

Developing an Automated Environmental Water Requirement Tool in Python

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Key Points

- Environmental water requirements are essential for long term water planning and useful for informing short term operational decisions
- There is a significant diversity in the characteristics and complexity of environmental water requirements throughout the Murray-Darling Basin
- Significant effort goes into the interpretation and calculation of these environmental water requirements
- The codifying of the environmental water requirement parameters and their calculation allows for water managers to efficiently embed the best available science into water planning and management
- The centralised implementation of the flow requirements and underlying assumptions allows for transparent decision making processes

Abstract

The states in the Murray Darling Basin have done extensive work in determining and defining a set of environmental water requirements for each valley in the Basin, which are detailed in their respective Long-Term Watering Plans. The environmental water requirements in these PDF documents represent a significant wealth of environmental science. The Murray-Darling Basin Authority (MDBA) needed a way to harness this environmental science in our analytical workflows to ensure water policy in the Basin is based on the best available science.

The MDBA has developed an Environmental Water Requirement tool in Python (EWR tool) to access an environmental water requirements dataset (EWR dataset). The tool has two modes:

1. Operational: environmental water requirement achievement is checked against observed flows at sites of interest.
2. Scenario testing: model scenarios are loaded into the tool and checked against environmental water requirements. This mode is for assessing the environmental impact of changes to variables including of policy settings, infrastructure, or the climate.

When developing the Basin Plan, the MDBA used approximately 100 flow metrics across the Basin to infer environmental outcomes that could be achieved against different water recovery and water sharing options. The environmental water requirements provided by the states is comprised of thousands of metrics across the Basin, greatly improving the hydrology-to-ecology information base for long-term water planning.

A codified tool is essential to streamline the process of interpreting and calculating this database of flow requirements to ensure they can be used in water management and policy, and to ensure their implementation is consistent and transparent. Having a tool allows for more of the conversation to move away from analytical methods and interpretation issues to the implications of the results. The MDBA has made significant progress with this tool, however, the next challenge will be working out how to communicate such a large amount of results to policy managers in a meaningful way.

Keywords

Environmental water requirements; Python; water planning; data science; Long-Term Water Plans

Introduction

Environmental water requirements are an integral element of the water planning process. Water planners typically explore a variety of water sharing arrangements using existing hydrological models, and these metrics are used to infer the anticipated environmental outcomes that would result from each scenario — they constitute the hydrology-to-ecology ‘translation matrix’.

During the process to determine the Basin Plan (2012) settings, there were approximately 100 environmental water requirements. They allowed for the testing of many model scenarios in order to determine the best balance of water take, while maintaining the health of the environment. This matrix of metrics was fit-for-purpose and represented the best available science at the time. However, since then there has been a proliferation of environmental water requirements, mostly through instruments developed by the states called Long-Term Water Plans. While the majority of environmental water requirements have characteristics foundationally similar to those used in the Basin Plan settings, there are more metrics tracking additional parts of the flow regime at the lower and higher end, as well as different categories to capture the complexity of the river system (for example: targeting weir pools and end of system wetlands). This growing dataset of environmental water requirements represents a valuable body of knowledge for water planners to tap into.

The size and complexity of this growing dataset in conjunction with the complex management arrangements in the Murray-Darling Basin, has contributed to the issue of multiple agencies, sometimes within the same jurisdiction, creating tools to harness and query this dataset. The result has been a range of disparate tools, each with differing underlying assumptions attempting to query the same environmental water requirements. The NSW government and the Murray-Darling Basin Authority (MDBA) recognised this challenge and agreed the MDBA should attempt to address it by creating a codified Basin wide tool linked to a master EWR dataset of environmental water requirements that could be used by all jurisdictions, or interested members of the public.

