NSW HEALTHY FLOODPLAINS

Modelled downstream effects of licensing floodplain harvesting

NSW Border Rivers & Gwydir valleys

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Executive summary

This report uses numerical simulation models to quantify the potential downstream impacts of implementing the *NSW Floodplain Harvesting Policy* (hereinafter called the *Policy*) in the NSW Border Rivers and Gwydir valleys.

The *Policy* establishes a framework for licencing floodplain harvesting activities and managing of diversions in a way that brings them back within statutory limits. The licencing framework will restrict the volume of water that can be taken from the floodplain providing gains to the system through foregone diversions.

Any gains in upstream systems such as the NSW Border-Rivers (which provides on average 18% of Barwon-Darling inflows) or the Gwydir (6% of Barwon-Darling inflows) may translate into the downstream. These additional volumes originating in each of the Barwon-Darling tributary valleys contribute to connectivity between the broader northern Murray-Darling Basin (the Basin) and provision of increased flows towards Menindee and into the Murray.

The behaviour of these additional volumes can be predicted using numerical simulation models. Water management in NSW (and globally) relies on models such as these to provide robust and reliable estimates of what water is available, how it moves through the system and to assess the predicted impact of rules and management responses. The models used for this report have been developed using current best practice, utilise the best available information and have been subject to independent review.

Models simulate highly complex physical processes. These processes have many inputs, outputs, dependent factors and feedback loops. Each source of data comes with a set of limitations, assumptions and a level of uncertainty around how well this information reflects the real world.

A limitation of the current river system models is that they do not model the return of flows from the floodplain to the river. This process is critical in analysing impacts of floodplain harvesting and without an established process the department was required to make two key assumptions:

1. **100% of foregone diversions return to the river** (i.e. all non-harvested water returns from the floodplain to the river)
2. **100% of that returning water contributes to end-of-system flows** (i.e. 100% of returned floodplain water flows unaltered to the end of system).

These two assumptions represent a simplification of the real world. In reality these volumes would attenuate, reducing in size as they are subject to natural floodplain and riverine processes. Simply put, the downstream impact shown in this analysis is greater than what will be realized by *Policy* implementation. Adoption of these assumptions provides insight into the **maximum possible effect** of implementing the *Policy*.

This analysis is intended as a range-finding exercise that find the potential scale of change after *Policy* implementation and is not intended to provide a specific volumetric outcome that people should expect to see in river. A sensitivity test (Appendix B) was undertaken to see the impact of these assumptions.

With adoption of both assumptions modelling indicates that implementation of the *Policy* within the NSW Border Rivers will result in a 5.5 GL return of water to floodplains, rivers, and creeks. In addition, licencing floodplain harvesting in the Gwydir valley is simulated to provide an additional 52.9 GL within this water source.

The foregone diversions produced by the *Policy* travel across the floodplain before re-entering rivers and creeks and provide additional volumes toward downstream systems. As a result of policy implementation in the upstream Border-Rivers and Gwydir valleys average annual inflows to the Barwon-Darling are modelled to increase by 43.0 GL. A quantity of the foregone diversions in the Gwydir (9.7 GL) will remain in the terminal Gwydir wetlands providing localized environmental benefits but not contributing to downstream outcomes. An additional 5.7 GL is lost due to model recalibration between the Gwydir and Barwon-Darling models.

This additional volume in the Barwon-Darling attenuates, reducing as it travels through the system towards the southern Basin. By the time these foregone diversions reach the end of the Barwon-Darling the model indicates that implementation of the *Policy* in the upstream Border-River and Gwydir will provide an annual average increase of up to 26.2 GL (1.9%) at Wilcannia.

The northern and southern Basin are connected by Menindee Lakes and the lower Darling River which adjoins the River Murray at Wentworth ~100km upstream of the South Australian border. *Policy* implementation is simulated to provide an annual average increase of 28.3 GL to Menindee inflows or 1.8% of the total. This additional volume has a negligible impact on diversion and/or allocations in the Lower Darling and Murray systems.

Any additional volumes created by the *Policy* are potentially available for extraction, contributing to water availability for downstream communities, town water supply, stock & domestic users and irrigators. The downstream effects assessment indicates that this additional volume has a negligible impact on access for A, B & C Class licence holders in the Barwon-Darling. This is due to the additional volume mostly being available during wetter years when flows are high and extraction opportunities for unregulated licences are already maximised.

Annual average results are not shared equally between years. Floodplain harvesting is highly variable in nature, reliant on wet conditions to create overland flows. In the wettest year on record (1955) an additional volume of up to 20x the annual average was seen in some valleys due to implementation of the *Policy*. Conversely, in drier years very little to no floodplain harvesting takes place and little *Policy* impact is seen.

Subsequent reports will be made available in early 2021 that include the impact of implementing the *Policy* in the Namoi, Barwon-Darling and Macquarie. Each valley will be looked at individually with additional analysis of the cumulative impact across the entire northern Basin.

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1 Introduction

The *Policy* establishes a framework for the assessment and determination of floodplain harvesting water access licences. Floodplain harvesting licences define the volume of water that users can legally harvest from floodplains. Bringing floodplain harvesting into the water licensing system will enable management of diversions within the long-term average annual extraction limit (LTAAEL) and sustainable diversion limit (SDL) established in *NSW Water Sharing Plans* for each valley.

The *Policy* was introduced in 2013 and is now being implemented across five river valleys in the northern Basin.

Floodplain harvesting estimates for each valley are being updated and modelling outputs show that implementation of the *Policy* will result in a reduction in the volume of floodplain water diverted into storages. These foregone diversions will remain in the system, travelling across the floodplain, with some of that water returning to river. These upstream gains may translate into the downstream with additional volumes originating in the Barwon-Darling and its tributary valleys contributing to connectivity between the broader northern Basin system and provision of increased flows towards Menindee and into the Murray.

An estimate of the volumes of water returned to the system through foregone diversions in the Gwydir valley is displayed in Figure 1 which shows the modelled change in annual volumes of water diverted, with and without the *Policy*, over a 40-year modelling period. The water returned to the system due to policy implementation is the foregone diversion and in the left hand side of Figure 1 is crosshatched in yellow.

The right side of Figure 1 also shows the modelled with and without *Policy* daily flows from the Gwydir into the Barwon-Darling for the year 1978 as an illustration of the connection between the annual diversion volume and daily flow.

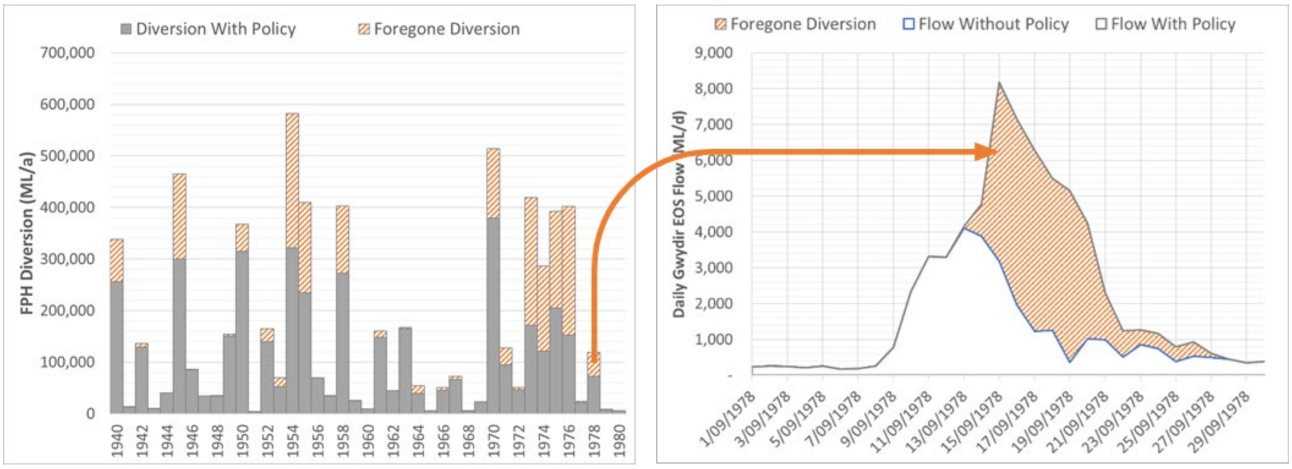

Figure 1 Modelled volumes of water (ML) returned under implementation of the *Policy* in the Gwydir valley. The chart on the left shows the modelled annual floodplain harvesting diversion and foregone diversion volumes with the *Policy* implemented over the 40-year (1940 to 1980) simulation period. The plot on the right shows the modelled without and with *Policy* daily flow from the Gwydir into the Barwon-Darling over the month of September in the 1978 water year, to illustrate when the *Policy* has most effect, in this example on the rising hydrograph

1.1 Report purpose and structure

This report aims to provide an initial understanding of how reductions in upstream floodplain harvesting diversions under the *Policy* impact downstream water availability. The impact is associated with implementation that occurs in an individual valley, in this case the NSW Border Rivers and Gwydir valleys and on a cumulative basis. The cumulative assessment will be added to when data become available for additional valleys. Currently the cumulative assessment encompasses the NSW Border Rivers and Gwydir valleys.

Chapter 2 overviews the *Policy* and the river system modelling that has been undertaken to support the assessment of floodplain harvesting entitlements. It describes the current situation where water diverted from the rivers through floodplain harvesting exceeds statutory limits, setting the context for Chapter 3.

Chapter 3 presents the results of modelling the downstream impacts of implementing the *Policy* within the NSW Border Rivers and Gwydir valleys on an individual and cumulative basis. Annual average volumes and peak volumes returned to system are investigated along with their impact on access for A, B & C Class licence holders in the downstream Barwon-Darling. This analysis is extended into the southern Basin and the with the cumulative impact of implementing the *Policy* assessed in regard to water availability and allocations in the lower-Darling and Murray regulated rivers.

Additional data, for example diversions disaggregated by licence type and a sensitivity analysis are included in appendices.

Formatting conventions

The report uses several formatting conventions to improve the accessibility of the text for reading software. Blue italics are used to identify terms that are specific to the model, either model terms, for example *Gauge Node*, or the names of model scenarios, for example *Current Conditions Scenario.* Standard italics identify legislation, plans, document titles and direct quotes. **Bold** text is used to highlight key terms and metrics, for example **planted areas**, as an aid for the reader to navigate through the text.

1.2 Companion reports

This report describes the downstream effects of implementing the *Policy* in the NSW Border Rivers and Gwydir valleys. A series of companion reports exist for each valley that describe the modelling and in-valley environmental benefits of *Policy* implementation. These reports together serve to describe how the modelling meets the objectives of the *Policy*.

1.2.1 Companion reports for the NSW Border Rivers valley

The building of the river system model which provides the data for assessing entitlements is described in companion report *Building the river system model for the Border Rivers Valley regulated river system* (DPIE Water, 2020a).

How the model has been used to update the *Water Sharing Plan* limit and calculate floodplain harvesting entitlements to bring total diversions back within that limit is described in companion report *Floodplain Harvesting Entitlements for NSW Border Rivers Regulated River System: Model Scenarios* (DPIE Water, 2020b).

The use of the model results for predicting potential environmental outcomes is described in companion report *Environmental outcomes of implementing the Floodplain Harvesting Policy in the Border Rivers Valley* (DPIE Water, 2020c).

1.2.2 Companion reports for the Gwydir valley

The building of the river system model which provides the data for assessing entitlements is described in companion report *Building the river system model for the Gwydir Valley regulated river system* (DPIE Water, 2020d).

How the model has been used to update the *Water Sharing Plan* limit and calculate floodplain harvesting entitlements to bring total diversions back within that limit is described in companion report *Floodplain Harvesting Entitlements for Gwydir Regulated River System: Model Scenarios* (DPIE Water, 2020e).

The use of the model results for predicting potential environmental outcomes is described in companion report *Environmental outcomes of implementing the Floodplain Harvesting Policy in the Gwydir Valley* (DPIE Water, 2020f).

2 Background

2.1 Floodplain harvesting policy

In 2013, the NSW Government introduced the *Policy* to manage floodplain water diversions more effectively in order to protect the environment and the reliability of water supply for downstream water users whilst ensuring compliance with the requirements of the *Water Management Act 2000*. The *Policy* also aligns with the objectives of the *National Water Initiative*, an intergovernmental commitment made by the Council of Australian Governments in 2004 to increase the efficiency of Australia's water use.

The *Policy* aims to bring floodplain harvesting under the traditional licensing framework, issuing landholders with water access licences and water supply works approvals. The licensing framework is being rolled out in the designated floodplains of five northern inland NSW valleys; the Border Rivers, Gwydir, Macquarie, Namoi and Barwon-Darling. Full policy implementation is scheduled for completion by 1 July 2021.

2.2 Modelling floodplain harvesting

Water management in NSW (and globally) relies on (numerical simulation) models to provide robust and reliable estimates of what water is available, how much is needed, and how the resource can be equitably shared. NSW DPIE Water manages the river system models that have been developed for this purpose. A model exists for each of the regulated valleys in NSW. These models were developed to support water management and planning processes and they represent the current best understanding of catchment climate, hydrological and water use behaviours.

