in the baseflow or very low flows categories.

Table 15: Proportion of time in long-term water plan river flow classes: Option 6 (195/250 top 2 lakes), 6b (480/640 all lakes), and 6c (195/250 all lakes)

Valley	Base case	Option 6 (195/250 top lakes)	Change	Option 6b (480/640 all lakes)	Change	Option 6c (195/250 all lakes)	Change
NSW Border Rivers at Mungindi							
Very low or no flows (<160 ML/day)	42.3%	42.8%	0.4%	43.3%	0.9%	42.7%	0.4%
Baseflows (160-550 ML/day)	25.9%	25.2%	-0.7%	24.6%	-1.3%	25.4%	-0.5%
Small freshes (550-5400 ML/day)	28.1%	28.2%	0.1%	28.1%	0.0%	28.1%	0.0%
Large freshes / floods (>5,400 ML/day)	3.7%	3.9%	0.2%	4.0%	0.4%	3.8%	0.1%
(Gwydir) Mehi River at Collarenebri							
Very low or no flows (<40 ML/day)	56.6%	55.7%	-1.0%	55.1%	-1.6%	56.2%	-0.5%
Baseflows (40-90 ML/day)	15.9%	15.5%	-0.4%	15.8%	-0.1%	15.6%	-0.3%
Small freshes (90-900 ML/day)	20.6%	20.9%	0.3%	20.8%	0.2%	20.9%	0.2%
Large freshes / floods (>900 ML/day)	6.9%	8.0%	1.1%	8.3%	1.5%	7.4%	0.5%

Valley	Base case	Option 6 (195/250 top lakes)	Change	Option 6b (480/640 all lakes)	Change	Option 6c (195/250 all lakes)	Change
(Gwydir) Gil Gil Creek at Galloway							
Very low or no flows (<40 ML/day)	56.8%	57.1%	0.3%	56.8%	0.1%	56.9%	0.1%
Baseflows (40-90 ML/day)	10.1%	9.9%	-0.2%	9.9%	-0.2%	10.2%	0.0%
Small freshes (90-900 ML/day)	29.5%	29.1%	-0.4%	29.3%	-0.2%	29.3%	-0.3%
Large freshes / floods (>900 ML/day)	3.6%	3.8%	0.3%	4.0%	0.4%	3.7%	0.1%
Namoi River at Walgett							
Very low or no flows (<30 ML/day)	42.4%	42.1%	-0.4%	42.0%	-0.4%	42.2%	-0.2%
Baseflows (30-200 ML/day)	27.4%	27.7%	0.3%	27.7%	0.2%	27.6%	0.1%
Small freshes (200-2,250 ML/day)	19.0%	19.0%	0.0%	19.0%	-0.1%	19.1%	0.1%
Large freshes / floods (>2,250 ML/day)	11.1%	11.2%	0.1%	11.3%	0.2%	11.1%	0.0%
Macquarie River at Carinda							
Very low or no flows (<100 ML/day)	72.9%	72.5%	-0.5%	72.4%	-0.5%	72.5%	-0.5%
Baseflows (100-140 ML/day)	3.3%	3.3%	0.0%	3.3%	0.1%	3.3%	0.1%
Small freshes (140-700 ML/day)	12.9%	13.3%	0.4%	13.3%	0.4%	13.2%	0.3%
Large freshes / floods (>700 ML/day)	10.9%	11.0%	0.0%	11.0%	0.1%	11.0%	0.1%

Water diversions

The results in Table 16 to Table 18 show that there are impacts to upstream water users from the restrictions using the Menindee Lakes total storage volume triggers for Option 6, 6b, and 6c, with impacts increasing with the trigger volumes (i.e. Option 6b with a 480/640 GL trigger across all lakes has the largest impact). The results also show that there are corresponding benefits to downstream water users, primarily in the Lower Darling.

Table 16: Long-term average diversions for Western Regional Water Strategy option 6: 195/250 GL active storage trigger in Wetherell and Pamamaroo

Valley	Base case total diversions (GL/y)	Option 6 diversions (GL/y)	Change	Largest annual impact (GL)
NSW Border Rivers	206.9	194.3	-6.1%	-84.3 (-43%)
Gwydir	451.2	433.8	-3.8%	-123.2 (-19%)
Namoi	227.0	218.7	-3.7%	-61.2 (-56%)
Macquarie	325.1	324.4	-0.2%	-20.8 (-10%)
Barwon-Darling	160.2	155.7	-2.8%	-160.5 (-61%)
Lower Darling	66.4	69.2	+4.2%	Not assessed
NSW Murray	1,575.8	1,576.5	+0.04%	Not assessed

Note 1: Maximum annual impacts are expressed as a volume, and in parentheses as a percentage of the base case diversions in that year

Note 2: no targeted restrictions to floodplain harvesting have been modelled

Table 17: Long-term average diversions for Wester Regional Water Strategy option 6b: 480/640 GL active storage trigger in Menindee Lakes

Valley	Base case total diversions (GL/y)	Option 6b diversions (GL/y)	Change	Largest annual impact (GL)
NSW Border Rivers	206.9	189.6	-8.4%	-102.5 (-34%)
Gwydir	451.2	425.5	-5.7%	-131.5 (-29%)
Namoi	227.0	214.3	-5.6%	-65.8 (-28%)
Macquarie	325.1	323.1	-0.6%	-25.6 (-13%)
Barwon-Darling	160.2	143.8	-10.2%	-212.6 (-76%)
Lower Darling	66.4	70.0	+5.4%	-
Murray	1,575.8	1576.9	+0.07%	-

Note 1: Maximum annual impacts are expressed as a volume, and in parentheses as a percentage of the base case diversions in that year

Note 2: no targeted restrictions to floodplain harvesting have been modelled.

Table 18: Long-term average diversions– for Western Regional Water Strategy option 6c: 195/250 GL total storage trigger across Menindee Lakes

Valley	Base case total diversions (GL/y)	Option 6 diversions (GL/y)	Change	Largest annual impact (GL)
NSW Border Rivers	206.9	201.1	-2.8%	-68.1 (-20%)
Gwydir	451.2	442.9	-1.8%	-95.7 (-21%)
Namoi	227.0	223.0	-1.8%	-59.5 (-37%)

Valley	Base case total diversions (GL/y)	Option 6 diversions (GL/y)	Change	Largest annual impact (GL)
Macquarie	325.1	324.9	-0.1%	-16.3 (-5%)
Barwon-Darling	160.2	159.4	-2.8%	-153.1 (-58%)
Lower Darling	66.4	67.4	+1.5%	-
Murray	1,575.8	1577.1	+0.08%	-

Note 1: Maximum annual impacts are expressed as a volume, and in parentheses as a percentage of the base case diversions in that year

Note 2: no targeted restrictions to floodplain harvesting have been modelled.

