

Hydrology Analysis to Inform the 2020 Basin Plan Evaluation

Joel Bailey¹, Matthew Coleman¹, Lara Palmer¹, Sara London¹

¹ Murray-Darling Basin Authority, 33 Allara Street Canberra ACT, 2601. Email: joel.bailey@mdba.gov.au

Key Points

- New techniques to account for climate variability were developed to inform the 2020 Basin Plan evaluation
- Results were mixed across the Basin with improvements since the beginning of Basin Plan implementation in some indicators and declines in others
- Evidence suggests the Basin Plan has buffered the impact of a changing climate

Abstract

The Basin Plan is the largest water reform of its kind in the world. It aims to bring the Murray-Darling Basin back to health to sustainably support communities now, and into the future. Every five years the Murray–Darling Basin Authority takes stock of the Basin Plan and how it is being implemented to determine which elements are working and where improvement is needed.

The 2020 Basin Plan Evaluation (released in December) used a multiple line of evidence approach drawing upon expertise and analysis from a wide range of sources — including from the science community, independent advisors, the Australian Government and state and territory governments, and stakeholders from communities and industries.

Major findings were developed across three themes:

- Hydrology and the environment
- Social, cultural and economic
- A changing climate

These findings demonstrate that the Basin Plan is having a significant and positive impact on the environment and communities. However, there has been a significant variation in outcomes across the Basin and climate change will require Governments to implement a range of additional, practical measures to achieve a healthy and resilient Basin. The evaluation has made several recommendations and identified six key priority focus areas for the future. This paper provides an overview of the 2020 Evaluation, with a focus on the hydrology analysis.

Keywords

Murray-Darling Basin, evaluation, hydrology

Introduction

This paper summarises the hydrological analysis undertaken to inform the 2020 Basin Plan Evaluation by the Murray–Darling Basin Authority and touches on the key findings from the broader 2020 Basin Plan Evaluation process. The hydrological analysis formed one line of evidence that was combined with additional analysis, research, and advice to draw key evaluation findings and identify priority areas for the future.

The 2020 Basin Plan Evaluation Framework

The 2020 Basin Plan Evaluation was the second evaluation of the 2012 Basin Plan. The first evaluation was the 2017 Interim Basin Plan Evaluation (MDBA, 2017), the next is scheduled to occur in 2025.

After the 2017 Evaluation a series of recommendations were made to improve the evaluative process. As a result, the Basin Plan Evaluation Framework (MDBA, 2019) was produced to guide the Authority’s 2020 and 2025 Basin Plan evaluations. It sets out the key steps for defining, designing, doing and using the evaluation of the Basin Plan including the key evaluation questions.

The framework organises Basin Plan evaluations into themes as shown in Figure 1. The hydrologic analysis was guided by the framework in its development and directly supports the outcome themes.