Floodplain harvesting simulations extend these models with a hydrological representation of the capture, diversion, storage and use of floodplain water. This representation is based on real-world information collected and collated in association with the floodplain harvesting licence determination process and calibrated flow and irrigator behaviours.

The models used by DPIE Water have been designed to support contemporary water management decisions, whether it is a rule change in a valley's *Water Sharing Plan* or estimating long term average water balances for components such as diversions for compliance purposes. They are now being upgraded to be used to determine volumetric entitlements for floodplain harvesting and to test the impact of changes within the regulated river system.

Changes to long-term climate output or the addition of new rules for example, are used as an input into the model which then projects the outcome of those changes over an extended period. Upstream models are also connected to their downstream counterparts. These connections allow us to assess any downstream impacts of changes in one or more valleys.

The rule changes and licensing framework associated with implementation of the *Policy* have been incorporated into the river system models for the five northern valleys. This allows comparison between the without and with *Policy* implementation world including assessment of any change at local or regional scale.

2.3 Floodplain harvesting within statutory limits

Water taken from water sources in NSW must comply with the lesser of two statutory limits:

- Long-term average annual extraction limit (LTAAEL)
- Sustainable diversion limit (SDL)

These limits are described in the following sub-sections.

2.3.1 Long term average annual extraction limit (Plan limit)

The 'long-term average annual extraction limit' (LTAAEL) is a term used in NSW water sharing plans to define the limit of water that can be taken for all purposes (including domestic and stock, urban, industrial, agricultural use and held environmental water) from each water source.

The setting of the LTAAEL restricts the overall take of water in a water source to a defined volume and constrains growth to that maximum. Water in excess of the LTAAEL is reserved for the environment and is called Planned Environmental Water[1].

Rules to assess compliance with the LTAAEL are set out in each valley's *Water Sharing Plan*, and the LTAAEL is called the *Plan Limit.* Assessing compliance involves calculating the average of annual extractions over a specified period. In those cases where the *Plan Limit* is exceeded, the Minister for Water will reduce the quantity of water than can be taken by lower priority licences in accordance with established rules.

2.3.2 Sustainable diversion limit

The 'sustainable diversion limit' (SDL) is a term used in the Commonwealth's *Basin Plan* to define limits on total extractions for human uses from a surface water source or a group of surface water sources in the Basin. Each of the 29 river catchments and 80 groundwater areas in NSW has their own limit.

Compliance to an SDL is based on the concepts of actual and permitted take:

- **actual take** – the annual actual take is the volume of water extracted during a water year from a water source
- **permitted take** – the permitted annual take is the volume of water that can be extracted during a water year from a water source.

The difference between these two volumes is recorded on a register of take as a debit (when actual take is greater than permitted take) or a credit (when actual take is less than permitted take).

Over time, a cumulative balance accrues based on each year's credit or debit. For the first ten years of the water resource plan, if the cumulative balance reaches a debit of 20% or more of the SDL for that resource, then it is non-compliant. A reasonable excuse provision may apply in the case of non-compliance.

2.3.3 Floodplain harvesting currently in exceedance of statutory limits

Currently floodplain harvesting occurs outside an established licensing framework. This means that water can be diverted from the floodplain without volumetric limitation. Modelling indicates that over the last two decades floodplain harvesting has grown above statutory limits and it is anticipated this will be the case for the 2020/21 water year.

The river system models that are used to assess *Plan Limit* compliance consider all water diverted from the water source, including water diverted from the floodplain. The setting of these models to describe and assess Plan Limit compliance is managed through the creation of model scenarios. *Plan Limit Compliance Scenarios* have been or are in the process of being developed for the Border-Rivers, Gwydir, Namoi, Macquarie, Upper Namoi and Lower Namoi regulated river systems[2].

Modelled data are available with a high degree of confidence for the Border Rivers (DPIE Water, 2020a) and Gwydir valley (DPIE Water, 2020d) regulated river systems. These data indicate a 6.1

[1] For more information on Planned Environmental Water in each valley, and how it is modelled, the reader is referred to the appropriate companion Model Build report (DPIE Water, 2020a) (DPIE Water, 2020d).
[2] The development of the *Plan Compliance Scenario* for each valley is described in the companion Scenarios reports (DPIE Water, 2020b) (DPIE Water 2020e).

GL growth above the Plan Limit for the Border Rivers and 48.4 GL growth above the Plan Limit for the Gwydir. Not all of this growth is attributed to floodplain harvesting.

Table 1 Modelled Plan Limit and current volumes (GL/year) in the NSW Border Rivers valley regulated river system for General and High Security, Supplementary and Floodplain harvesting licences

Development conditions	Plan Limit	Current
General & High Security	92.1	92.6
Supplementary	69.2	70.0
Floodplain harvesting	38.7	43.6
Plan limit	200.0	206.1
Growth above the Plan Limit		**6.1**

Table 2 Modelled Plan Limit and current volumes (GL/year) in the Gwydir valley regulated river system for General and High Security, Supplementary and Floodplain harvesting licences

Development conditions	Plan Limit	Current
General & High Security	216.5	213.2
Supplementary	111.3	92.7
Floodplain harvesting	103.7	174.0
Plan limit	431.5	479.9
Growth above the Plan Limit		**48.4**

2.3.4 Outcome of returning to statutory limits

Returning the volume of water diverted within a valley to within the Plan Limit will result in more water in the river, leading to improved environmental outcomes and increased water availability in downstream systems.

Environmental benefits

Improved environmental outcomes for floodplains is one of the key outcomes sought through implementation of the *Policy*. Harvesting of water from floodplains reduces the volume, frequency and duration of floods and can change the timing of flood events, impacting on the health of floodplains and downstream waterways. Floodplain harvesting can also affect connectivity between a river and its local floodplain wetlands by reducing flow volume and redirecting flood flows.

DPIE Water has undertaken a valley-by-valley assessment of potential outcomes for the environment from implementing the *Policy*. Using modelled long-term (1895–2019) changes to the hydrology of the floodplain, each valley-specific *Environmental Outcomes of Implementing the*

Floodplain Harvesting Policy report[3] considers the predicted ecological responses to changed floodplain harvesting volumes after licensing floodplain harvesting.

Key hydrological metrics and environmental water requirements were used to test and identify these outcomes for assets (e.g. location) and values (e.g. species) including native fish, native vegetation, waterbirds, important ecosystem functions and wetlands.

Most assessed environmental water requirements are achieved more frequently under the *Plan Limit Compliance Scenario* than under the *Current Conditions Scenario*, i.e. model without licensing of floodplain harvesting. Improvements are seen in the number of flow days, frequency and timing of floods for native fish, waterbirds and floodplain vegetation.

Increased water availability in downstream systems

Whilst the Environmental Outcomes assessment looks at changes in the volume of water at the localised, within-valley scale, implementation of the *Policy* is also predicted to increase the volume of water reaching downstream water sources. This volume is potentially available for extraction, contributing to water availability for downstream communities, town water supply, stock & domestic users and irrigators. Implementation of the *Policy* in the Barwon-Darling and four of its tributary systems will have a cumulative effect with each valley providing contributions to downstream.

[3] For example, the Border Rivers report (DPIE Water, 2020c). For more information on the key findings and recommendations, the reader is referred to each valley specific *Environmental Outcomes of Implementing the Floodplain Harvesting Policy* report on the DPIE Water website.

3 Assessing the downstream effects of *Policy* implementation

Growth in floodplain harvesting has led to a level of take that, in the NSW Border Rivers and Gwydir valleys, is above statutory limits. When the licensing framework is established, floodplain harvesting licences will be subject to a volumetric limit that returns overall take to within the long-term average annual extraction limit (LTAAEL) set in each valley's *Water Sharing Plan*. This means that some of the water previously diverted through floodplain harvesting will be foregone. These foregone diversions will remain in the system, travelling across the floodplain, with some of the water returning to the river and continuing downstream.

This assessment explores the difference in diversions at the valley scale, considering the current unconstrained situation and what would occur post *Policy* implementation in each of the five northern inland valleys. The volumetric difference between the scenario with unconstrained floodplain harvesting (the *Current Conditions Scenario*) and the post policy implementation scenario (the *Valley Scale Compliance Scenario*) is the **foregone diversions**. The volume of foregone diversions in each valley is then an input to the downstream Barwon-Darling river system model to assess the downstream impact of these contributions.

Foregone diversions from each valley are input in the model at the point(s) that valley intercepts the Barwon-Darling, added to the in-river volume that flows from the outlined tributary valleys (Figure 2). These foregone diversions pass through the Barwon-Darling adding to water availability and attenuating as they flow south west into the Murray system.

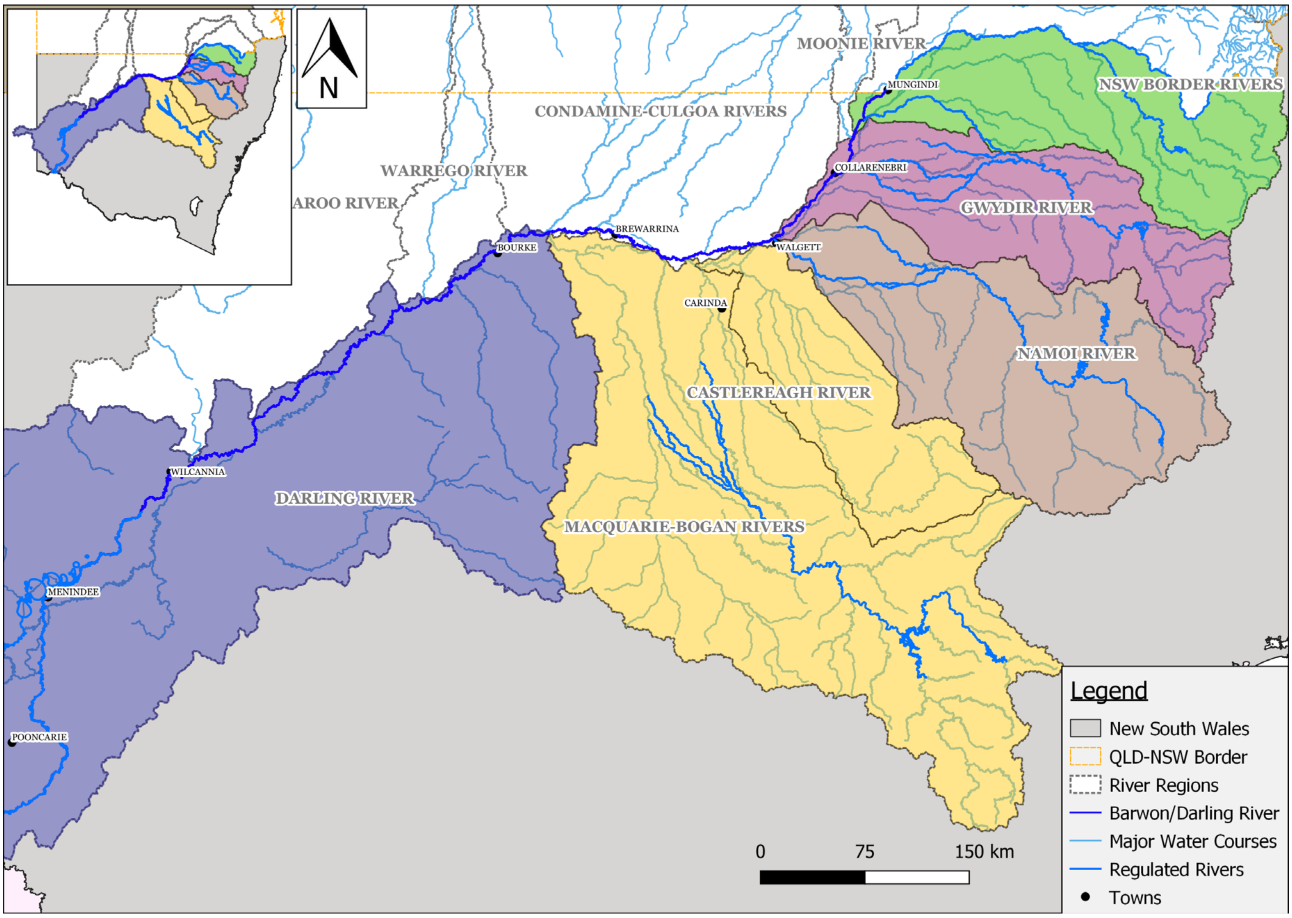

Figure 2 Map showing the Barwon-Darling tributary valley links

An assessment of this increased extraction opportunity and water allocations for downstream water users was undertaken at water source scale using the Barwon-Darling model. As the foregone diversions attenuate as they cross the floodplain, reducing in size before they return to the river, the model was tested using a plausible range of assumed return flow proportions. This sensitivity analysis considers the full range of results (0% of foregone diversions return to river to 100% of foregone diversions return to river) that may be expected following implementation of the *Policy*.

3.1 Inputs and assumptions

Models simulate highly complex physical processes. These processes have many inputs, outputs, dependent factors and feedback loops. Each source of data comes with a set of assumptions and a level of uncertainty around how well this information reflects the real world.