9. Stage 2C – Replenishment releases

Option description

This option (Western Regional Water Strategy option 4) has been investigated to test the potential for "replenishment" releases from storage in the major NSW regulated tributary river systems to reduce periods of very low or no flows. Replenishment flows were trialled from the NSW Border Rivers, Gwydir and Namoi regulated rivers.

The modelled commencement of restrictions in the Barwon-Darling valley under the existing "resumption of flow rule" was used as a trigger for a release of water from the storages in the regulated tributaries to test how well regulated releases could break up extended periods of low flows.

Model configuration and assumptions

A replenishment release of 20 GL of water from storage in each of the NSW Border Rivers, Gwydir, and Namoi valleys was configured to occur over a period of 20 days whenever restrictions under the resumption of flows rule commenced, with flows ordered at the end of each regulated system at the operational supply limit. Water was supplied to the end of each river system in a simple pattern with flows ramping up quickly to the operational limits shown in Table 19 over three-four days, held at that limit for approximately 12-14 days, and then ramping down more slowly over approximately a week.

No restrictions were placed on water users in the Barwon-Darling Valley for this scenario due to restrictions in modelling capacity. If inflows to the Barwon-Darling River from these releases are protected under the existing active management arrangements (not currently able to be modelled), there will be some small additional benefits compared to the results shown in Table 20.

Table 19: Assumed operation flow limits for replenishment flows

End of system flow point	Estimated operational limit (ML/day)
Macintyre River at Mungindi	1,000
Mehi River at Collarenebri	800

End of system flow point	Estimated operational limit (ML/day)
Carole Creek at Galloway	200
Namoi River at Walgett	1,000

Modelling results

River flows

The replenishment releases provide additional flows to the end of the NSW Border, Gwydir, and Namoi regulated river systems. Table 20 below shows the changes to the end of system flows across the flow classes defined in the relevant valley long-term water plan.

Table 20: Proportion of time in long-term flow plan river flow classes: Western Regional Water Strategy option 4 - replenishment releases

Valley	Base case	Option 4	Change
NSW Border Rivers at Mungindi			
Very low or no flows (<160 ML/day)	42.3%	41.2%	-1.1%
Baseflows (160-550 ML/day)	25.9%	26.2%	0.4%
Small freshes (550-5400 ML/day)	28.1%	28.9%	0.8%
Large freshes / floods (>5400 ML/day)	3.7%	3.7%	0.0%
(Gwydir) Mehi River at Collarenebri			
Very low or no flows (<40 ML/day)	56.5%	55.5%	-1.0%
Baseflows (40-90 ML/day)	16.0%	16.0%	0.0%
Small freshes (90-900 ML/day)	20.6%	21.3%	0.7%
Large freshes / floods (>900 ML/day)	6.9%	7.1%	0.2%
(Gwydir) Gil Gil Creek at Galloway			
Very low or no flows (<40 ML/day)	56.8%	56.0%	-0.8%
Baseflows (40-90 ML/day)	10.2%	10.1%	-0.1%
Small freshes (90-900 ML/day)	29.4%	30.4%	1.0%
Large freshes / floods (>900 ML/day)	3.6%	3.6%	0.0%
Namoi River at Walgett			

Valley	Base case	Option 4	Change
Very low or no flows (<30 ML/day)	42.4%	38.8%	-3.6%
Baseflows (30-200 ML/day)	27.4%	30.0%	2.6%
Small freshes (200-2250 ML/day)	19.0%	20.1%	1.0%
Large freshes / floods (>2250 ML/day)	11.1%	11.1%	0.0%

Water diversions

The long-term average diversions under the base case and option 4 for each valley are shown in Table 21.

Table 21: Long-term average diversions: Western Regional Water Strategy option 4 - replenishment releases

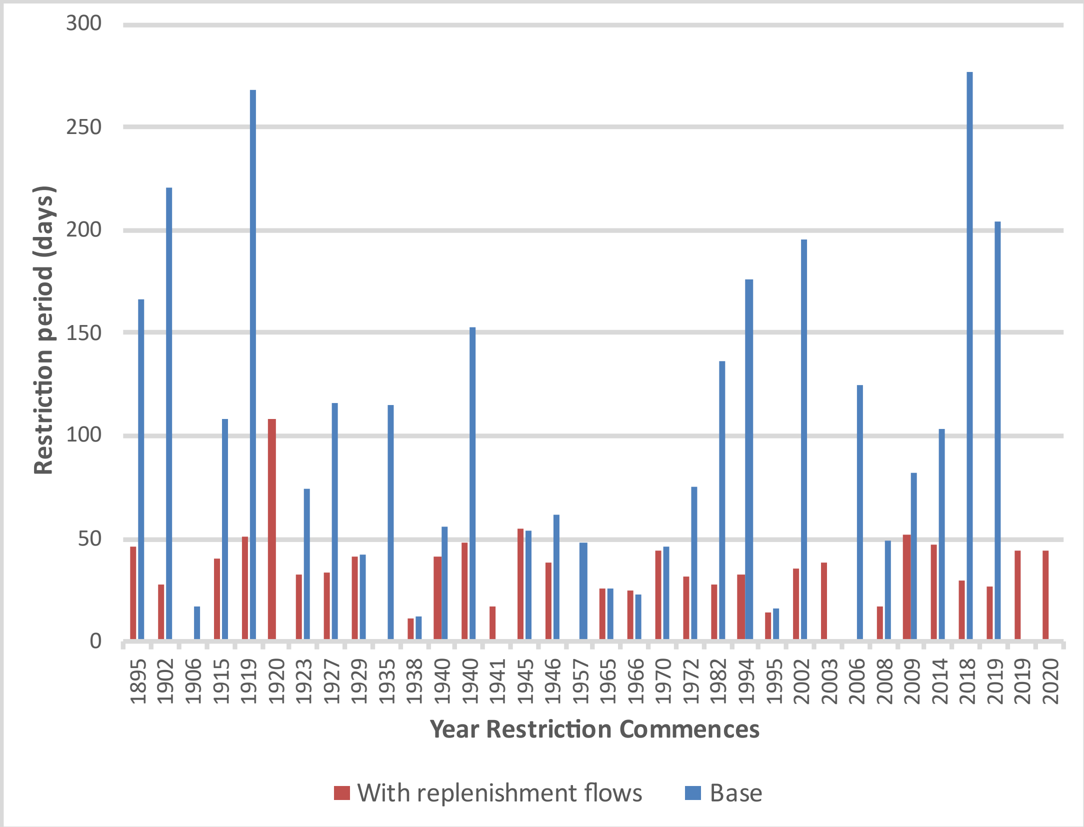
Valley	Base case total diversions (GL/y)	Option 4 total diversions (GL/y)	Change	Maximum annual impact (GL)
NSW Border Rivers	206.4	200.5	-2.9%	-31.8 (-19%)
Gwydir	449.5	444.6	-1.1%	-36.6 (-6%)
Namoi	226.9	220.4	-2.9%	-35.9 (-9%)
Barwon-Darling	161.8	163.7	+1.2%	-

Note: Maximum annual impacts are expressed as a volume, and in parentheses as a percentage of the base case diversions in that year

The periods of restrictions under the resumption of flow rule are shown in **Error! Reference source not found.** below. This shows that

- the proportion of years where there are restrictions do not change significantly, as the ordering of replenishment flows does not commence until the restriction period commences
- the average period of restrictions is significantly reduced from an average of 105 days per event in the base case to 38 days per event with the replenishment releases, and
- the longest period of restriction is significantly reduced from 277 days to 108 days.