The need for a codified solution

Time intensive

Prior to a codified tool, when a need to use environmental water requirements arose, planners often turned to spreadsheets for calculations. The numerous environmental water requirements result in this being a time intensive exercise to complete. The diversity of environmental water requirements within even a single river reach compounds the time required. By having a ready-made tool to use for all parts of the Basin, more time from water managers can be spent discussing the management and policy implications of the results.

Conflicting results

A codified tool linked to a managed dataset allows for the same set of underlying assumptions and interpretations to be applied to the various environmental water requirement categories. A significant risk of having multiple disparate tools arises from the complexity of some environmental water requirements which may cause two jurisdictions to have differing underlying assumptions around their interpretation. Some requirements are restricted to the core elements of the flow regime that need to be reached to meet the target (including the flow rate/volume/water level, duration to maintain this for, ideal timing window, return interval), and are therefore simple to perform a pass/fail check on, with little room for differences in interpretation. However, others have complex additional requirements. Jurisdictions may make different assumptions about which additional requirements to include when attempting to perform a pass/fail check. Table 1 (A) shows three example environmental water requirements from different catchments on this spectrum, with the top row having less room for interpretation differences, and the bottom row having more room due to the more complex additional requirements detailed.

Environmental water requirements are being constantly refined through updates to Long-Term Water Plans arising from improving science. Having a codified tool linked to a master dataset of environmental water requirements allows for constant updates to the dataset without requiring significant changes to the tool. Adequate version control of the EWR dataset and tool will allow for conflicts that do arise (perhaps from different jurisdictions running different versions of the tool or dataset) to be immediately queried and resolved.

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Table 1 (A) – top: Three example environmental water requirements. The top row shows a requirement with simple characteristics, the middle row has some added complexity, and the bottom row is considered one of the more complex types.

Table 1 (B) – bottom: Shows the same requirements after going through the proposed filtering process

Flow category	EWR code	Flow rate	Timing	Duration	Frequency	Maximum interevent	Additional requirements and comments
Very low flow ¹	VF1	>1 ML/d	Any time	365 days (or 110 days minimum in very dry years)	93% of years	34 days	
Nesting support ²	NestS1	If flows are 4500–12,000 ML/d at 1 Oct, apply EWR requirements	Oct-Nov	21 Days minimum (starting 1 Oct)	5–10 years in 10 (75%)	2 years	If flows are in this range at 1 Oct or other observed start date of Murray cod nesting, provide variable flows but avoid large sudden decreases in water level to prevent loss of nesting sites. Maximum daily rate of fall = 4% change in flow per day
Destratifying flow (Weir pool mixing pulse) ³	DSF1	>1000 ML/d (further work required to confirm)	Nov-Mar	2 days of flow above mixing threshold flow rate	Whenever Lower Murrumbidgee weir pools thermally stratify and lower layer is expected to become hypoxic. Deliver before bottom layer becomes hypoxic. Likely to be required multiple times in such years.	Period should not exceed time required for pools to stratify and the bottom layer to become hypoxic	As these flows are to maintain water quality, weir level management, natural and rain rejection flows, operational water and nondiscretionary environmental water should be used in the first instance before considering the use of discretionary environmental water.

EWR code	Flow rate (ML/day)	Trigger day	Timing	Duration (days)	Frequency	Max interevent period	Max rate of fall
VF1 ¹	>1		July-June	365	93%	34 days	
VF1_VD ¹	>1		July-June	110			
NestS1 ²	4500–12,000	1 October	Oct-Nov	21	75%	2 years	4% per day
DSF1 ³	Cannot be calculated in an automated tool						

1. Derived from Table 8, Namoi Long-Term Water Plan; 2. Derived from Table 3, Murray Lower Darling Long-Term Water Plan; 3. Derived from Table 9, Murrumbidgee Long-Term Water Plan

Closer links between the developers and the ecologists

As shown in Table 1 (A), there exists a spectrum of complexity when it comes to defining environmental water requirements. Having a codified tool has allowed development to progress with the writing of a plain English manual detailing any assumptions made about the different categories of environmental water requirements, and the calculation process for each one of these categories. This allows for the methodology to be checked with the ecologists and water planners who designed the environmental water requirements and ensure scientific integrity is not lost in their implementation.