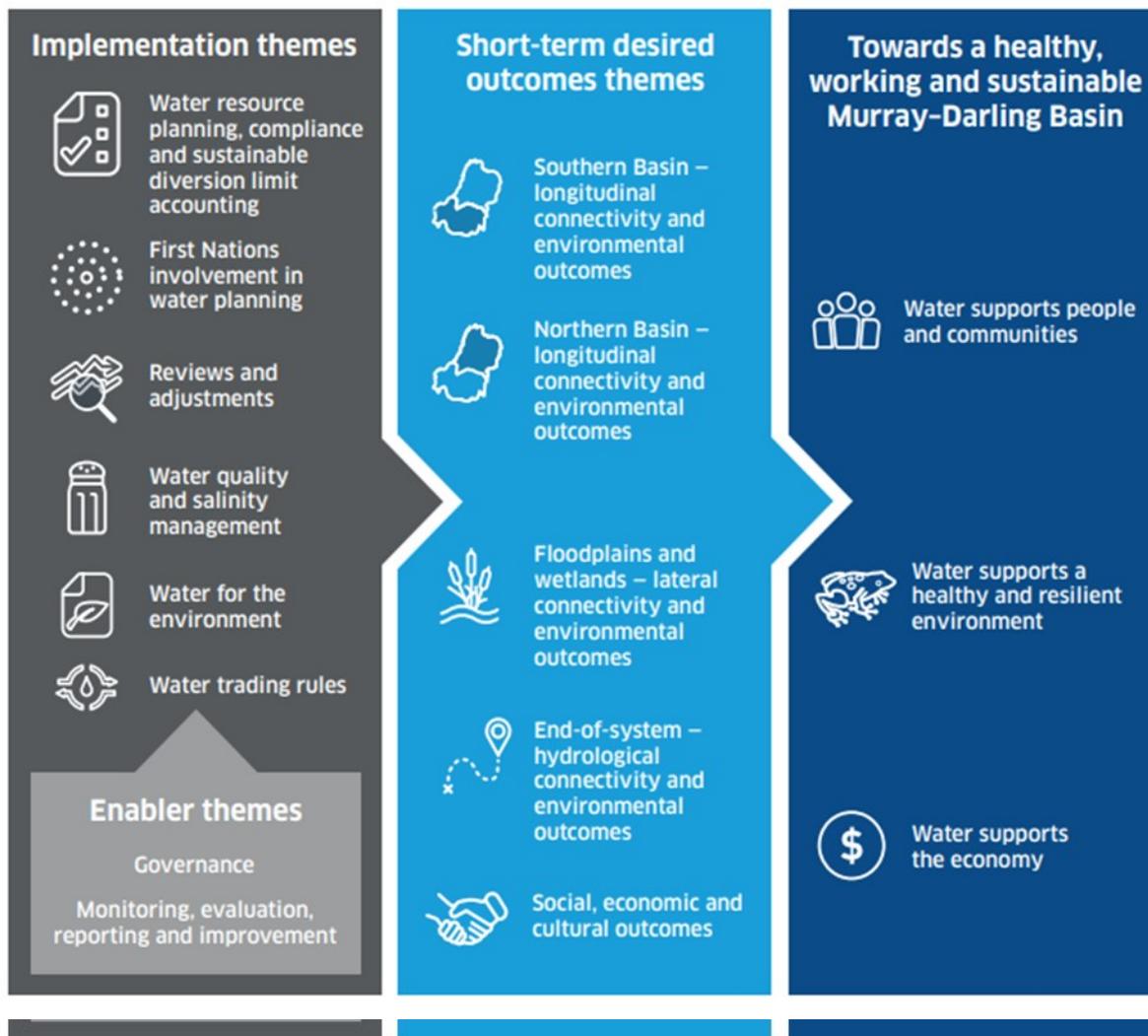


Figure 1. Basin Plan Evaluation Framework

Hydrology Analysis Methods

Several guiding pieces of legislation dictated the 2020 Evaluation scope of analysis. Most relevant to the analysis outlined in this report is Schedule 7 of the Basin Plan (MDBA, 2012), specifically the intermediate targets to 30 June 2019 that there be “no loss of, or degradation in” flow regimes or hydrologic connectivity. Future evaluations will be required to determine the extent to which the Plan has provided long-term improvements in the flow regime. The separation date of 30 June 2019 recognises that many parts of the Plan are still under implementation, hence any resulting changes in the flow regime would appear on an event-by-event basis rather than as a long-term step change signal.

As such, the methods outlined assess only if conditions have changed without attributing the changes to the Basin Plan or assessing if the changes were beneficial. Additional more qualitative analysis in other evaluation products delve into judgements regarding the changed hydrological conditions on ecosystems and communities.

A significant learning from the 2017 evaluation of the Basin Plan was the need to include consideration of prevailing climatic conditions as part of future hydrological evaluations. Significant progress was made in the 2020 Basin Plan Evaluation to account for climate variability.