The work undertaken to support the implementation of the *Policy* has already substantively reduced uncertainty in the river system models. All datasets have been extensively reviewed to ensure the best quality available data are used. Multiple lines of evidence such as remote sensing and hydraulic modelling have been used, where possible, to substantiate the data, as has comparing datasets to published literature. Uncertainty can be further reduced with better information. This will require ongoing measurement and monitoring of harvesting volumes and management practices, and better representation of return flows from floodplains to river channels.

All hydrologic assessment modelling was undertaken using DPIE Water's river system models developed in either the Integrated Quality and Quantity Model (IQQM) or eWater Source software. These models produce timeseries of floodplain diversion in each of valley under the *Current Conditions* and *Valley Scale Compliance* scenarios that are then input to the downstream effect's assessment model. These timeseries was provided for the period 01/07/1895 to 30/06/2009, consistent with the benchmark climate period defined in the Basin Plan.

3.1.1 Assumptions and sources of uncertainty in the river system models

The downstream effects assessment has been generated using DPIE Water river system models. As described in the previous section, all care has been taken to ensure that these river system models are reliable and robust – they have been rigorously tested and refined subject to the DPIE Water's risk assessment framework. As the assessment described herein utilises these river system models, it is subject to the same suite of assumptions and sources of uncertainty.

Assumptions and sources of uncertainty in the river system models are documented in the Model Build report for each valley[4].

3.1.2 Assumptions and sources of uncertainty for downstream effects assessment

A limitation of the current river system models (mainly as a result of insufficient data) is that they do not model return flows. As a result, assumptions about return flows must be made to be able to assess downstream effects. These assumptions fall under two headings:

1. **Volume returned from the floodplain to the river**

Due to *Policy* implementation a quantity of diversions is foregone by each property. This water is left in systems and must travel across the floodplain before returning to rivers and creeks. As it travels across the floodplain the water attenuates and decreases in volume as it is subject to a series of complex ecological and hydrological processes, each specific to the individual location on the floodplain.

[4] For example, the Border Rivers Model Build report (DPIE Water, 2020a). Reports for each Valley are available from the DPIE Water website.

At present there is no established process or body of evidence that would enable the accurate representation of returned flows in river models. Circumstances vary broadly from property to property and from floodplain to floodplain preventing the generation of ‘standard’ rules or the broad application of proportional returns. There is no known model that represents these complex processes. In lieu of the ability to model this process this report assumes that:

- **100% of foregone diversions return to the river** (i.e. all non-harvested water returns from the floodplain to the river)

2. Contribution to end-of-system flows

There is no established process to represent the return of flows to the river from the floodplain. Without the ability to represent this process the department is unable to accurately delineate where the foregone diversions from each property return to the river. The location of these return flows is an important consideration for the modelling. From the time the flows reach the river they are subject to in-stream attenuation, reducing in size as they move along the length of the tributary catchments. The process for representing in-stream attenuation is established in the modelling for the five valleys where *Policy* implementation is taking place.

Whilst the process for in-stream flow attenuation is established we are currently unable to confidently associate foregone diversions from each property with a location from which they would be subject to attenuation losses. In lieu of the ability to accurately position these return flows in the model this report assumes that:

- **100% of that returning water contributes to end-of-system flows** (i.e. 100% of returned floodplain water flows unaltered to the end of system).

This assumption holds up well in valleys where floodplain harvesting occurs along the length of the regulated river. In these systems foregone diversions are added to a large channel with comparatively limited in-stream losses.

In valleys where floodplain harvesting occurs away from the main channel foregone diversions may have to travel through a series of sinuous river deltas and extensive wetlands to reach the Barwon-Darling. Many of these areas are considered terminal and have little to no downstream hydrological connectivity outside large flood events.

In valleys where this situation exists a more detailed analysis of water source connectivity may be undertaken. Water sources with little to no connectivity through to the Barwon-Darling may be removed from downstream outcomes calculations. More information can be found under the valley-specific assessment section.

3.1.3 Summary

Put simply, these two assumptions mean that any additional flow associated with foregone diversion is routed directly to the end-of-valley-system outflow and added to the inflows from that valley into the Barwon-Darling river system.

This is of course a simplification of the real world. In reality end-of-valley flows would not increase linearly with an increase in the volume of foregone diversions within each valley. Other natural processes such as evaporative losses, aquifer recharge and other local and/or catchment hydrological processes would influence the total volume and timing of flow reaching the end of the system.

Adoption of these assumptions maximises the volume of additional flow reaching the Barwon-Darling providing insight into the **maximum possible effect** of implementing the *Policy*. As the downstream effects assessment is intended to provide insights in the potential scale of change after implementation of the *Policy*, and not to provide definitive volumetric outcomes, adoption of these assumptions is justified.

Whilst this report focuses on the maximum possible effect of *Policy* implementation, a sensitivity test was also undertaken to assess the impact of these assumptions on model results. The test assumed that 50% of foregone diversions return to river as opposed to 100%. Results for both 100% and 50% return flows are reported in in Appendix A.

Modelling is based on the best available data and as this improves, assumptions can be refined to provide increasingly improved estimates of the changes that could be expected through implementation of the *Policy*.

3.2 Valley-specific assessment – NSW Border Rivers

To date, return flow impact assessment has been undertaken for the NSW Border Rivers valley under two scenarios:

- Without policy implementation (*Current Conditions Scenario*)
- with policy implementation (*Valley Scale Compliance Scenario*).

The Border Rivers valley is located in southern Queensland and northern New South Wales. The valley has several rivers that straddle the Queensland and NSW border and is one of the most northern of the Basin catchments. The Macintyre River (which becomes the Barwon River downstream) forms the main trunk of the regulated river system. Its tributaries rise west of the Great Dividing Range and continue to run westward before gradually merging to form the Barwon River upstream of Mungindi.

3.2.1 Location of properties eligible for floodplain harvesting

Eligible properties in the NSW Border Rivers are located along the southern side of the Border-Rivers Regulated River. The majority of properties are concentrated in the downstream end of the valley below the confluence of the Macintyre and Dumaresq rivers. All properties are within close proximity to the regulated river main channel so connectivity between floodplain, river and downstream systems is assumed to be high.

3.2.2 Annual average diversions

Modelled timeseries of floodplain harvesting diversions in the Border Rivers were provided for before (DPIE Water 2020a) and after (DPIE Water 2020b) implementation of the *Policy*. Their difference allows assessment of the downstream impacts of licensing floodplain harvesting.

Table 3 provides a summary of the modelled change in annual floodplain harvesting diversions in the Border Rivers under the *Policy*. Results indicate a 13% reduction in average annual floodplain harvesting diversions under the *Policy*, with diversions reduced from about 44 to about 38 GL/year. The assumption of 100% return flows returns an additional ~5.5 GL to the Border Rivers system per year on average.

Table 3 Total annual diversions and annual end-of-system flow without and with implementation of the *Policy* in the NSW Border Rivers valley

Results	without *Policy* (GL)	with *Policy* (GL)	Change (GL)	Change (%)
Total annual FPH diversion	43.6	38.0	-5.5	-12.7%
Annual end-of-system flow	538.3	543.8	+5.5	+1.0%

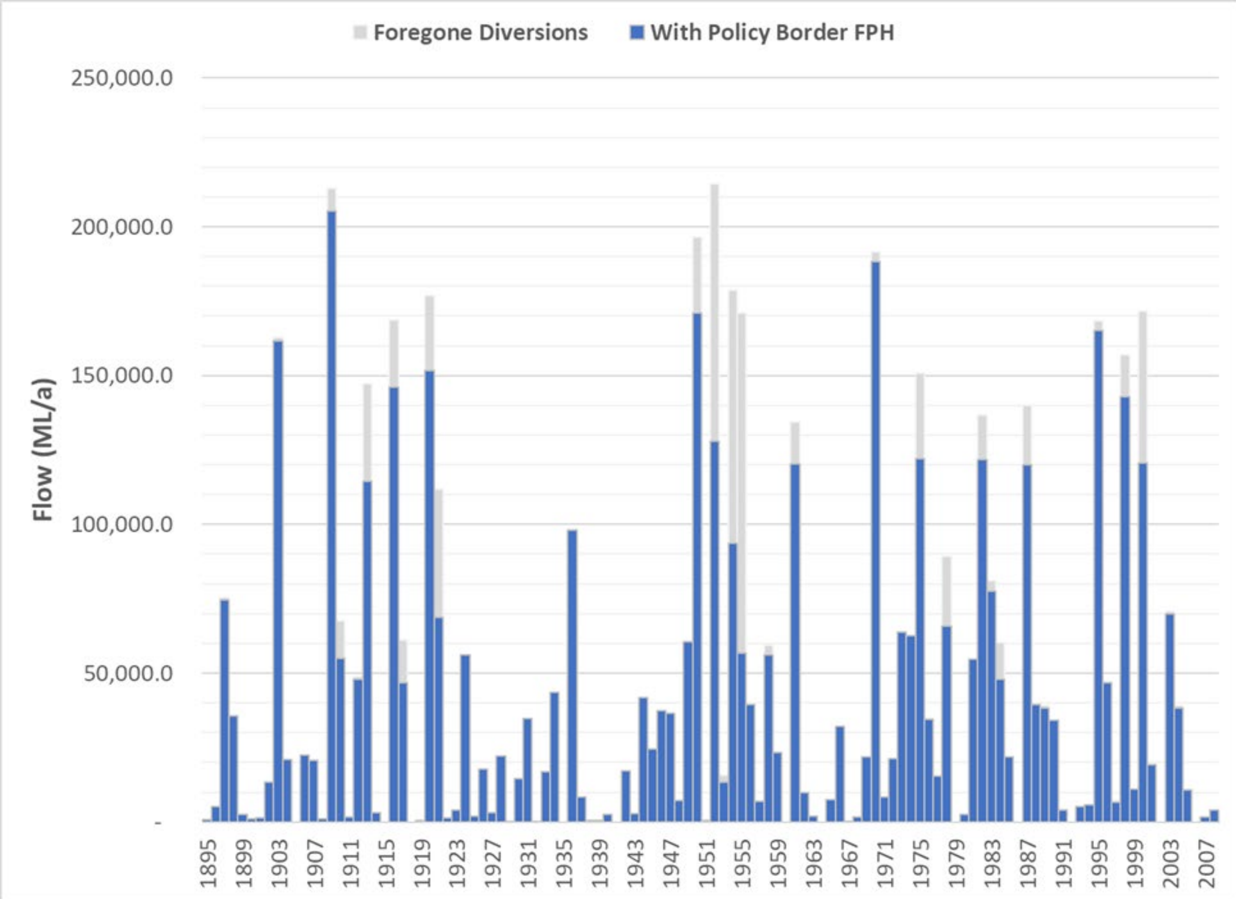

Figure 3 Modelled annual floodplain harvesting diversions with the *Policy* implemented over the 114-year climate record for the Border Rivers valley. Each annual bar shows the floodplain harvesting diversions and the foregone diversions with the *Policy* implemented

The effect of *Policy* implementation is not shared equally between years. Floodplain harvesting is highly variable in nature, reliant on wet to very wet conditions to create overland flows. In drier years very little to no floodplain harvesting takes place. This variability is masked when reporting average annual results (such as in Table 3), making it important to report at annual time step.

Figure 3 shows the modelled floodplain harvesting volumes and foregone diversions with the *Policy* implemented. The blue represents the modelled annual floodplain harvesting volumes after the licensing framework is established. The grey represents the volume of diversions that is foregone after licensing. Conversely this volume can be thought of as the additional amount that would be diverted if licensing is not implemented.

3.2.3 End of system flows

Floodplain harvesting diversions in the NSW Border Rivers are estimated to represent about 8.1% of total end-of-valley-system flow without *Policy* implementation. The chart in Figure 4 shows the modelled annual floodplain harvesting diversions and end-of-system flow volumes without the *Policy* being implemented, over the 114-year climate period. It can be seen from that floodplain harvesting diverts a small proportion of the total end-of-system flow in most years. The estimated 5.5 GL/year that would be returned to the river system under the *Policy* contributes 1.0% of the total end-of-system flow.