An inevitable step in going from more complex environmental water requirements to a logical pass/fail test is the filtering of information not essential to the calculation of the requirement. This means agreeing on a general line in the sand for information required in the calculation, and information not necessary to complete the check, as well as excluding those not able to be reduced to an automated pass/fail check. Table 1 (B) shows the result of the filtering process applied to the environmental water requirements listed in Table 1 (A). As shown in the table, the very low flow requirement (VF1) has been split in two, with the tool using the very dry option (VF1_VD) only in years with a very dry climate, and VF1 in all other years. The NestS1 requirement has a ‘trigger day’ field and a ‘maximum rate of fall’ field added, which the tool uses to handle the additional complexity of the nesting requirements. The DSF1 has been filtered out for two reasons, the first being the unfinished nature of the requirement, and the second being the inability to check, in an automated tool, for the frequency part of the requirement. Having this process documented ensures the elements excluded from the automated check do not compromise the integrity of the original environmental water requirement.

The process

The process the MDBA went through to go from environmental water requirements in text format to a codified EWR tool has been outlined in Figure 1 and discussed in more detail below.

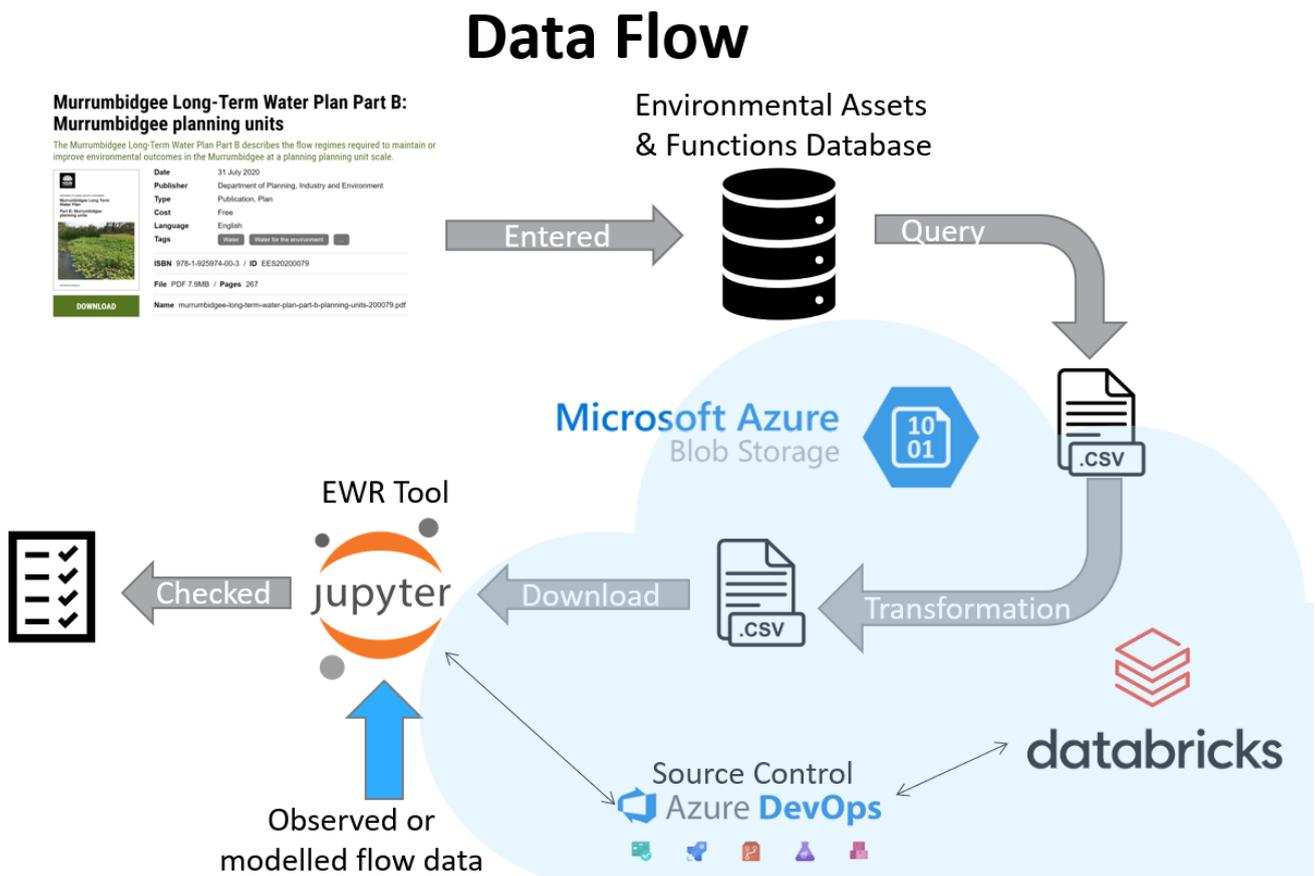


Figure 1 Project flow, from Long Term Watering Plans to logical tests

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Long-Term Water Plans to a database

Environmental water requirements for all Murray-Darling catchments were manually entered into a database. There was little transformation of data done during this stage, with the main activity being the classification of data from all states into a standard set of fields. Some fields were added to classify the data, such as into Basin Plan flow component categories (e.g. large fresh/bankfull).

Database to refined dataset

The database was ingested into a Python program written by the MDBA. The purpose of this program was to pull out the relevant pieces of information in the environmental water requirements that were essential for the calculations, and filter those not relevant to the calculations.