A multiple lines of evidence approach was used in the 2020 Basin Plan Evaluation to assess the complex adaptive system that is the Murray-Darling Basin. In terms of hydrologic analysis, this means that various data sources and analysis techniques were utilised. Both modelled and observed flow data were considered, and analysis developed internally by the MDBA was supplemented by other relevant information, such as the Commonwealth Environmental Water Office Long Term Intervention Monitoring hydrology analysis (Stewardson & Guarino 2020).

The Basin Plan guided the analysis to look across the flow regime at various elements or flow regime components as described in Table 1.

Table 1: Elements of the flow regime considered in the 2020 evaluation

Flow Regime Element	Parameters
Transmission Ratio	Annual end of catchment gauge volume measured as a function of annual inflow volume (outflow/inflow)
Cease to Flow	Days per year of cease to flow measured as a function of log of annual inflow
Baseflows	Lyne & Hollick Base flow index (BFI), 2013 standardised approach (Ladson, Brown, Neal & Nathan, 2013)
Freshes	Days per year over fresh threshold measured as a function of inflows
Overbank Flow	Qualitative analysis
Flow Seasonality	Qualitative analysis
Flows to Terminal Wetlands	Annual upstream gauge volume measured as a function of inflows

To account for the highly variable climatic conditions of the Basin, all metrics (excluding baseflows) were measured as a function of catchment inflows. That is, the dynamics of the individual metrics were not assessed but rather the dynamics of the relationship between the metric and catchment inflows. The Bureau of Meteorology AWRA-L landscape water balance model (Frost et al 2018) was used to generate annual inflow data for each catchment, e.g. the horizontal axis on Figure 2.

Transmission Ratio

pre/post Basin Plan ● <2012 ● >2012

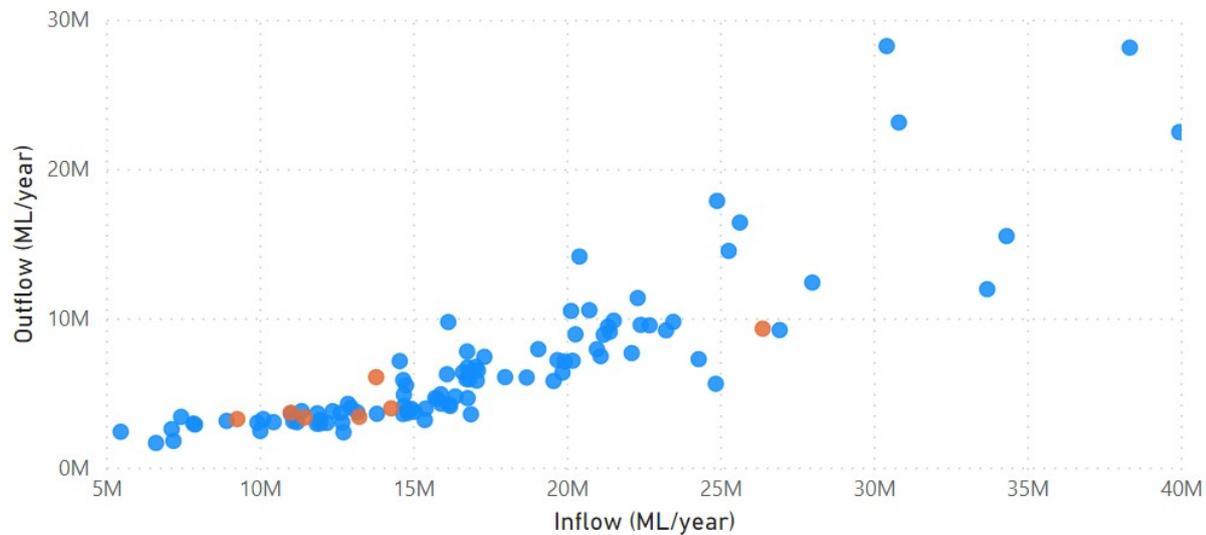


Figure 2. Southern Basin Transmission Ratio Scatter Plot – (Maintained Result)

To develop assessment techniques that are consistent, transparent and repeatable, a quantitative results-assignment matrix was developed, shown in Figure 3. Each flow regime element was assigned one of four results: decreased, increased, maintained or unclear. Where the two tests provide conflicting indications, the result is classified as unclear. The unclear result category is necessary where the conditions for only one test are met to reduce the chance of reporting false positives.