Figure 29: Periods of restricted Barwon-Darling water access under the resumption of flow rule



The results show that replenishment style releases can be highly effective at breaking up long periods of cease to flow and very low flow outcomes. We would also understand conceptually that the degree of alteration can be adjusted at will by increasing or decreasing the volumes reserved for replenishment release.

10. Stage 2D – Target flow at Bourke

Option description

This option tests the impacts of making releases from major NSW storages to maintain a flow of 500 ML/day in the Darling River at Bourke. Releases from the NSW Border Rivers, Gwydir, and Namoi regulated river systems were included in this option. Releases from the Macquarie regulated river system were not included, as the losses within the Macquarie Marshes would be prohibitively high.

Model configuration and assumptions

A time series of periods where flows at Bourke fall below 500 ML/day was constructed from the base case model results and used to create orders for flows at the bottom of the NSW Border, Gwydir, and Namoi regulated river systems in a model scenario.

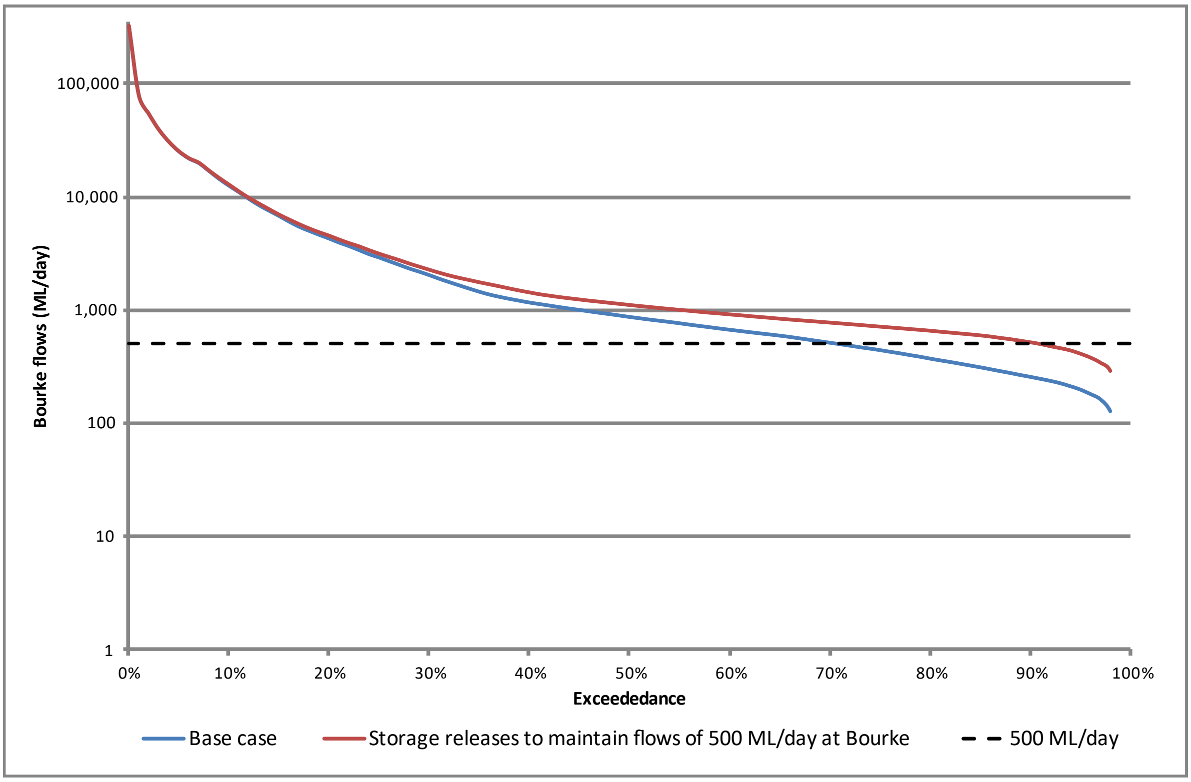
A daily order of 233 ML/day placed at the end of each of the NSW Border, Gwydir, and Namoi regulated river systems was trialled. This order was selected to provide 500 ML/day at Bourke even if there was little other flow available.

Modelling results

River flows

The effect on flows at Bourke from the additional releases in the regulated river systems is shown in Figure 30. The additional releases from storages resulted in flows at Bourke above 500 ML/day increasing from 71% to 91% of the time. With some more sophisticated modelling effort and iterative model runs the proportion of time that flows at Bourke exceed 500 ML/day could be further increased without increasing the impacts much more.

Figure 30: Darling River at Bourke modelled flow exceedance



Water diversions

The modelled diversions are shown in Table 22 below, which indicate that there would be significant impacts to water users in the regulated river systems. No restrictions were applied in the Barwon-Darling, but 500 ML/day is below most of the pumping thresholds for the main B Class users, and the diversions did not increase significantly. Virtually all the impacts are felt by the general security licences, as the releases drain the storages. Gwydir has a higher volume of general security use, and the proportional change is smaller, but volumetrically similar to the Border Rivers. Namoi impacts are larger, as there are higher losses delivering small volumes to the end of the system – particularly during periods when significant flows are not being delivered to the end of the regulated river system at Walgett.

Table 22: Long-term average diversions from option to target 500 ML/day at Bourke

Valley	Base case total diversions (GL/y)	Option (500 ML/day target) diversions (GL/y)	Change
NSW Border Rivers	203.1	168.8	-17%
Gwydir	449.5	412.6	-8%
Namoi	236.6	185.5	-22%
Barwon-Darling	159.4	166.9	+5%

The results show that it is feasible to use regulated system storage releases to maintain a minimum flow style target at Bourke, however this comes at a large cost to irrigation in the northern regulated valleys.

11. Stage 2E – Replenishments releases and Border Rivers inland diversions

Option description

Modelling was undertaken to assess the potential benefits of combining a connectivity option with an option for inland diversions to the Border Rivers that was investigated as part of the NSW Border Rivers Regional Water Strategy. The Border Rivers replenishments scenario (Wester Regional Water Strategy option 4) was extended to include a 50 GL/year diversions from the Clarence River (coastal) catchment to the Mole River (Border Rivers tributary).