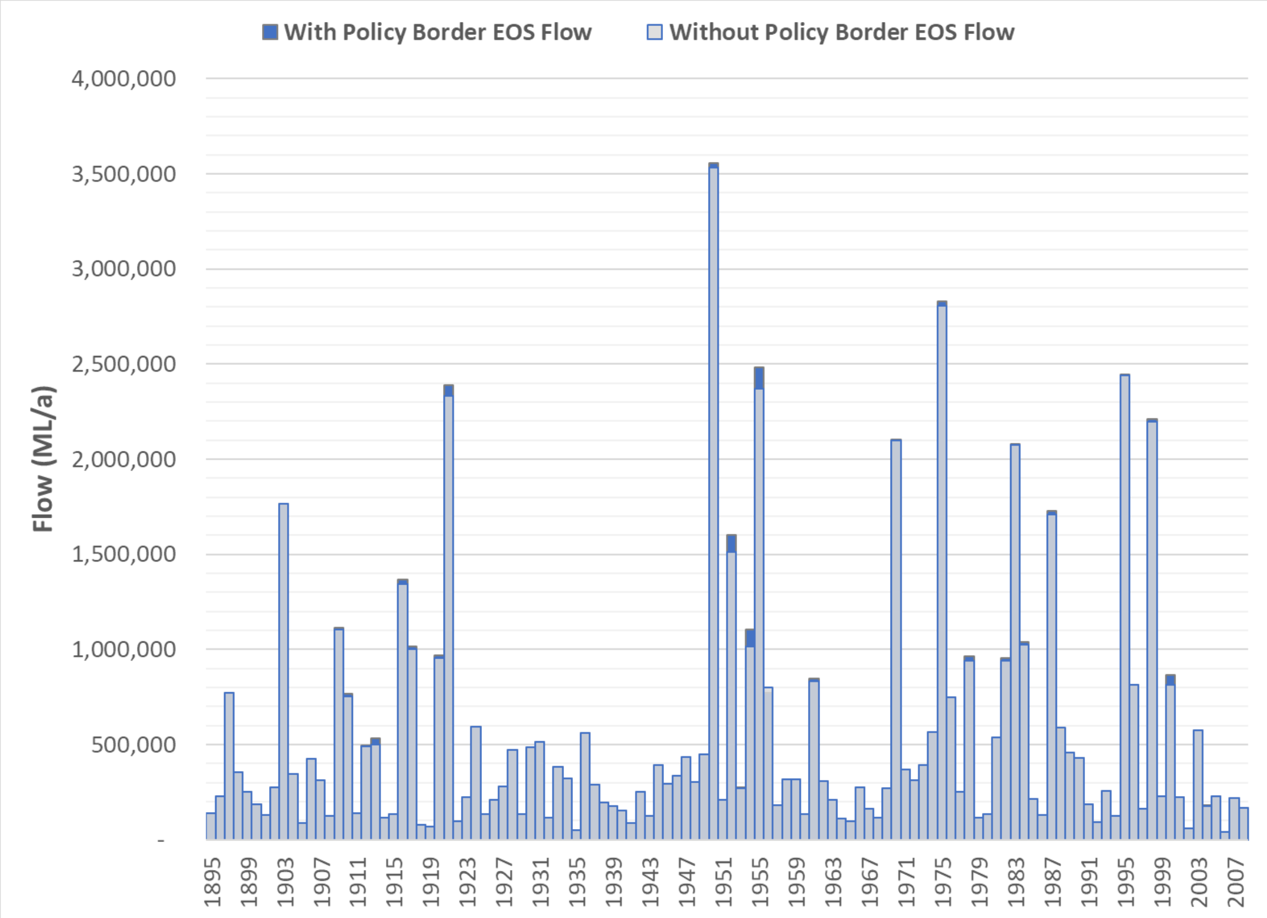

Figure 4 Modelled annual end of system (EOS) flow volume and floodplain harvesting diversions over the 114-year climate record (1895-2009) without the *Policy* being implemented in the Border Rivers valley

Foregone diversions are ranked (Figure 5) from largest effect to least illustrating the estimated proportion of years in which the *Policy* will have impact and the magnitude of that impact. Under the *Policy*, end-of-system flow volumes are predicted to show some increase in about 50% of years, with the largest volumetric effect in wet to very wet years and over consecutive wet years.

In about 10% of the years, equivalent to the size of a 1:10 year flood event, implementing the *Policy* is predicted to provide an increase in end-of-system flows of more than 19 GL, or more than three times the average (5.5 GL). In the top 5% of wet years, equivalent to a 1:20 year flood, implementing the *Policy* is predicted to provide an increase in end-of-system flows of more than 33 GL or more than 6 times the average. In the wettest year on record (1955) a maximum floodplain harvesting foregone diversion of about 110 GL is predicted (Figure 5).

Under consecutive years with frequent and/or large volume overland flow events, the potential exists under the *Policy* for account limits to 'cap out' during a water year. This cap may be realised before storages are completely full. These storages would have been filled in the without *Policy* scenario, i.e. the *Current Conditions Scenario*. A relative volume of free storage space then remains for use in the following water year which would not have existed otherwise.

With subsequent credit to the annual account at the beginning of the following water year and this remaining free storage volume, the potential exists for greater floodplain harvesting under subsequent flood events than would have been the case before implementation of the *Policy.* Nevertheless, and taking this into account, total diversions over multiple years under the *Policy* are predicted to remain equivalent to or lower than modelled diversions without the *Policy* implemented.

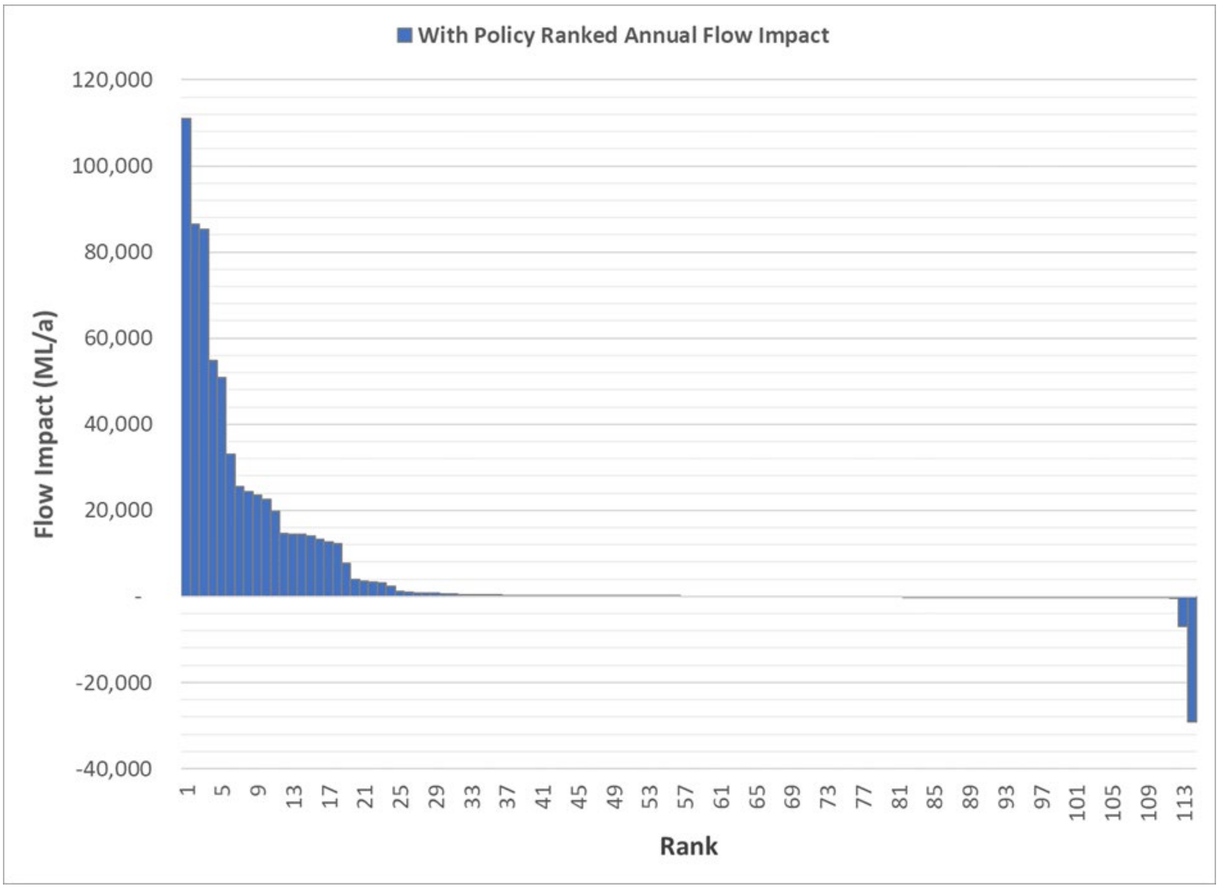

Figure 5 Modelled end of system ranked change in annual end-of-system flow volume with the *Policy* implemented for the Border Rivers valley

3.3 Valley-specific assessment – Gwydir

To date, return flow impact assessment has been undertaken for the Gwydir valley under two scenarios:

- without policy implementation (*Current Conditions Scenario*)
- with policy implementation (*Valley Scale Compliance Scenario*).

The Gwydir valley is located immediately below the Border Rivers catchment in northern New South Wales. The Gwydir River itself begins on the New England Tablelands flowing westward through steep valleys before being regulated by Copeton Dam.

Releases from Copeton flow west to Moree, where the Gwydir River widens into a flat alluvial floodplain and splits into a series of water courses. The Gingham and the lower Gwydir watercourse flow into the Gwydir wetlands where the river spreads further across the floodplain to-create a terminal delta where wetlands and swamps soak up much of the river flow.

The Gwydir Wetlands are among the most extensive and significant semi-permanent wetlands in north-west New South Wales and include four Ramsar listed sites. There is little to no hydrological connectivity between the area that encompasses the Gwydir wetlands and the Barwon-Darling.

To the north and south of the wetlands the Mehi River, Moomin Creek and Gil Gil Creek carry the bulk of the volume in the Gwydir Regulated River providing connectivity to the Barwon-Darling.

3.3.1 Location of properties eligible for floodplain harvesting

The Gwydir designated floodplain begins just east of Moree extending to the west and spreading to encompass most of the lower Gwydir.

The Gwydir diverges close to Moree into three broad water courses. The northern divergence of the Gwydir regulated river contains a series of floodplain harvesting properties located along Carole Creek and Gil Gil Creek. This system connects through to the Barwon Darling.

In the center of the Gwydir designated floodplain there are a much smaller number of floodplain harvesting properties located across the Gingham Watercourse and Gwydir water sources. This location is a highly sinuous terminal delta associated with the Gwydir wetlands and there is little to no hydrological connectivity outside major flooding events. Water that enters the Gingham Watercourse and Gwydir water sources remains in these areas, providing benefits to local wetland ecosystems. These water sources do not connect to the Barwon-Darling and foregone diversions from these properties have not been included in the end of system flow calculations.

A larger number of floodplain harvesters exist in the southern part of the Gwydir designated floodplain along the Mehi River and Moomin Creek. There are multiple connected wetlands through the southern Gwydir however the floodplain harvesting properties in this region are largely connected to the regulated river system and have good connectivity to the downstream Barwon-Darling.

3.3.2 Annual average diversions

Modelled timeseries of floodplain harvesting diversions in the Gwydir were provided for before (DPIE Water, 2020d) and after (DPIE Water, 2020e) implementation of the *Policy*. Their difference allows assessment of the downstream impacts of licensing floodplain harvesting.

Table 4 provides a summary of the modelled change in annual floodplain harvesting diversions in the Gwydir under the *Policy*. Results indicate a 30.4% reduction in average annual floodplain harvesting diversions under the *Policy*, with diversions reduced from about 174 to about 121 GL/year. The assumption of 100% return flows from these water sources returns an additional ~53 GL to the Gwydir system per year on average.

Note - The Barwon-Darling model uses a specific flow calibration process for catchment inflows to attempt to correct higher flow events not captured by upstream gauges. The application of this flow calibration results in the estimated impact on Gwydir end of system flow due to Policy implementation decreasing from approximately 43 GL to 37.5 GL, a 14% reduction. The change is not material to the outcomes of the assessment

Table 4 Total annual diversions and annual end-of-system flow without and with implementation of the *Policy* in the Gwydir valley

Results	without *Policy* (GL)	with *Policy* (GL)	Change (GL)	Change (%)
Total annual FPH diversion	174.0	121.0	-52.9	-30.4
Annual FPH diversion in terminal water sources (do not contribute to end of system flow)	29.3	19.6	-9.7	-33.1
Annual end-of-system flow	170.1	207.6	37.5	+22.0