Result Assessment Matrix		Are we confident the distributions are different? **	
		Yes	No
Are we confident the means are different? *	Yes	Increased or Decreased	Unclear
	No	Unclear	Maintained

* answered quantitatively with Welch’s t test , alpha = 0.1

** answered quantitatively with the Kolmogorov-Smirnov test, alpha =0.1

Figure 3. Result Assessment Matrix

The tests were applied to parameters representing each suitable flow regime component (overbank flows and seasonality were found to be unsuitable) comparing samples of data before and after the beginning of the Basin Plan implementation. They are targeted at answering the question “are we confident the relationship between this parameter and inflows has changed?”

Special consideration needs to be given to the simultaneous application of multiple statistical tests. This issue is termed variously as the multiple comparisons, multiplicity or multiple testing problem and is referred to in certain fields as the look elsewhere effect. With two tests using alpha at 0.1, there is a 19% chance of observing at least one significant result, even if all the underlying distributions are the same.

The result assessment matrix is constructed in such a way that to achieve an increased or decreased result two significant results are required, i.e. a change in both the cumulative distribution and mean of the two samples needs to be detected. This means that there is a 19% chance of observing an unclear or increased/decreased 'false' result, while the underlying data is from the same distribution. However, the chances of a 'false' increased/decreased result are much lower.

Typically, methods for dealing with multiple tests call for adjusting alpha in some way, however, these methods are designed for statistical investigations looking for a single significant result, 'a discovery'. This is not the case in the application of two statistical tests looking for concurrent significant results as is depicted in Figure 3. Setting alpha to 0.1 in both tests so that the chance of a false positive 'increased' or 'decreased' result is 1% is suitably rigorous and decidedly reasonable for the task at hand.

Pseudoreplication also needs to be carefully considered when assessing environmental measurements with statistical tests. Pseudoreplication is defined as the use of inferential statistics to test for treatment effects where treatments are not replicated and/or replicates are not statistically independent. Pseudoreplication would be a significant issue if this analysis was being used to directly attribute any observed changes in hydrology to the implementation of the Basin Plan. However, the tests are not being used to determine if a change in hydrology condition can be attributed to the influence of the Basin Plan or any other intervention. Instead, the tests are being used to detect if a change in Basin hydrology has occurred or not, i.e. the different time periods is the treatment being assessed.

For assessing if there has been a change in the condition of the Basin's hydrology with statistical tests, pseudoreplication does not disqualify the results. This was a significant consideration in only applying statistical tests to assess the condition of the Basin hydrology and relying on other lines of evidence and analysis to identify the contribution of the Basin Plan to the observed condition.

Considerable effort was applied to making the analysis as transparent as possible. As such, several products targeted at various audiences were curated or prepared and made publicly available including:

- raw river system model data,
- observed flow data,
- Python notebooks used to perform analysis for each flow regime component,
- PowerBI dashboard to display interactive map-based results, and
- a technical Report (MDBA 2020a)

The analysis and how it was communicated was developed with input from experts in:

- ecohydrology,
- river systems modelling,
- communications, and
- data science

Feedback and advice was also sought from:

- relevant experts from Basin jurisdictions,
- members of the Basin Community Committee and
- the eco-hydrology community of practice maintained by the MDBA.

As a final step before being integrated with findings from other evaluation themes the hydrological analysis, results and associated key messages were tested by a specifically convened expert panel and found to be fit for purpose.

Hydrology Analysis Findings

Table 2 summaries the analysis of hydrological condition that utilised the quantitative result assessment matrix. It shows a trend of the results being more positive in the Southern Basin compared to the North.