Model configuration and assumptions

A transfer of 50 GL/yr into the Mole River at a uniform rate each day of 137 ML/day[29] has been incorporated into the modelling undertaken for Option 4 (replenishment releases from storages).

Previous modelling indicated that the coastal rivers are quite reliable, and this diversion volume can be achieved in nearly all the years modelled.

Modelling results

River flows

The long-term average end of system flows at Mungindi increase by 3.3%, or 18 GL/yr (compared to an increase of 0.5% or 3 GL/yr under the replenishments scenario).Table 23 shows the changes in the proportion of time flows occur in each long-term water plan flow class at the end of the Border Rivers regulated river system at Mungindi, with a slight decrease in very low flows and minor increases in the proportion of time flows occur across the higher flow categories.

[29] Further information is available in the *Hydrologic Analysis of options for the Border Rivers Regional Water Strategy,* www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies/what-we-heard/border-rivers-regional-water-strategy

Table 23: Changes in long-term water plan river flow classes at Mungindi– Replenishment releases (option 4) and Border Rivers inland diversions

Long-term water plan flow class	Base case	Option 4 + Border Rivers inland diversion	Change
Very low or no flows (<160 ML/day)	42.4%	41.2%	-1.2%
Baseflows (160-550 ML/day)	25.9%	26.2%	0.4%
Small freshes (550-5400 ML/day)	28.1%	28.9%	0.8%
Large freshes / floods (>5400 ML/day)	3.7%	3.7%	0.0%

Water diversions

The impact to total diversions under the replenishment scenario is -2.2%, which reduces to -1.3% with the inland diversion (so an improvement +0.9%).

Transfer of 50 GL/yr into the Mole River at a uniform rate each day translates to 137 ML/day. This is probably not enough to provide supplementary access during September to April, when supplementary access is only announced if flows will exceed 100 ML/day, unless other inflows occur. We can see that the modelled supplementary access barely increases from the base case.

Table 24: Border Rivers long-term average diversions – replenishment releases (option 4) with Border Rivers inland diversion

Licence category	Base case (GL/y)	Option 4 (replenishments) (GL/y)	Change from base case	Option 4 + Border inland diversion (GL/y)	Change from base case
General security	88.98	84.79	-4.7%	85.02	-4.7%
Supplementary	68.60	68.50	-0.1%	69.85	-0.1%
Floodplain harvesting (including rainfall runoff harvesting)	45.5	45.5	0	45.6	0.2%
TOTAL	203.1	198.7	-2.1%	200.5	-1.3%

The results show very small improvements to flows and the option is unlikely to very be viable when considering the costs of an inland diversion scheme.

12. Stage 2F – Changes to Barwon-Darling flow thresholds for water access

Option description

This option investigates the impacts of changing flow thresholds in the Barwon-Darling river system for B Class and C Class licences to align with the small freshes and large freshes flow classes defined in the Barwon-Darling Long-Term Water Plan.

Model configuration and assumptions

The lower flow thresholds for B Class and C Class licences in each river reach defined in the water sharing plan for the Barwon-Darling unregulated river water source are shown in Table 25 and Table 26 respectively, alongside the relevant long-term water plan flow class thresholds. For nearly all river reaches, the small fresh flow thresholds are slightly larger than the existing B Class flow thresholds, whereas the large fresh flow thresholds are more significantly higher than the existing C Class flow thresholds. The water sharing plan defines existing C Class flow thresholds at the upstream flow gauge in each section as being the same as B Class but are much larger than B Class at the downstream flow gauge.

The Barwon-Darling model only models the much smaller upstream C Class flow threshold in a few cases. To be consistent with the intent of the existing licence access flow thresholds, modelling of the changed C Class thresholds in these few instances has used an upstream threshold for C Class that has been set equal to the small freshes flow threshold, while the downstream flow threshold for C Class has been set to equal the large freshes flow threshold.

Table 25: B Class water access licence access thresholds compared to small fresh flow thresholds in the Barwon-Darling Long-Term Water Plan

Reach		Existing flow threshold		Small Fresh threshold		Difference	
Upstream flow gauge	Downstream flow gauge	Upstream threshold (ML/day)	Downstream threshold (ML/day)	Upstream threshold (ML/day)	Downstream threshold (ML/day)	Upstream threshold (ML/day)	Downstream threshold (ML/day)
Mungindi	Presbury Weir	230	270	540	500	310	230
Presbury Weir	Mogil Mogil	270	570	500	680	230	110
Mogil Mogil	Collarenebri	570	500	680	650	110	150
Collarenebri	Tara	500	430	650	500	150	70
	Dangar Bridge	0	900	0	700	0	-200
Dangar Bridge	Boorooma	900	870	700	850	-200	-20
Geera	Brewarrina	870	840	1,000	1,000	130	160
Brewarrina	Beemery	840	760	1,000	1,200	160	440
Warraweena	Bourke	1,330	1,250	1,500	1,550	170	300
Bourke	Louth	1,250	1,130	1,550	1,500	300	370
Louth	Tilpa	1,130	1,010	1,500	1,450	370	440
Tilpa	Wilcannia	1,010	850	1,450	1,400	440	550

Table 26: C Class water access licence thresholds compared to large fresh flow thresholds in the Barwon-Darling Long-Term Water Plan

Reach		Existing flow threshold		Large Fresh threshold		Difference	
Upstream flow gauge	Downstream flow gauge	Upstream threshold[1] (ML/day)	Downstream threshold (ML/day)	Upstream threshold[2] (ML/day)	Downstream threshold (ML/day)	Upstream threshold (ML/day)	Downstream threshold (ML/day)
Mungindi	Presbury Weir	230	1,500	540	2,700	310	1,200
Presbury Weir	Mogil Mogil	270	1,800	500	5,200	230	3,400
Mogil Mogil	Collarenebri	570	2,900	680	4,200	110	1,300
Collarenebri	Tara	500	3,050	650	3,500	150	450
	Dangar Bridge		5,650		6,500		850
Dangar Bridge	Boorooma	900	5,500	700	7,000	-200	1,500
Geera	Brewarrina	870	6,800	1,000	9,000	130	2,200
Brewarrina	Beemery	840	8,250	1,000	12,000	160	3,750
Warraweena	Bourke	1,330	11,000	1,500	15,000	170	4,000
Bourke	Louth	1,250	11,150	1,550	15,000	300	3,850
Louth	Tilpa	1,130	11,000	1,500	14,500	370	3,500
Tilpa	Wilcannia	1,010	12,000	1,450	14,000	440	2,000

[1]The Barwon-Darling model does not simulate upstream licence access thresholds for most C Class licences. In most cases the much larger downstream licence access threshold controls access.