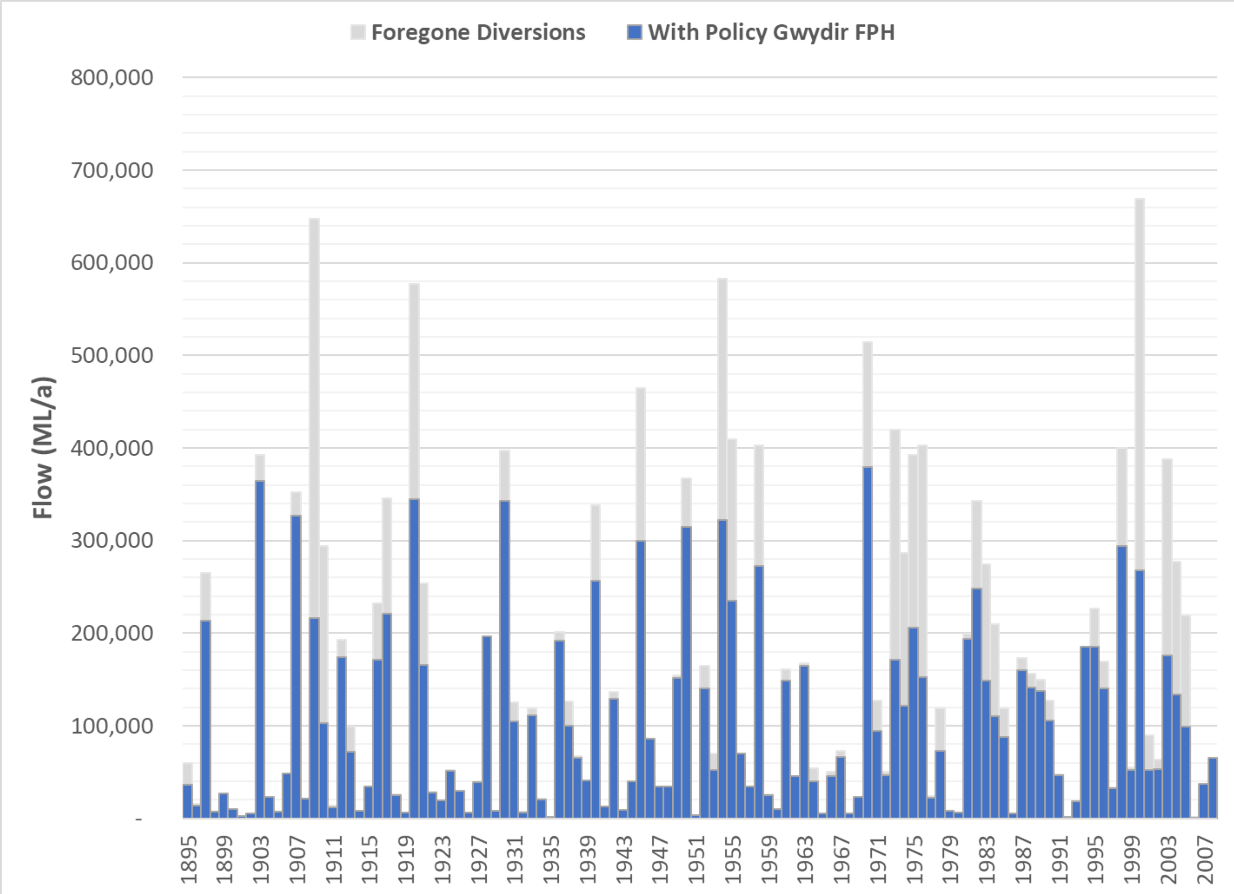

Figure 6 Modelled annual floodplain harvesting diversions with the *Policy* implemented over the 114-year climate record for the Gwydir valley. Each annual bar shows the floodplain harvesting diversions and the foregone diversions with the *Policy* implemented

The effect of *Policy* implementation is not shared equally between years. Floodplain harvesting is highly variable in nature, reliant on wet to very wet conditions to create overland flows. In drier years very little to no floodplain harvesting takes place. This variability is masked when reporting average annual results (such as in Table 4), making it important to report at annual time step.

Figure 6 shows the modelled floodplain harvesting volumes and foregone diversions with the *Policy* implemented. The blue represents the modelled annual floodplain harvesting volumes after the licensing framework is established. The grey represents the volume of diversions that is foregone after licensing. Conversely this volume can be thought of as the additional amount that would be diverted if licensing is not implemented.

3.3.3 End of system flows

In the Gwydir not all water sources connect through to the downstream Barwon-Darling. The Gingham Watercourse Water Source and the Gwydir Water Source have been removed from the assessment of downstream outcomes including any calculation of end of system flow. These water sources are considered terminal wetlands and have no connectivity outside major flooding events. Any foregone diversions produced by the *Policy* would remain in the water source contributing to local environmental outcomes as detailed in the Environmental Benefits report (DPIE Water, 2020f).

Annual average floodplain harvesting diversions in these water sources total 29.3 GL without policy implementation (Table 4). After establishing the licensing framework analysis indicates that annual average diversions in the Gingham Watercourse Water Source and the Gwydir Water Source will be reduced by 33.1% to 19.6 GL. The additional 9.7 GL left in system due to *Policy* implementation would remain in the RAMSAR listed Gwydir wetlands and has not been considered as part of any further downstream analysis. These foregone diversions would not contribute to Barwon-Darling inflows

The water sources that do connect to the Barwon-Darling also display the sinuous, delta-like characteristics of the lower Gwydir. Large volumes of water are retained in system and the Gwydir has far lower end of system flows and contributes far less to the Barwon-Darling than other similar northern Basin tributary systems. Gwydir end of system flows are more than three time smaller than that of the NSW Border Rivers whilst Gwydir floodplain harvesting diversion are approximately four times larger.

The chart in Figure 7 shows end-of-system flow volumes with and without the *Policy* being implemented, over the 114-year climate period. The grey also represents the volume of foregone diversions after licensing that contribute to end of system flows. It can be seen from that floodplain harvesting diverts a small proportion of the total end-of-system flow in drier years but has a more significant impact in wetter years. The estimated 37.5 GL/year annual average that would be returned to the river system under the *Policy* would contribute +22.0% of the total end-of-system flow.

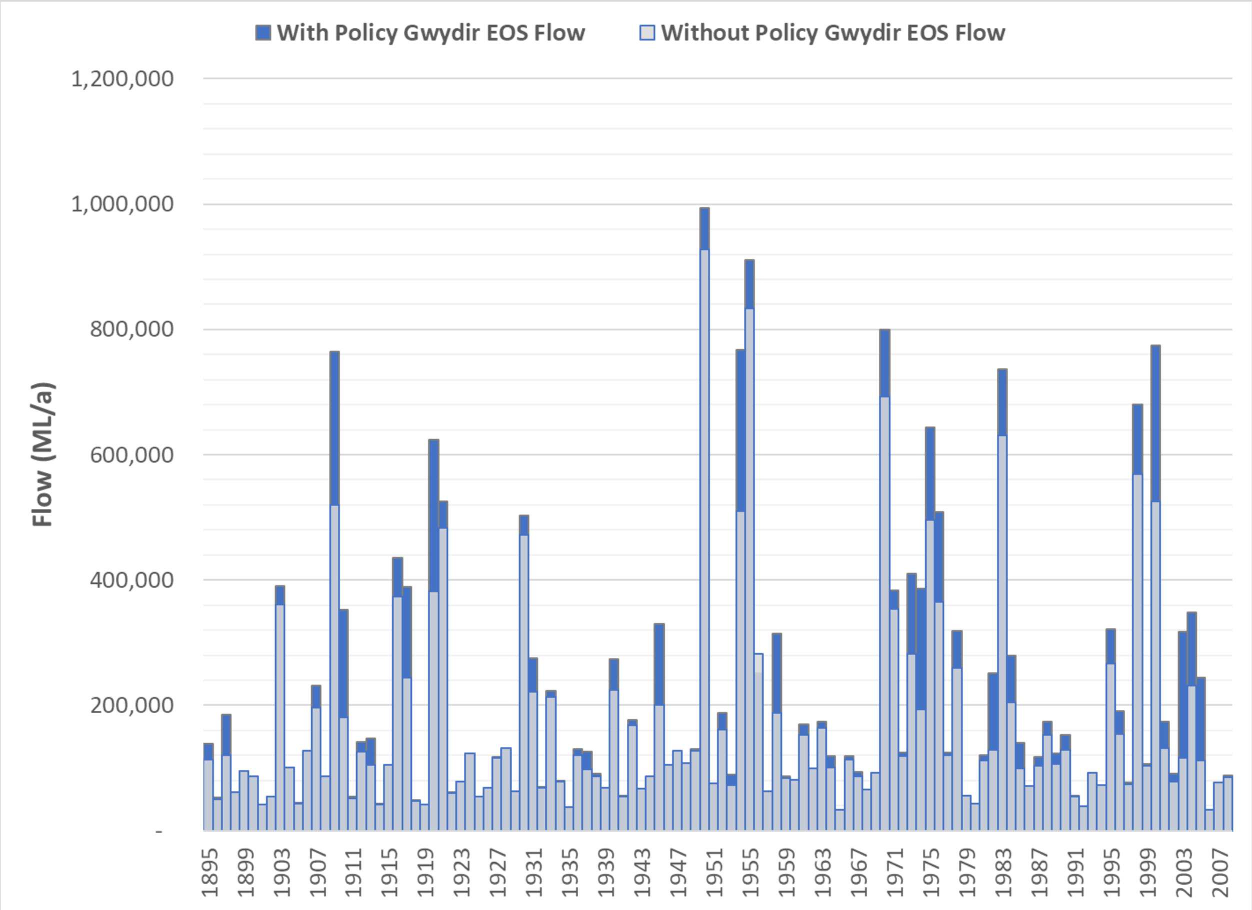

Figure 7 Modelled annual end of system (EOS) flow volume and floodplain harvesting diversions over the 114-year climate record (1895-2009) without the *Policy* being implemented in the Gwydir valley

Foregone diversions are ranked (Figure 8) from largest effect to least illustrating the estimated proportion of years in which the *Policy* will have impact and the magnitude of that impact. Under the *Policy*, end-of-system flow volumes are predicted to show some increase in about 63% of years, with the largest volumetric effect in wet to very wet years and over consecutive wet years.

In about 10% of the years, equivalent to the size of a 1:10 year flood event, implementing the *Policy* is predicted to provide an increase in end-of-system flows of close to 150 GL, or more than four times the average (37.5 GL). In the top 5% of wet years, equivalent to a 1:20 year flood, implementing the *Policy* is predicted to provide an increase in end-of-system flows of approximately 250 GL or more than 6 times the average. These flood years would see the *Policy* contribute up to 50.3% to end of system flows.

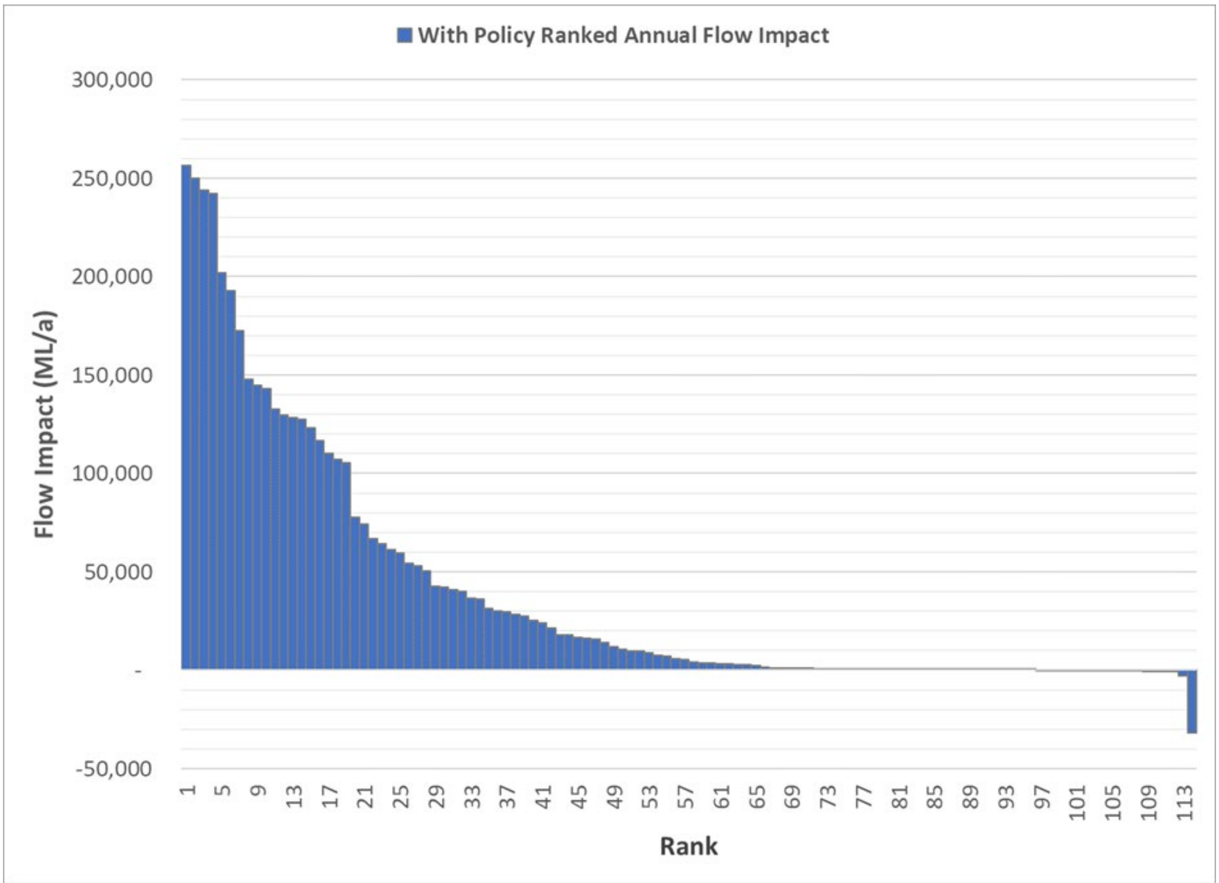

Figure 8 Modelled end of system ranked change in annual end-of-system flow volume with the *Policy* implemented for the Gwydir valley

3.4 NSW Northern Basin assessment

Modelling of the Barwon-Darling river system was undertaken for a series of scenarios:

1. Without *Policy* implementation in any valley (*Current Conditions Scenarios*)
2. With *Policy* implementation in the Border Rivers and Gwydir valleys (*Valley Scale Compliance Scenario*)

This initial assessment report quantifies the impacts that licensing floodplain harvesting in the Border Rivers and Gwydir valleys is predicted to have on downstream systems. Impacts stemming from the Barwon-Darling and its tributary valleys are assessed individually and cumulatively.

Future extensions to this report will include the modelled impacts of licensing in the remaining three valleys; Namoi, Macquarie and Baron-Darling, as well as the cumulative influence of all five valleys.