Table 1 Summary of hydrological analysis findings

Basin	Catchment	Transmission		Cease to flow	Flow Thresholds		L&H Base Flow Index	Flows to Terminal Wetlands
		Model Baseline	Observed Baseline	Observed Baseline	Model Baseline	Observed Baseline	Observed Baseline	Observed Baseline
Northern Basin	Paroo	Decreased	Unclear	Unclear	-	-	-	-
	Warrego	Unclear	Maintained	Maintained	-	Maintained	Maintained	-
	Condamine-Balonne	Decreased	Decreased	Maintained	Unclear	Maintained	Maintained	Maintained
	Moonie	Maintained	Maintained	Increased	-	-	-	-
	Border Rivers	Unclear	Maintained	Maintained	Maintained	Maintained	Maintained	-
	Gwydir	Maintained	Maintained	Maintained	Unclear	Increased	Unclear	Increased
	Namoi	Decreased	Unclear	Maintained	Decreased	Unclear	Maintained	-
	Macquarie-Castlereagh	Unclear	Maintained	Multiple	Maintained	Increased	Maintained	Increased
	Barwon-Darling	-	-	Maintained	Unclear	Maintained	Maintained	-
	Overall North	Unclear	Unclear	-	-	-	-	-
Southern Basin	Lachlan	Maintained	Maintained	-	-	-	-	Maintained
	Lower Darling	-	-	-	Unclear	Maintained	Increased	-
	Murrumbidgee	Maintained	Increased	-	Maintained	Increased	Maintained	Increased
	Ovens	-	Maintained	-	-	-	-	-
	Goulburn-Broken	Maintained	Increased	-	Maintained	Increased	Maintained	-
	Campaspe	Unclear	Increased	-	Increased	Increased	Maintained	-
	Loddon	-	Increased	Decreased	-	Maintained	Maintained	-
	Murray	-	-	-	Multiple	Maintained	Maintained	-
	Overall South	Maintained	Increased	-	-	-	-	-
Wimmera-Avoca	-	Maintained	Decreased	-	-	-	Maintained	
Overall MDBA System	Maintained	Increased	-	-	-	-	-	

Implementation of the Basin Plan has been occurring against the backdrop of unprecedented hot and largely dry climatic conditions (interspersed with the odd median-to-wet period). Despite the difficult climate and relatively low water availability, there is clear evidence the delivery of environmental water is having a positive impact on the hydrology of the Basin.

At the highest level, there are clear signs that there are positive changes in the Southern Basin. The Basin Plan has protected flow regimes across much of the Southern Basin, including base and fresh flows in some rivers. Positive ecological responses have resulted from the delivery of water for the environment (Hale et.al. 2020)

However, results are mixed in the North. Flow has degraded across parts of the Northern Basin when comparing before and after the implementation of the Basin Plan, particularly the Namoi and Condamine-Balonne. In the regulated rivers of the Northern Basin, the Basin Plan has protected some rivers from the worst impacts of the unprecedented drought. Implementation of the Basin Plan has been associated with improvements to the flow regimes, including reductions in the effects from the severity and duration of dry spells and protection of the first flows after needed rain fell.

Some key wetlands where water for the environmental can and has been delivered, such as the Macquarie Mashies or the Gwydir wetlands, were found to be receiving increased flows since 2012 when accounting for the climate signal.

2020 Basin Plan Evaluations Findings

The practice of evaluation often incorporates multiple lines of evidence to develop the best possible understanding of the value of a program or policy, Numbers and statistics are important but they often don't provide the complete story, hence it's important to include lived experience as part of any evaluation. In the Murray-Darling Basin different types of information is being collected for a range of purposes, using varying methods, and at varying spatial scales. As a result, the information available to assess the outcomes of the Basin Plan varies depending on the indicator being assessed. This means that the approach to assessing the individual indicators, and the confidence in the assessment, varies depending on the information available to develop a comprehensive understanding of the Basin Plan implementation progress and outcomes.