[2]For those C Class licences where an upstream licence access threshold has been included in the model, this has been set to the small fresh flow thresholds, to replicate the existing C Class upstream flow threshold being set to the B Class upstream flow threshold.

Modelling results

River flows

The relatively small changes required in B and C Class licence access thresholds required to respectively match small or large fresh flow thresholds results in relatively small improvements to river flows.

Modelling indicates that there is a slight reduction overall in base flows or very low/no flows. With slightly less access to higher flows, modelling indicates that water users upstream of Bourke may have more airspace in their on-farm storages (than the base case) at times, leading to slightly more water use at other times when there is access to lower flows.

Table 27: Changes in river flows at Bourke– B and C Class licence access threshold changes

Barwon Darling long-term water plan flow class	Base case	B & C Class threshold changes	Change
Darling River at Bourke			
Very low or no flows (<500 ML/day)	29.5%	29.4%	0.0%
Baseflows (500-1,550 ML/day)	36.7%	36.4%	-0.3%
Small freshes (1,550-15,000 ML/day)	25.1%	25.5%	0.4%
Large freshes (>15,000 ML/day)	8.7%	8.6%	-0.1%
Darling River at Wilcannia			
Very low or no flows (<350 ML/day)	32.7%	32.6%	-0.1%
Baseflows (350-1,400 ML/day)	32.8%	32.9%	0.2%
Small freshes (1,400-14,000 ML/day)	24.9%	24.9%	0.0%
Large freshes (>14,000 ML/day)	9.6%	9.6%	0.0%

Water diversions

Consistent with the small improvements in flows, the impacts to water use were also small. Reduced access for B and C Class licences leads to overall small reductions in water use, as shown in Table 28. Some of this impact is offset by very small increases in use of A Class licences.

Table 28: Long-term average diversions – Option: B and C Class licence access threshold changes

Licence category	Base case diversions (GL/y)	Option B& C Class thresholds diversions (GL/y)	Change
A Class	5.8	5.8	0.5%
B Class	92.7	92.0	-0.8%
C Class	32.5	32.3	-0.8%
Floodplain harvesting	20.3	20.0	-1.2%
Rainfall runoff harvesting	8.1	8.1	0.0%
Total	159.4	158.25	-0.7%

13. Menindee/Lower Darling Option 50 – Release water from Lake Cawndilla to the Great Darling Anabranch.

Option description

This option investigates the impacts of releasing the remaining water from Lake Cawndilla to the Great Darling Anabranch (Anabranch) after the Lake becomes separated from Lake Menindee and the Lower Darling. The objectives are to reduce evaporation losses from Lake Cawndilla, and improve fish migration from the lake to the Murray River.

Model configuration and assumptions

The base case model already has provision for making some releases from Lake Cawndilla to the Anabranch. This option was implemented by adding a lake draining requirement to the orders already implemented in the base case model. The configuration of the outlet from Lake Cawndilla restricts total releases to a physically realistic rate.

The following assumptions[30] were incorporated to the model for this option:

- When a decision is made to drain Lake Cawndilla to the Anabranch, releases to the Anabranch are maximised subject to existing release capacity constraints,
- Draining Lake Cawndilla will only be implemented after the lake can no longer divert back to Lake Menindee or the Darling River, i.e., Lake Cawndilla must be below the level of 55.46m AHD,
- To reduce risk of spilling water from Lake Victoria, draining will only be implemented:
  - if Lake Victoria's volume is less than 450 GL, and
  - during January through April

[30] An additional assumption that releases would only be initiated if the combined storage volumes Lakes Cawndilla and Menindee was less than 1000 GL was modelled, however this is not described in the main text, as it would always be true when the Cawndilla level criterion was met.

- Further analysis could improve these rules.

The following flow time series are from the base case IQQM Barwon-Darling model:

- End of system flow – Wilcannia (inflow to Lake Wetherell)
- Wilcannia aggregate
- Talyawalka Creek
- Bourke.

Modelling results

River flows

The modelling results presented in Table 29 show that Lower Darling River flows decrease slightly and Anabranch flows to the Murray River increase by a similar amount on average, with only a negligible overall increase in flows reaching the Murray River. Over the period of simulation, the additional draining releases 1660 GL from Lake Cawndilla to the Anabranch, representing an increase in Lake Cawndilla releases of 18%.

Table 29: Changes in river flows due to release of water from Lake Cawndilla to the Anabranch (option 50)

Location	Base case (GL/y)	Option 50: releases to Anabranch (GL/y)	Change
Darling River to the Murray	866	860	-0.7%
Anabranch to the Murray	111	118	6.3%
Total Darling System to the	977	978	0.1%
Murray to South Australia	6,309	6,312	0.0%

Extractions

The modelling indicates there is generally very little change in diversions, consistent with the small change in flows. There are small impacts to general security water users in the Lower Darling and Murray arising from an increase of 20% in Lake Cawndilla releases to the Anabranch over the simulation period (1895 – 2020), resulting in use of subsequent inflows to Menindee Lakes being used to refill Lake Cawndilla when they were not required (or not to the same extent) in the base case model scenario.

Modelling indicated that some categories of licences had very small increases in water use, which would not be expected to occur, and are likely a result of difficulties representing system operation during extremely dry periods.

Table 30: Changes in consumptive use due to additional release of water from Lake Cawndilla to the Anabranch (option 50)

Licence category	Base case (GL/y)	Option 50: releases to Anabranch (GL/y)	Change
Pooncarrie local water utility	84.7 (ML/y)	84.8 (ML/y)	0.1%
Lower Darling high security	3.30	3.33	0.7%
Lower Darling general	33.1	33.0	-0.3%
Murray high security	151	151	0%
Murray general security	1,399	1,391	-0.6%

Water Allocations (Available Water Determination)

The model results presented in Table 31 indicates that there is almost no change in allocations with a small decrease in general security allocations for the Lower Darling. This decrease is due to a 20% increase in releases to the Anabranch over the simulation period (1895-2020) resulting in subsequent inflows to the Menindee Lakes being used to refill Lake Cawndilla when they were not required (or not to the same extent) in the base case model scenario.

Table 31: Changes in water allocations

Licence category	Base case	Option 50	Change
Pooncarrie local water utility (30 June)	100%	100%	0%
Lower Darling high security (30 June)	100%	100%	0%
Lower Darling general security (30	91.4%	90.9%	-0.5%
Murray high security (30 June)	99%	99%	0%
Murray general security (30 September)	46%	46%	0%

Losses

Table 32 presents the changes in losses in the Menindee Lakes and the Anabranch, with overall losses reduced by 3.3 GL/y, or 0.6%.