3.4.1 Impact of *Policy* implementation in the NSW Border Rivers valley

Table 5 and Figure 9 provide quantification of potential changes in the Barwon-Darling due to *Policy* implementation in the NSW Border Rivers valley at the key gauge locations of:

- Border Rivers end-of-system (i.e. inflows to the Barwon-Darling)
- Darling River at Bourke
- Darling River at Wilcannia.

Table 5 Potential changes in annual mean flow at three key locations without and with the *Policy* implemented in the NSW Border Rivers valley. Locations are shown in Figure 8

Location	Without *Policy* annual mean flow (GL)	With *Policy* annual mean flow change (GL)	With *Policy* annual mean flow change (%)
Border Rivers inflow	538.3	+5.5	+1.0%
Bourke (425003)	1,864.4	+4.4	+0.2%
Wilcannia (425008)	1,383.1	+2.8	+0.2%

An important message from these results is that the predicted benefits of *Policy* implementation effectively decrease as flow moves down through the system, with natural channel losses such as local aquifer recharge, seepage and evaporation/riparian evapotranspiration and consequent reduction in the effect on flow outcomes at downstream locations. The relative effect of *Policy* implementation also decreases as you move downstream as the same volume represents a smaller percentage of the total flow volume which has increased after contribution of inflow from other major tributaries such as flow from the Warrego and Paroo Rivers from the north.

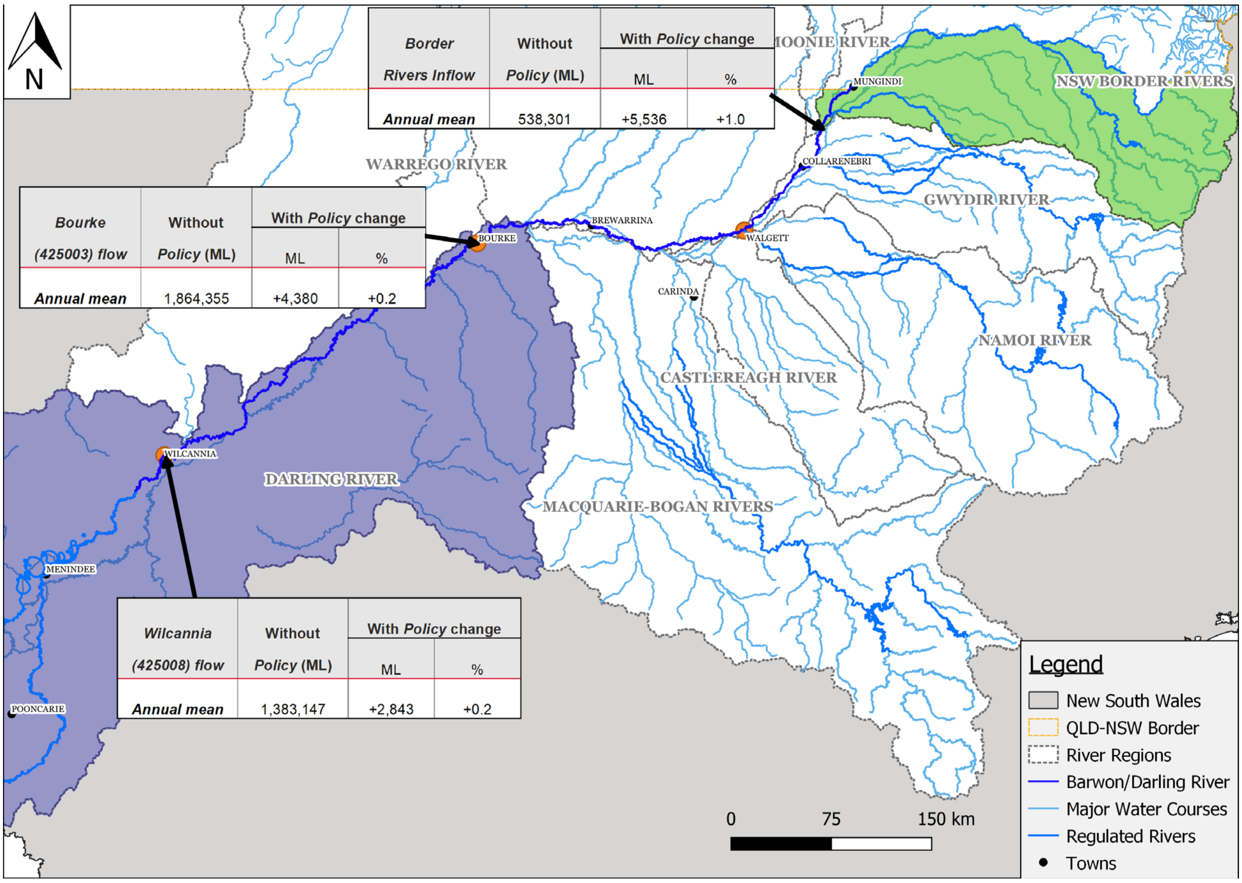

Figure 9 Map of the Barwon-Darling system, showing modelled flow metrics at 3 key locations after *Policy* implementation in the NSW Border Rivers valley

3.4.2 Impact of *Policy* implementation in the Gwydir valley

Table 6 and Figure 10 provide quantification of potential changes in the Barwon-Darling due to *Policy* implementation in the Gwydir valley at the key gauge locations of:

- Gwydir end-of-system (i.e. inflows to the Barwon-Darling)
- Barwon River at Walgett
- Darling River at Bourke
- Darling River at Wilcannia.

Foregone diversions occurring in the Gingham Watercourse Water Source and the Gwydir Water Source have been removed from this assessment as these water source have no downstream connectivity to the Baron-Darling and do not contribute to end of system flow.

Table 6 Potential changes in annual mean flow at four key locations without and with the *Policy* implemented in the Gwydir valley. Locations are shown in Figure 10

Location	Without *Policy* annual mean flow (GL)	With *Policy* annual mean flow change (GL)	With *Policy* annual mean flow change (%)
Gwydir inflow	170.1	+37.5	+22.0%
Walgett (422001)	1,293.1	+36.4	+2.8%
Bourke (425003)	1,864.4	+32.7	+1.8%
Wilcannia (425008)	1,383.1	+23.4	+1.7%

An important message from these results is that the predicted benefits of *Policy* implementation effectively decrease as flow moves down through the system, with natural channel losses such as local aquifer recharge, seepage and evaporation/riparian evapotranspiration and consequent reduction in the effect on flow outcomes at downstream locations. The relative effect of *Policy* implementation also decreases as you move downstream as the same volume represents a smaller percentage of the total flow volume which has increased after contribution of inflow from other major tributaries such as flow from the Warrego and Paroo Rivers from the north.

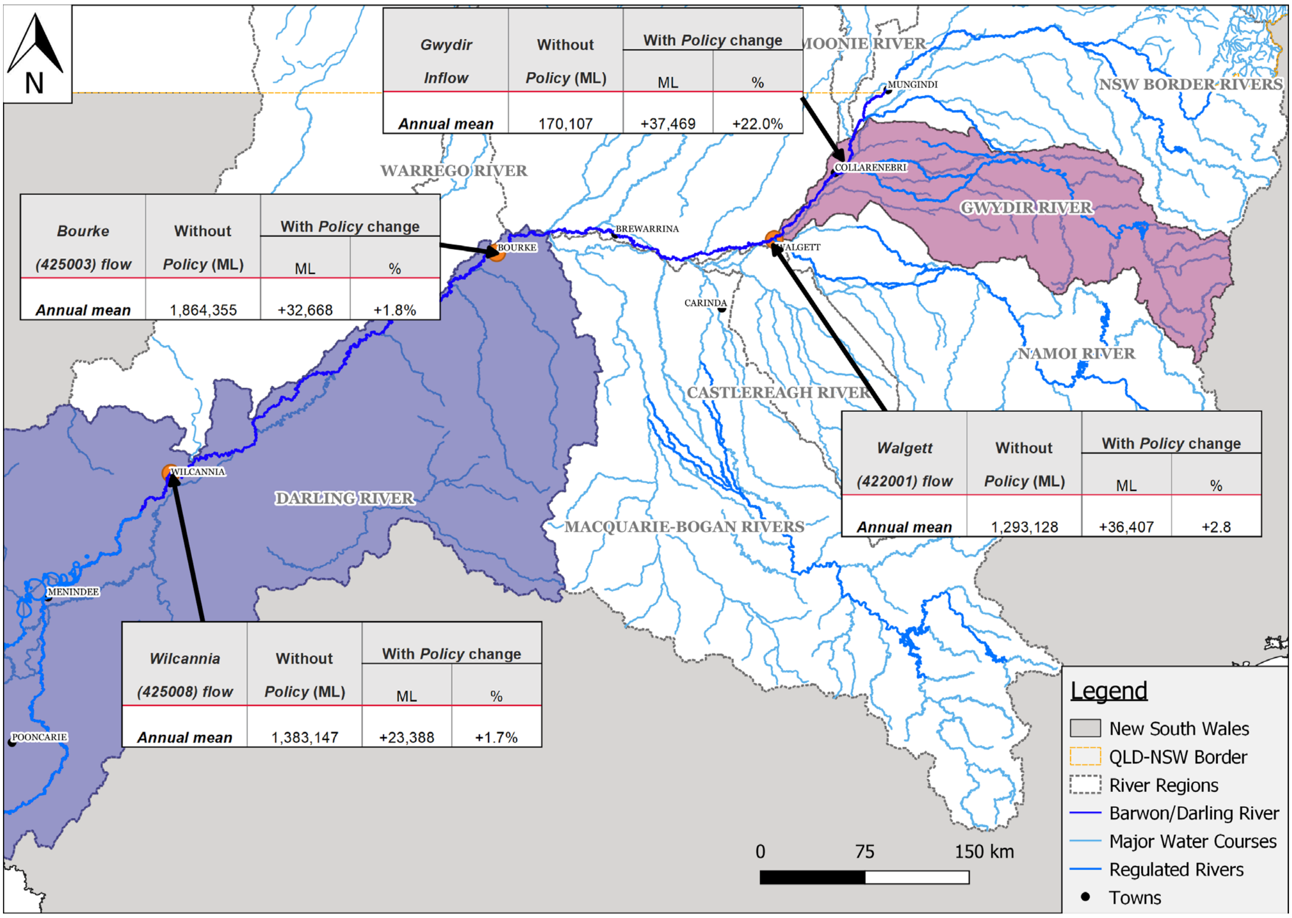

Figure 10 Map of the Barwon-Darling system, showing modelled flow metrics at 3 key locations after *Policy* implementation in the Gwydir valley

3.4.3 Cumulative impact of *Policy* implementation in the NSW Border Rivers and Gwydir valleys

Two sets of metrics are used to quantify the potential impact:

1. Annual flows at key locations
2. Water availability in the Barwon-Darling disaggregated by licence type.

Impact on flows by location

Table 7 and Figure 11 provide quantification of potential changes in the Barwon-Darling due to *Policy* implementation in the NSW Border Rivers and Gwydir valleys at the key gauge locations of:

- Border Rivers inflow
- Gwydir inflow
- Barwon River at Walgett
- Darling River at Bourke
- Darling River at Wilcannia.

Border River provides an addition annual average of 5.5GL into the northern section of the Barwon River above Collarenebri after *Policy* implementation. This is joined by an additional 37.5 GL annual average from the Gwydir from streams above Walgett.

Once these inflows join the larger Barwon-River they make up a smaller portion of the larger whole. The additional 41.1GL annual average provided by both *Policy* implementation in the NSW Border River and Gwydir represents 3.2% of the total at the Walgett gauge. As this volume travels further down the system it attenuates, reducing to 37.1 GL (2.0%) at Bourke and 26.2GL (1.9%) reaching Wilcannia at the bottom of the Barwon-Darling.

Table 7 Potential changes in annual mean flow without and with the *Policy* implemented in the NSW Border Rivers and Gwydir at Border Rivers and Gwydir inflows to the Barwon-Darling and three key locations in the Barwon-Darling. Some locations are shown in Figure 11

Location	Without *Policy* annual mean flow (GL)	With *Policy* annual mean flow change (GL)	With *Policy* annual mean flow change (%)	With *Policy* annual max flow change (GL)	With *Policy* flow change in max year (%)
Border Rivers inflow	538.3	+5.5	+1.0	+111.1	+4.7
Gwydir inflow	170.1	+37.5	+22.0	+256.7	+50.3
Walgett (422001)	1,293.1	+41.1	+3.2	+311.6	+7.8
Bourke (425003)	1,864.4	+37.1	+2.0	+283.2	+3.8
Wilcannia (425008)	1,383.1	+26.2	+1.9	+180.3	+15.2

The year of maximum effect vary from location to location based on a series of local hydrological and climatic factors. For example, *Policy* was simulated to have maximum effect at Wilcannia in 1974 whilst 1954 saw the most change at Bourke. Comparison between location may therefore not be like for like.

In the Gwydir year of maximum effect, end of system annual flow changed by 50% with an additional 256.7 GL modelled as a result of foregone diversions. This is ~11x the average benefit seen at this location. Similar maximum volume changes (283.3 GL) are seen further downstream at Bourke however this only represents 3.8% of the total volume in that year at that location.