The hydrology analysis was combined with other lines of evidence drawn from a wide range of sources including assessments of ecological, social, economic, and cultural outcomes and assessments of the implementation progress to develop high level evaluation findings. An example insight from drawing multiple lines of evidence together is that the Namoi and Condamine-Balonne catchments with observed decreases in the ratio of inflows to outflows also have had the most limited progress toward their water recovery for the environmental targets reinforcing the importance of achieving the sustainable diversion limit set out in the Basin Plan.

The Basin Plan is having a significant and positive impact on the Murray–Darling Basin's environment. This has been crucial for sustaining water-dependent ecosystems during the recent drought but is unlikely to be sufficient to achieve long-term outcomes unless further implementation and other actions are fast-tracked.

The Basin Plan has enabled delivery of water for the environment to support the Coorong, Lower Lakes and Murray Mouth ecosystems through the most recent drought, substantially avoiding the environmental degradation that occurred during the Millennium drought.

The Basin Plan is unable to effectively support many floodplain and wetland ecosystems until implementation of critical improved water infrastructure and river operating rules are in place. These are committed to be delivered through the package of projects to adjust limits, including supply and constraints projects. Also needed is the accreditation of all water resource plans as these set the rules on how much water can be taken from the system on an annual basis, ensuring the sustainable diversion limits are not exceeded over time. The plans also set the rules for management of water for the environment.

The major fish death events in 2019 demonstrate the need for whole-of-system management and are a stark reminder of the potential impacts that full implementation of the Basin Plan seeks to mitigate. Basin

governments and the Basin Plan need to continue to adapt and improve approaches to managing water quality, particularly in the context of low or no-flow conditions. It is clear that a substantial shift in focus and effort is needed to adapt water management in the Basin to climate change — which will reshape water availability and use in the Basin.

Conclusions

The 2020 Basin Plan Evaluation identified 6 priority areas for the future. These will require Basin governments, communities and change makers to work together to improve the health and productivity of the Murray–Darling Basin. The priority areas for these efforts are:

- Implementing the Basin Plan
- Adapting to climate challenges and increasing resilience
- Strengthening focus and support to enable social and economic outcomes
- Establishing a clear and committed pathway for First Nations social and economic outcomes
- Integrating water management with other activities to achieve environmental restoration
- Advancing science and monitoring.

Acknowledgments

For a list acknowledging contributors please see the 2020 Basin Plan Evaluation MDBA (2020).

References

Frost, A. J., Ramchurn, A., and Smith, A. (2018) The Australian Landscape Water Balance model (AWRA-L v6). Technical Description of the Australian Water Resources Assessment Landscape model version 6. Bureau of Meteorology Technical Report

Hale J, Bond N, Brooks S, Capon S, Grace M, Guarino F, James C, King A, McPhan L, Mynott J, Stewardson M, Thurgate N, (2020) Murray–Darling Basin Long Term Intervention Monitoring Project — Basin Synthesis Report. Report prepared for the Agriculture, Water and the Environment, Commonwealth Environmental Water Office by La Trobe University, Centre for Freshwater Ecosystems, CFE Publication 252. May 2020 59p.

MDBA (2019). Framework for evaluating the Murray–Darling Basin Plan - Revised version. Murray–Darling Basin Authority

MDBA (2020a) Hydrological Analysis to Inform the 2020 Basin Plan Evaluation. Murray–Darling Basin Authority

MDBA (2020b) The 2020 Basin Plan Evaluation. Murray–Darling Basin Authority

Ladson, A. R., Brown, R., Neal, B., & Nathan, R. J. (2013). A standard approach to baseflow separation using the Lyne and Hollick filter. *Australian Journal of Water Resources*, Volume 17, Issue 1, Pages 25 - 34.

Stewardson MJ and Guarino F (2020) 2018–19 Basin-scale evaluation of Commonwealth environmental water: hydrology, report to the Commonwealth Environmental Water Office, La Trobe University

Zhang, L, Zheng, HX, Teng, J, Chiew, FHS, and Post DA (2020). Plausible Hydroclimate Futures for the Murray–Darling Basin. A report for the Murray–Darling Basin Authority, CSIRO, Australia. 34pp.