Table 32: Changes in losses in The Great Anabranch and the Menindee Lakes

Location	Base case	Option 50	Change
Menindee Lakes	438.9 GL/y	434.7 GL/y	-4.2
Anabranch	75.1 GL/y%	76.0 GL/y	0.9

Reduction in fish stranding events

Overall, the option results is a modest saving in losses of 3.3 GL/y. There were 54 release events from Lake Cawndilla over the 125 years of analysis – one release event every 2.3 years on average. That is, additional opportunities for fish migration down the Anabranch to the Murray were provided every 2.3 years on average. The maximum period between release events was 11.3 years. The average volume of additional discharge was 27.4 GL/event.

14. Menindee/Lower Darling Option 52 – Revisit the 480/640 rule.

Option description

This option investigates the impacts of changing the 480/640 rule specified by clause 95 of the Murray-Darling Basin Agreement (Schedule 1 of the Water Act, 2007, Commonwealth). Clause 95 of the Agreement provides that if the volume in store drops below 480 GL, control of the Menindee Lakes transfers to NSW, and releases from the lakes are used to supply requirements in the Lower Darling only until the volume in storage next exceeds 640GL. When the volume reaches 640 GL the MDBA retakes direction of operations and resumes supplying water to meet demands in the Lower Darling and Murray Rivers. The difference in shares of water in store of NSW and Victoria that existed when the volume dropped below 480 GL is re-instated. This effectively means that all inflows to the Menindee Lakes when under NSW control are assigned to NSW.

At present the rule is implemented using total storage of the Menindee Lakes. The option investigates changing the implementation to use active storage[31] rather than total storage when assessing whether control of the lakes transfers to or from NSW.

The triggers to move between NSW and Murray-Darling Basin Authority control of the storage in Menindee are based on an assessment of NSW drought reserves required to meet Lower Darling needs for two years.

This option would investigate how storage volumes are calculated in the Menindee Lakes. The investigation would look at whether threshold management decisions should be based on active storage or total storage volumes.

Operating the lakes based on active storage could provide more flexibility in supporting critical human and environmental needs in the Lower Darling. Low storage volumes in the Menindee Lakes also have negative economic, social, environmental and cultural impacts on the Lower Darling communities. Similarly, there is a high risk of negative impact on fish populations and water quality arising from low storage volumes. The lakes are an important ecological site.

[31] Active storage is the water in storage that is able to be released, and excludes the "dead" storage which cannot be released. Most storages have a small amount of dead storage below the outlet point that remains after the storage has been drained through the available outlets.

Model configuration and assumptions

The Source Murray Model considers the following water bodies to comprise the Menindee Lakes:

- Lake Wetherell
- Lake Tandure
- Lake Pamamaroo
- Copi Hollow
- Lake Menindee
- Lake Speculation
- Lake Cawndilla.

Of these, Lakes Wetherell, Cawndilla, and Copi Hollow are configured to have dead storage, and so active storage is less than total storage for these water bodies. The dead storage of Lake Cawndilla, as referenced to its outlet to the Great Darling Anabranch, is 10.9GL. For the purposes of this option however a dead storage volume of 167.8 GL was adopted, which is the volume inaccessible to the rest of the Menindee Lakes and the Darling River.

The option was implemented by making the NSW/MDBA control decision function reference active volume rather than total volume in store. Active volume in store was calculated separately for each water body, then summed for all the water bodies to obtain the total active storage volume.

The following flow time series are from the base case IQQM Barwon-Darling model:

- End of system flow – Wilcannia (inflow to Lake Wetherell)
- Wilcannia aggregate
- Talyawalka Creek
- Bourke.

Modelling results

River flows

The modelling results in Table 33 show that there is a very small reduction to the long-term flows from the Lower Darling to the Murray River, which is consistent with NSW retaining control of Menindee Lakes for slightly longer period of time under this option.

Table 33: Changes in river flows from changing operating rules for Menindee Lakes (option 52)

Licence category	Base case (GL/y)	Option 52 (GL/y)	Change
Darling River to the Murray	866	861	-0.6%
Anabranch to the Murray	111	111	0.0%
Total Darling System to the Murray	977	971	-0.6%
Murray to South Australia	6,309	6,311	0.0%

Extractions

Retaining NSW control of the lakes for longer results in very small changes to most categories of long-term water use, with small benefits in the Lower Darling and similar disbenefits in the NSW Murray system, as shown in Table 34. The change would provide a benefit to Lower Darling high security use, although this use is only around 10% of the Lower Darling General Security use. It should be recognised that the valley-scale hydrologic models often do not reproduce system behaviour well during extreme (dry or wet) conditions, and the benefits for the Lower Darling in very dry periods may not be fully apparent.

The very small reduction in diversions for the township of Pooncarie is not considered significant with respect to model uncertainty, and likely indicates that diversions for the township are unaffected.

Table 34: Changes in consumptive use from changing operating rules for Menindee Lakes (option 52)

Licence category	Base case (GL/y)	Option 52 (GL/Y)	Change
Pooncarrie local water utility	84.7 (ML/y)	84.6 (ML/y)	-0.1%
Lower Darling high security	3.3	4.5	37%
Lower Darling general security	33.1	33.6	1.5%
Murray high security	151	150	-0.7%
Murray general security	1,399	1,395	-0.3%

Water Allocations (Available Water Determination)

Retaining NSW control of the lakes for longer results in marginal modelled change to long-term allocations, with small benefits in general security allocations in the Lower Darling and a similar scale of disbenefit to high security allocations in the NSW Murray system.

However, as noted above, the valley-scale hydrologic models often do not reproduce system behaviour well during extreme (dry or wet) conditions, and the benefits for the Lower Darling in very dry periods may not be fully apparent.

Table 35: Changes in water allocations from changing operating rules for Menindee Lakes (option 52)

Licence category	Base case	Option 52	Change
Pooncarrie local water utility (30 June)	100%	100%	0%
Lower Darling high security (30 June)	100%	100%	0%
Lower Darling general security (30	91%	92%	1.1%
Murray high security (30 June)	99%	98%	-1%
Murray general security (30 September)	46%	46%	0%

Menindee Lakes Water Storage

Changing the 480/640 rule to be based on active storage rather than total storage would provide environmental benefits in the lakes, as shown in Table 36. It can be seen that during the drier periods there is up to 37% more water stored in the Lakes, which would assist prevent fish kills, And support other wildlife.

Table 36: Impacts of Option 52 on water storage (total GL) in the Menindee Lakes

Licence category	Base case (GL)	Option 52 (GL)	Change (GL)	Change (%)
Lakes volume exceeded 50%	936	949	13	1.4%
Lakes volume exceeded	475	512	37	7.9%
Lakes volume exceeded 90%	274	338	64	23.2%
Lakes volume exceeded	206	276	70	34.1%
Lakes volume exceeded 99%	120	165	45	37.1%

15. Menindee/Lower Darling Option 30 – Provide an annual environmental water allowance when the Menindee Lakes are in NSW control.