An important message from these results is that the predicted benefits of *Policy* implementation are maximized immediately downstream of the tributary valleys subject to *Policy* implementation and vary from year to year. Annual average benefits are modeled to decrease (as a proportion and volume) as flow moves down through the system, with natural channel losses such as local aquifer recharge, seepage and evaporation/riparian evapotranspiration and consequent reduction in the effect on flow outcomes at downstream locations. Savings from the NSW Border Rivers and Gwydir input into the northern Barwon-Darling were reduced by 36% by the time they reach Wilcannia.

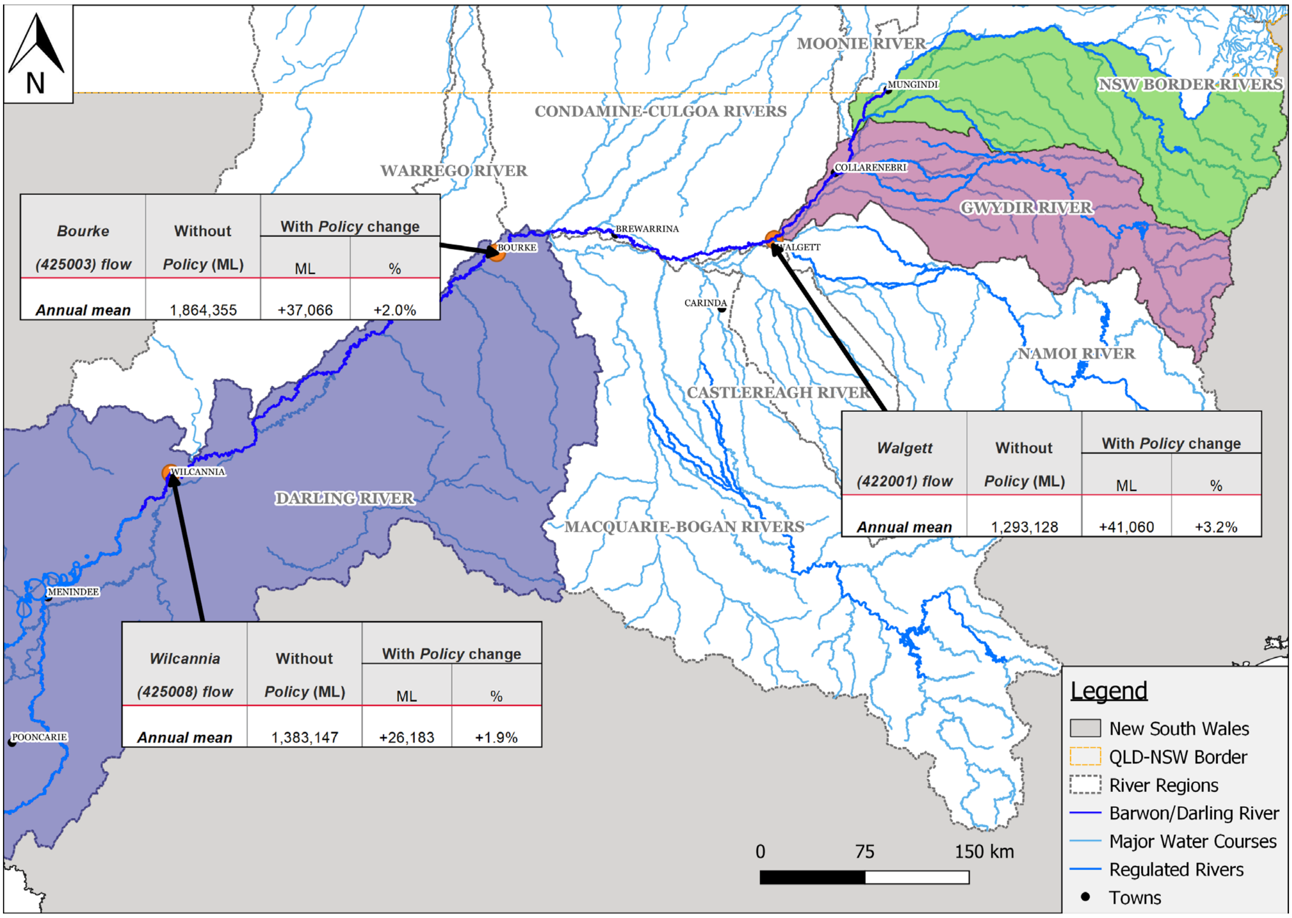

Figure 11 Map of the Barwon-Darling system, showing modelled flow metrics at 3 key locations for potential downstream outcomes of *Policy* implementation in the NSW Border Rivers and Gwydir valleys

Water availability for Barwon-Darling licences

The additional volume produced by *Policy* implementation in each of the Barwon-Darling tributary valleys is potentially available for extraction in the Barwon-Darling, contributing to water availability for downstream communities, town water supply, stock & domestic users and irrigators.

The downstream effects assessment indicates that this additional volume has a negligible impact on A, B & C Class licence holders in the Barwon-Darling. This is due to the additional volume mostly being available during wetter years when flows are high and extraction opportunities for unregulated licences are already maximised.

As a further set of information providing insights into potential effects of *Policy* implementation, Tables 8 provides detail of modelled annual outcomes as a result of implementing the *Policy* in the NSW Border Rivers and Gwydir valley for each licence class in the Barwon-Darling *Water Sharing Plan*:

- Class A
- Class B
- Class C
- floodplain harvesting.

The impact on availability for downstream licence classes has been undertaken under the base assumption of 100% return flows. Additional results (3-, 5- and 10-year outcomes) are provided in Appendix A , and include results under base (100% return flows) and sensitivity (50%) return flows).

Table 8 Barwon-Darling diversion summary results – Border Rivers and Gwydir

Mean annual diversion (GL/a)	Base case (without *Policy*) (GL)	With *Policy* (GL)	*Impact (%)*
Class A	6.3	6.3	< ±0.1%
Class B	115.6	115.7	< ±0.1%
Class C	45.7	45.9	+0.5%
Floodplain harvesting	177.0	182.0	+2.9%

3.5 NSW Southern Basin assessment

Modelling of the Southern Basin was undertaken for a series of scenarios:

1. Without *Policy* implementation in any valley (*Current Conditions Scenarios*)
2. With *Policy* implementation in the Border Rivers and Gwydir valleys (*Valley Scale Compliance Scenario*)

This initial assessment quantifies the impacts that licensing floodplain harvesting in the Border Rivers and Gwydir valleys is predicted to have on flows in the NSW Southern Basin. To calculate these impacts with and without *Policy r*esults from the DPIE Barwon-Darling model were provided to the Murray-Darling Basin Authority and used as an input into their Murray model. This model is used to calculate diversion and allocations in the Lower Darling and Murray systems. Future extensions to this report will include the modelled impacts of licensing in the remaining three valleys; Namoi, Macquarie and Barwon-Darling.

Murray and Lower Darling system

The northern and southern sections of the NSW Murray-Darling Basin are connected through the lower Darling River. Just as the Barwon-Darling connects the northern tributary valleys to Menindee Lakes so does the lower Darling connect Menindee to the River Murray. Only a small amount of run-off is generated within the lower Darling catchment and nearly all the water seen in system is a result of flows originating in the Barwon–Darling and its upstream valleys.

Below the Menindee Lakes, the river has 2 large and distinct channels — its main channel, the lower Darling River, and the Great Darling Anabranch. The lower Darling continues south for 530 kilometers connecting to the Murray at Wentworth. The Great Darling Anabranch runs parallel to the lower Darling and has a number of overflow lakes that can hold water for prolonged periods following a flood. It branches from the main channel of the river about 55 km south of Menindee and joins the River Murray just a few kilometers downstream of Wentworth.

At this point the waters of the northern and southern Basin combine and the River Murray travels for a short distance (~100km) before crossing the border into South Australia.

3.5.1 Impact of *Policy* Implementation on the Lower Darling Regulated River

The additional volume produced by *Policy* implementation in the NSW Border Rivers and Gwydir valleys contributes 28.3 GL average annual inflow to Menindee Lakes. This volume represents a minimal annual average increase of 1.8%.

This small proportional increase to inflows has a negligible impact on diversions or allocations in the Lower Darling Regulated River Water Source as supplied by Menindee Lakes. Modelling actually indicates a small reduction in diversions and allocations after these additional inflows. These small changes are within the model's error tolerances and may be the result of model artefacts. The analysis shows no effective impact of *Policy* implementation on annual average diversions or allocations in the Lower Darling over the modelled timescale.

Table 9 Potential changes in annual metrics in the Lower Darling without and with the *Policy* implemented in the NSW Border Rivers and Gwydir valleys.

	Without *Policy*	With *Policy*	With *Policy* annual mean change	With *Policy* annual mean change (%)
Menindee Lakes Inflow (GL)	1,533.8	1,562.1	+28.3	+1.8%
Net Diversions (GL)	47.9	47.5	-0.4	-0.8%
General Security Allocation (30th June)	96.5	96.0	-0.5	-0.5%

Whilst the analysis shows no effective long-term average impact of *Policy* implementation on Lower Darling General Security Allocations there are some years in the timeseries that see change. In approximately 3 of the 114 years (~3% of years) we see any improvement greater than 0.1% in General Security allocations because of *Policy* implementation in the NSW Border Rivers and Gwydir valleys (Figure 12).

This seemingly small change to Lower Darling General Security Allocations may be attributed to the large proportion of years when the system is fully allocated (100%). In these years any change in volume would not translate to additional allocations. Only 7 years in the 114-year time series show a General Security Allocation of less than 100% i.e. an opportunity to improve through *Policy* implementation. In one of those years allocations are modelled to improve from ~70% to 100% due to additional upstream volumes provided by *Policy*.

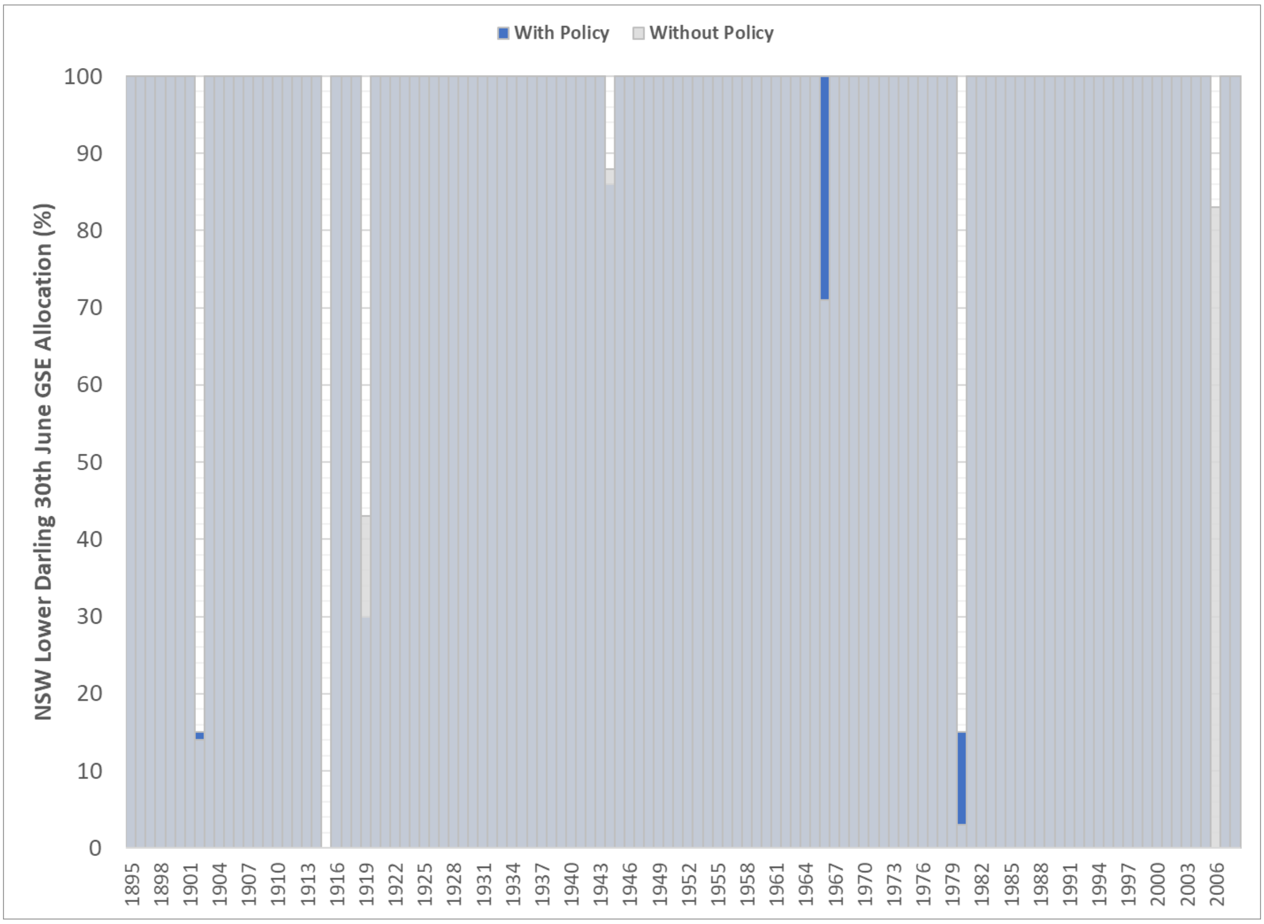

Figure 12 Lower Darling General Security Allocations on 1 July with and without *Policy* implementation in the NSW Border Rivers and Gwydir valleys

3.5.2 Impact of *Policy* Implementation on the NSW Murray Regulated River

The additional volume produced by *Policy* implementation in the NSW Border Rivers and Gwydir valleys contributes 28.27 GL average annual flow at Wentworth. The model indicates a very minimal attenuation as water flows down the Lower Darling into the Murray system.

This 28.27 GL only represents a very small proportion (0.4%) of total flows at the location where the Lower Darling joins the far larger River Murray. This volume remains similar as it moves the small distance and flows across the border at South Australia.

This small proportional increase to inflows has a negligible impact on diversions or allocations in the Murray Regulated River Water Source. Modelling actually indicates a small reduction in allocations after these additional inflows. These small changes are within the model's error tolerances and may be the result of model artefacts. The analysis shows no effective impact of *Policy* implementation on annual average diversions or allocations in the Murray over the modelled timescale.

Table 10 Potential changes in annual metrics in the Murray without and with the *Policy* implemented in the NSW Border Rivers and Gwydir valleys.

	Without *Policy*	With *Policy*	With *Policy* annual mean change	With *Policy* annual mean change (%)
Wentworth Flow (GL)	7,768.1	7,796.3	+28.3	+0.4%

	Without *Policy*	With *Policy*	With *Policy* annual mean change	With *Policy* annual mean change (%)
Flow to South Australia (GL)	7,286.5	7,316.0	+29.5	+0.4%
Net Diversions (GL)	1,401.1	1,405.4	+4.2	+0.3%
General Security Allocation (30th June)	85.6	85.6	-0.1	-0.1%

There are far more changes to General Security Allocations in the Murray than what modelling indicates for the Lower Darling. The Murray is fully allocated far less than the Lower Darling and there is considerably more opportunity for change because of *Policy*. In approximately 11 of the 114 years (~10% of years) we see improvement in General Security allocations because of *Policy* implementation in the NSW Border Rivers and Gwydir valleys (Figure 13).

Whilst these 11 years see positive change there are a number of years that see a minor negative impact and as a whole the analysis shows no effective long-term average impact of *Policy* implementation on Murray allocations.

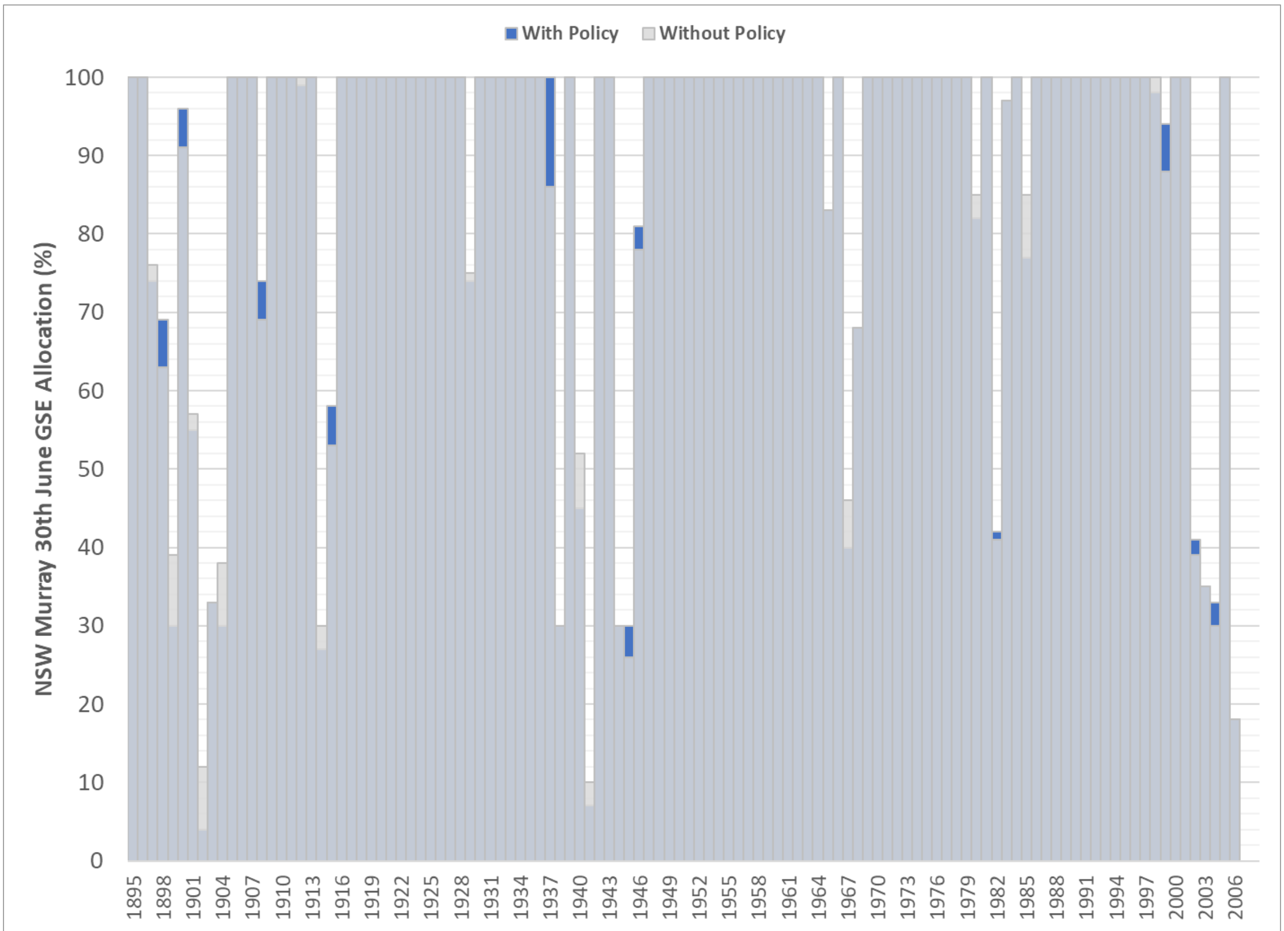

Figure 13 Murray General Security Allocations on 1 July with and without *Policy* implementation in the NSW Border Rivers and Gwydir valleys

4 References

Legislation, policies and plans

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Appendix A: Modelled annual flows by licence class

Table 11 Modelled annual, 3-, 5- and 10-year extractions for Barwon-Darling A Class licences, without and with the *Policy* implemented in the NSW Border Rivers and Gwydir valleys, with base (100%) and sensitivity (50%) return flow assumption

Class A	Without-Policy (GL)	With Policy (100% return flows) (GL)	With Policy (50% return flows) (GL)
Annual			
Mean	6.3	6.3	6.3
Median	6.5	6.5	6.5
Max	8.1	8.1	8.1
Min	3.0	3.0	3.0
3-year			
Mean	19.1	19.1	19.1
Median	19.4	19.4	19.4
Max	21.3	21.3	21.3
Min	13.8	13.8	13.8
5-year			
Mean	31.8	31.8	31.8
Median	32.1	32.1	32.1
Max	35.1	35.1	35.1
Min	25.9	25.9	25.9
10-year			
Mean	63.8	63.8	63.8
Median	64.0	64.0	64.0
Max	68.3	68.3	68.3
Min	55.4	55.4	55.4

Table 12 Modelled annual, 3-, 5- and 10-year extractions for Barwon-Darling B Class licences, without and with the *Policy* implemented in the NSW Border Rivers and Gwydir valleys, with base (100%) and sensitivity (50%) return flow assumption

Class B	Without-Policy (GL)	With Policy (100% return flows) (GL)	With Policy (50% return flows) (GL)
Annual			
Mean	115.6	115.7	115.7
Median	119.0	118.7	118.9
Max	220.0	220.2	220.0
Min	9.3	10.0	10.4
3-year			
Mean	347.0	347.4	347.3
Median	356.9	356.1	356,957
Max	444.7	444.5	444.6
Min	211.5	211.0	211.1
5-year			
Mean	579.7	580.2	580.1
Median	592.6	592.4	592.3
Max	680.3	679.7	679.8
Min	383.0	393.0	392.0
10-year			
Mean	1,164.6	1,165.2	1,165.1
Median	1,177.9	1,178.5	1,178.1
Max	1,264.3	1,262.9	1,263.4
Min	961.6	977.9	973.7

Table 13 Modelled annual, 3-, 5- and 10-year extractions for Barwon-Darling C Class licences, without and with the *Policy* implemented in the NSW Border Rivers and Gwydir valleys, with base (100%) and sensitivity (50%) return flow assumption

Class C	Without-Policy (GL)	With Policy (100% return flows) (GL)	With Policy (50% return flows) (GL)
Annual			
Mean	45.7	45.9	45.8
Median	49.3	49.7	49.7
Max	112.4	112.8	112.8
Min	0.6	0.6	0.6
3-year			
Mean	137.7	138.2	138.0
Median	141.3	142.1	141.7
Max	201.8	202.3	202.0
Min	64.0	63.5	63.6
5-year			
Mean	229.7	230.6	230.3
Median	230.3	231.6	230.2
Max	298.6	298.1	298.1
Min	159.6	167.6	167.0
10-year			
Mean	460.1	461.6	461.0
Median	461.4	461.5	462.2
Max	544.7	542.7	542.4
Min	383.7	385.7	384.7

Table 14 Modelled annual, 3-, 5- and 10-year extractions for Barwon-Darling Floodplain Harvesting licences, without and with the *Policy* implemented in the NSW Border Rivers and Gwydir valleys, with base (100%) and sensitivity (50%) return flow assumption

Floodplain harvesting	Without-Policy (GL)	With Policy (100% return flows) (GL)	With Policy (50% return flows) (GL)
Annual			
Mean	17.7	18.2	18.0
Median	9.3	9.4	9.3
Max	93.8	98.6	97.8
Min	-	-	-
3-year			
Mean	53.3	54.9	54.1
Median	39.7	40.6	40.2
Max	153.8	158.1	156.3
Min	198.0	198.0	198.0
5-year			
Mean	89.7	92.3	91.1
Median	85.2	90.3	87.7
Max	203.2	214.5	208.0
Min	4.2	4.2	4.2
10-year			
Mean	185.0	190.1	187.6
Median	192.2	199.4	196.7
Max	335.5	344.0	339.8
Min	53.5	54.5	53.6

Appendix B: Sensitivity testing

A high-level sensitivity assessment was undertaken with results under base (100%) and sensitivity (50%) assumptions for end of system flow volumes. Results provide initial insights into the scale of impact that local effects such as aquifer recharge, vegetation and evaporation, local floodplain connectivity and river channel routing could have on the estimated/expected outcomes of floodplain harvesting policy implementation.

Table 15 Modelled average annual end of system flow volumes without the *Policy* and with the *Policy* under assumptions of 100% and 50% return flows for the NSW Border Rivers valley

Scenario	Average annual end-of-system flow (GL/year)	Floodplain harvesting reduction (i.e. foregone diversion) (GL/year)
Without *Policy* (current)	538.3	Not applicable
With *Policy* and 100% return flow assumption	543.8	5.5
With *Policy* and 50% return flow assumption	541.1	2.8

Table 16 Modelled average annual end of system flow volumes without the *Policy* and with the *Policy* under assumptions of 100% and 50% return flows for the Gwydir valley

Scenario	Average annual end-of-system flow (GL/year)	Floodplain harvesting reduction (i.e. foregone diversion) (GL/year)
Without *Policy* (current)	170.1	Not applicable
With *Policy* and 100% return flow assumption	207.6	52.9 (43.2)
With *Policy* and 50% return flow assumption	190.7	26.5 (21.6)

Table 17 Modelled average annual flows without the *Policy* and with the *Policy* implemented in the Border Rivers and Gwydir valleys under assumptions of 100% and 50% return flows at Walgett

Scenario	Average annual flow (GL/year)	Floodplain harvesting reduction (i.e. foregone diversion) (GL/year)
Without *Policy* (current)	1293.1	Not applicable
With *Policy* and 100% return flow assumption	1336.2	43.1
With *Policy* and 50% return flow assumption	1314.7	21.6

Table 18 Modelled average annual flows without the *Policy* and with the *Policy* implemented in the Border Rivers and Gwydir valleys under assumptions of 100% and 50% return flows at Bourke

Scenario	Average annual flow (GL/year)	Floodplain harvesting reduction (i.e. foregone diversion) (GL/year)
Without *Policy* (current)	1864.4	Not applicable
With *Policy* and 100% return flow assumption	1901.5	37.1
With *Policy* and 50% return flow assumption	1883.0	18.6

Table 19 Modelled average annual flows without the *Policy* and with the *Policy* implemented in the Border Rivers and Gwydir valleys under assumptions of 100% and 50% return flows at Wilcannia

Scenario	Average annual flow (GL/year)	Floodplain harvesting reduction (i.e. foregone diversion) (GL/year)
Without *Policy* (current)	1383.1	Not applicable
With *Policy* and 100% return flow assumption	1406.3	26.2
With *Policy* and 50% return flow assumption	1396.2	13.1