Option description

Current water management rules provide for water quality maintenance releases, when needed, to the Lower Darling when the Menindee Lakes are under MDBA control. When the lakes are under NSW control per the 480/640 rule (see Section 14), there is no provision for such releases. When the lakes are under MDBA control there is more water available, and also less need for environmental water quality releases. It is assumed for this investigation that a typical usage of the environmental water allowance will be a water quality release requirement that would provide flows sufficient to mix water in Lower Darling weir pools to prevent blue-green algae blooms.

Model configuration and assumptions

This option was not explicitly modelled in the Source Murray Model, rather it was analysed by examining flow conditions in the Lower Darling modelled by the base case of the Source Murray Model. The underlying assumptions are that flows of less than 1,000ML/d[32] for 7 days will enable development of blue-green algae blooms, and a flow of at least 1,000 ML/d will be required to mix weir pools to break up an existing blue-green algae bloom.

Base case model output (representing established rules) was analysed to identify periods when flows at Burtundy or Weir 32 over a 7-day period average less than 1,000ML/d. Following each such period, the volume of additional release required to achieve the pattern depicted for Wetherell releases in Figure 31 was determined. This abides by operational limits on rates of rise and fall in the river and achieves the desired flow target along the Lower Darling after allowing for attenuation (delay and smoothing) of rising flows. In practice the design of the pulse would need to be

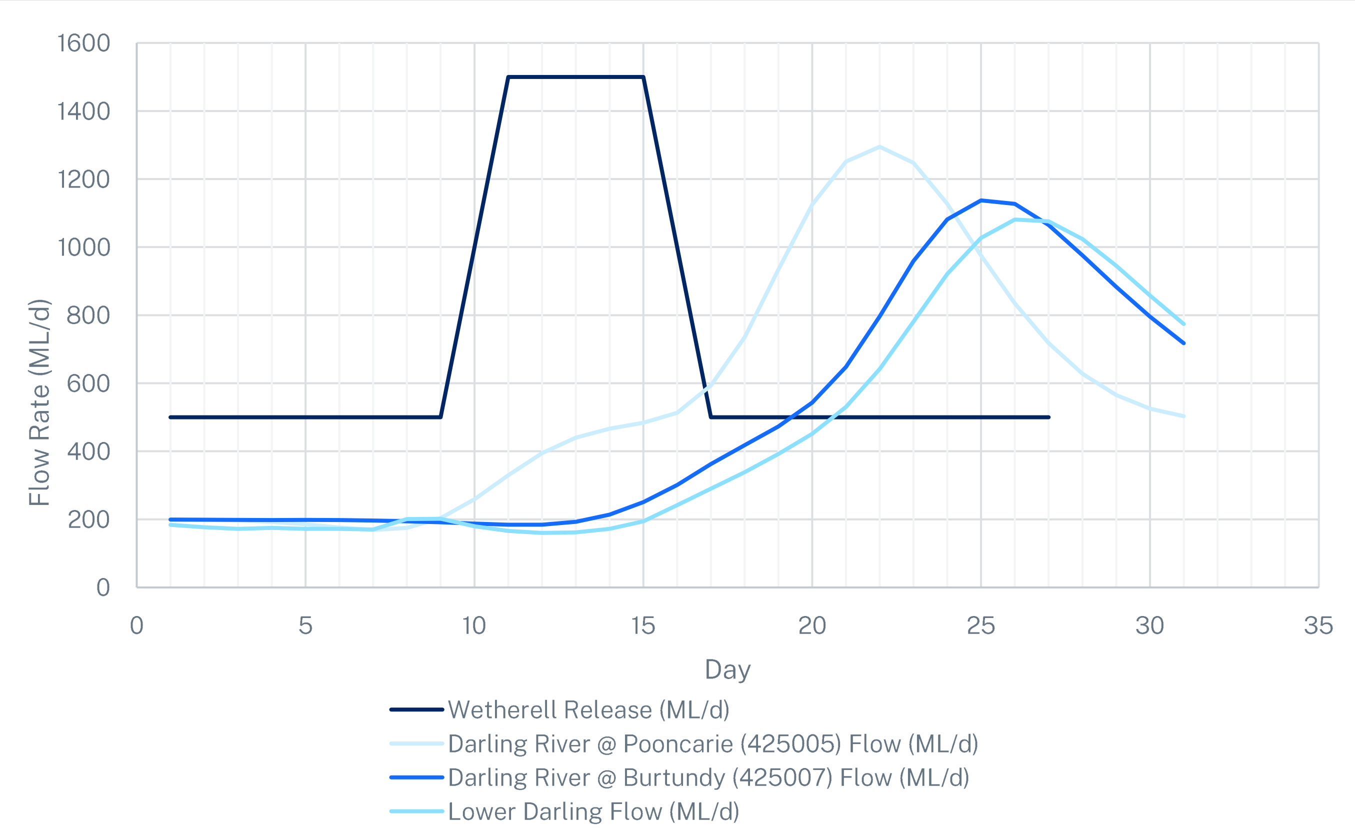
[32] Target flow along the Lower Darling based on a combination of expert advice and operational feasibility.

adaptively managed to adjust for real-time attenuation and losses. This can also be informed by undertaking operational test pulses.

The countdown for the next trigger (7-day average flow less than 1,000 ML/d) begins when the Wetherell release next drops below 1,000 ML/d. This implicitly assumes river pools could begin to stratify within 7 days of low flows (7 days less than 1,000 ML/d). This analysis simply looks at annual environmental water allowance (EWA) requirements.

The analysis does not consider additional losses caused by storing the EWA provision.

Figure 31: Modelled pattern of releases from Menindee Lakes and the associated modelled flows along the Darling River



Modelling results

The analysis of this option focusses on determining the cost (in ML), and viability of delivering desired EWA volumes to the Lower Darling when the Menindee Lakes are in NSW control.

It was found that there was no need for an additional EWA release to provide for blue green algae suppression mixing in more than 50% of years. The average annual requirement was found to be 26.6GL, with the median three-year additional release requirement of 63.0GL (requirements were higher than this in 50% of sequences, and lower than this in 50% of sequences), as shown in Table 37. These results help indicate potential need for carrying over EWA entitlements for up to three years, bearing in mind that any carryover likely involves significant evaporative losses not factored above. So from these results, at least 10% of three year EWA sequences would require an amount of 189.6GL plus losses over the three years, or 63GL/year plus losses, at the start of the sequence.

Table 37: Additional EWA releases to suppress algal blooms when Menindee Lakes are under NSW control (option 52)

Additional EWA release requirements	One year sequence (GL)	Three-year sequence (GL)
Median (exceeded 50% of the time)	0	63.0
Average	26.6	78.3
Exceeded 25% of the time	58.4	138.1
Exceeded 10% of the time	79.3	189.6
Maximum	90.0	241.9

Prior to allowing for EWA releases, accessible water in the Menindee Lakes averaged 169GL prior to each event, and was only 85GL, or less,10% of the time.

The above results indicate that at those times when there is a need for an EWA based blue-green algae suppression release and the Menindee Lakes are under NSW control (480/640 rule), there is often little accessible water in storage, or little ability to store water in advance for a future EWA requirement. Implementation of a useful additional EWA allowance that would be largely used for algae suppression flows would only be possible with a major change to the inter-government management arrangements of the Menindee Lakes. There are a number of processes affecting water quality, and it may be that flow management interventions are not always able to provide a desirable solution to lower Darling water quality issues.

The analysis indicates that the high degree of evaporative loss in Menindee Lakes is incompatible with concepts based on reserving volumes for high value purposes during extended droughts.

16. Menindee/Lower Darling Option 50 – Release water from Lake Cawndilla to the Anabranch together with Stage 2B (Option 6) – targeted restrictions in the Barwon-Darling for critical upper Menindee Lakes storage volumes (195 GL).

Option description

This option investigates the impacts of combining two options which have opposing impacts on different lakes within the Menindee Lakes – Option 50 which releases stranded water from Cawndilla, and Stage 2B (Option 6), which aims to support a minimum volume of 195GL in Lakes Wetherell and Pamamaroo. The former aims to reduce evaporation losses within Cawndilla, and support fish migration to the Murray, while the latter aims to maintain critical supplies in the Lower Darling. The option assesses whether implementing Option 50 would have a detrimental impact on the outcomes of Stage 2B.It was found that targeting 195 GL in the upper Lakes results in a reduction of time below 150 GL of 4.7% from Baseline. Combining with the Cawndilla draining option 50 only reduces the impact to 4.5%. Consequently, combining these two options during drought periods causes negligible conflict between their differing objectives.

Model configuration and assumptions

This option was based on the model developed for Option 50, but with the following flow time series updated to the IQQM model targeting restrictions in the Barwon-Darling for critical upper Menindee Lakes storage volumes:

- End of system flow – Wilcannia (inflow to Lake Wetherell)
- Wilcannia aggregate

- Talyawalka Creek
- Bourke.

Modelling results

River flows

The modelling results presented in Table 38 show that Lower Darling River flows increase slightly consistent with targeted restrictions to supplementary and B/C Class access upstream of Menindee in option 6 and Anabranch flows to the Murray River increase by the same amount as option 50. This means that the additional inflows to Menindee Lakes from upstream restrictions have not changed the amount of additional release from Cawndilla modelled under option 50.

Table 38: Changes in river flows

Location	Base case (GL/y)	Option 50 + target 195 GL in upper Menindee Lakes (GL/y)	Change
Darling River to the Murray	866	886	2.3%
Anabranch to the Murray	111	118	6.3%
Total Darling System to the Murray	977	1,004	2.8%
Murray to South Australia	6,309	6,329	0.3%

Extractions

The modelling indicates there are small improvements in diversions in the Lower Darling, with the additional inflows to Menindee Lakes adding to the very small improvements (or compensating for small impacts) in diversions under option 50. The very small reduction in diversions for the township for Pooncarie is not considered significant with respect to model uncertainty, and likely indicates that diversions for the township are unaffected.

The small impacts to general security water users in the Lower Darling and Murray arising from option 50 have been reduced by the additional inflows to Menindee Lakes from Option 6. The very small impact to NSW Murray high security is unexpected, but is also a negligible change from the base case diversions.

Table 39: Changes in consumptive use

Licence category	Base case (GL/y)	Option 50 + target 195 GL in upper Menindee Lakes (GL/y)	Change
Pooncarrie local water utility	84.7 (ML/y)	84.5 (ML/y)	-0.2%
Lower Darling high security	3.3	4.0	20.5%
Lower Darling general security	33.1	34.5	4.2%
Murray high security	151	150	-0.7%
Murray general security	1,399	1,395	-0.3%

Water Allocations (Available Water Determination)

The model results presented in Table 40 indicates that there is almost no change in allocations with a small increase in general security allocations for the Lower Darling with the additional inflows to Menindee Lakes a compensating for the small impact to allocations under option 50.

Table 40: Changes in water allocations

Licence category	Base case	Option 50 + target 195 GL in upper Menindee Lakes	Change
Pooncarrie local water utility (30 June)	100%	100%	0%
Lower Darling high security (30 June)	100%	100 %	0%
Lower Darling general security (30	91%	96%	5.5%
Murray high security (30 June)	99%	98%	-1.0%
Murray general security (30	46%	46%	0%

Critical upper lakes storage volumes

Upstream flow diversion interventions were implemented for upper Menindee Lakes storage volumes (Wetherell plus Pamamaroo) of less than 195GL, until the storage next reached 250GL. The flow diversion interventions would have little impact on statistics of storage levels below 195 GL, because the interventions only commence at that storage level. To assess the impact of the diversion interventions a lower reference volume of 150 GL was selected. The results are presented in Table 41 below. This shows that targeting 195 GL in the upper Lakes results in a reduction of time below 150 GL of 4.7% from Baseline. Combining with the Cawndilla draining option 50 only reduces the impact to 4.5%. Consequently, combining these two options during drought periods causes negligible conflict between their objectives.

Table 41: Critical storage volumes in lakes Wetherell and Pamamaroo for Option 50 plus Stage 2B, and Stage 2B only

	Base case	Option 50 + target 195 GL in upper Menindee Lakes	Change	target 195 GL in upper Menindee Lakes	Change
% of time below 150	14.4%	9.9%	-4.5%	9.7%	-4.7%

Attachment 1 Model versions

Model	Base case scenario file
Border Rivers Source Model	15_16 FPH Est Run Used for RWS (BorderRivers_2020_09_011_APT.rsproj)
Macquarie IQQM	Macq_CC_wExempt_20210422.sqq
Gwydir IQQM	cc_v27-e8_FPHLIC-285pca.sqq
Namoi Source	08_09 FPH Est Run Used for RWS (NAMO_CAL_218_Source5.0.0.10890.rsproj)
Barwon Darling IQQM	Cur_BD_FPH_07_Uncon.sqq
Source Murray Model	NSW RWS version 4 with IQQM modelled inflows to Lake Wetherell. Files are stored on Confluence at https://nswwmmi.atlassian.net/wiki/spaces/SCSRWS/pages/2588180481/Model+Index+Page+RWS+Southern+System+modelling Baseline, Option 50 (Release water from Lake Cawndilla to the Great Darling Anabranch), Option 52 (Revisit the 480/640 rule): River Murray Model 5.10.0_NSW_RWS_20220805_480_640_v3.1_Anabranch_correct_inflows.rsproj Option 50 + targeted restrictions in the Barwon-Darling for critical Menindee storage volumes (195 GL): 5.10.0_NSW_RWS_20220805_480_640_v3.1_W195_Anabranch_correct_inflows.rsproj