Part 2 of this phase involved a manual check of each derived environmental water requirement against the original environmental water requirement listed in the relevant Long-Term Water Plan. This was to ensure no fields were missed and also to check the Python program for extracting the information was pulling the correct information, and to highlight where it missed it. This information is then fed back into the original Python program to improve its accuracy for future runs.

This dataset with the derived and checked environmental water requirements is then hosted in a publicly accessible cloud storage location.

Pulled into the EWR tool

The EWR tool is hosted on the MDBA's public Github account (https://github.com/MDBAuth/EWR_tool), and the EWR dataset is hosted in a publicly accessible cloud storage location. Each time the EWR tool is run, it accesses the dataset and uses the gauge number and planning unit as the keys to then query it.

The EWR tool (current state)

There are two modes of the tool:

1. Operational: this mode checks environmental water requirements against observed flow data
2. Scenario testing: this mode requires the user to load in at least one simulated model run, and locations in the model run are assessed for environmental water requirement achievement

Each time the EWR tool is run, it fetches the EWR dataset hosted by the MDBA. Within the package of files that comes with the tool is also another dataset containing the climate classification for each catchment in the Basin going back to the year 1911. If the scenario testing mode is used, the user is required to select the type of model format being uploaded (including Source, Bigmod and IQQM), and the relevant relational dataset is accessed to link the model node ID used in the model file to the gauge ID used in the EWR dataset.

A simple user interface has been put over the top of the EWR tool Python modules, so once the user has set up the EWR tool, no knowledge of Python is necessary to run the tool. Figure 2 (A) shows the dashboard the user will interact with to configure the variables and run the first mode (operational mode) of the tool, and Figure 2 (B) shows the dashboard used to configure the variables for the second mode of the tool (scenario testing mode). Once these settings have been configured and the program run, the user will enter the second sub tab of the relevant mode to view a summary table of the results (an example summary table is shown in figure 3 with some of the key indicator metrics assessed). The user can then enter the third sub tab of the relevant mode and click a button to output the summary table and a detailed yearly breakdown of the results to excel, or continue in the Python notebook environment for further querying, depending on preferences.

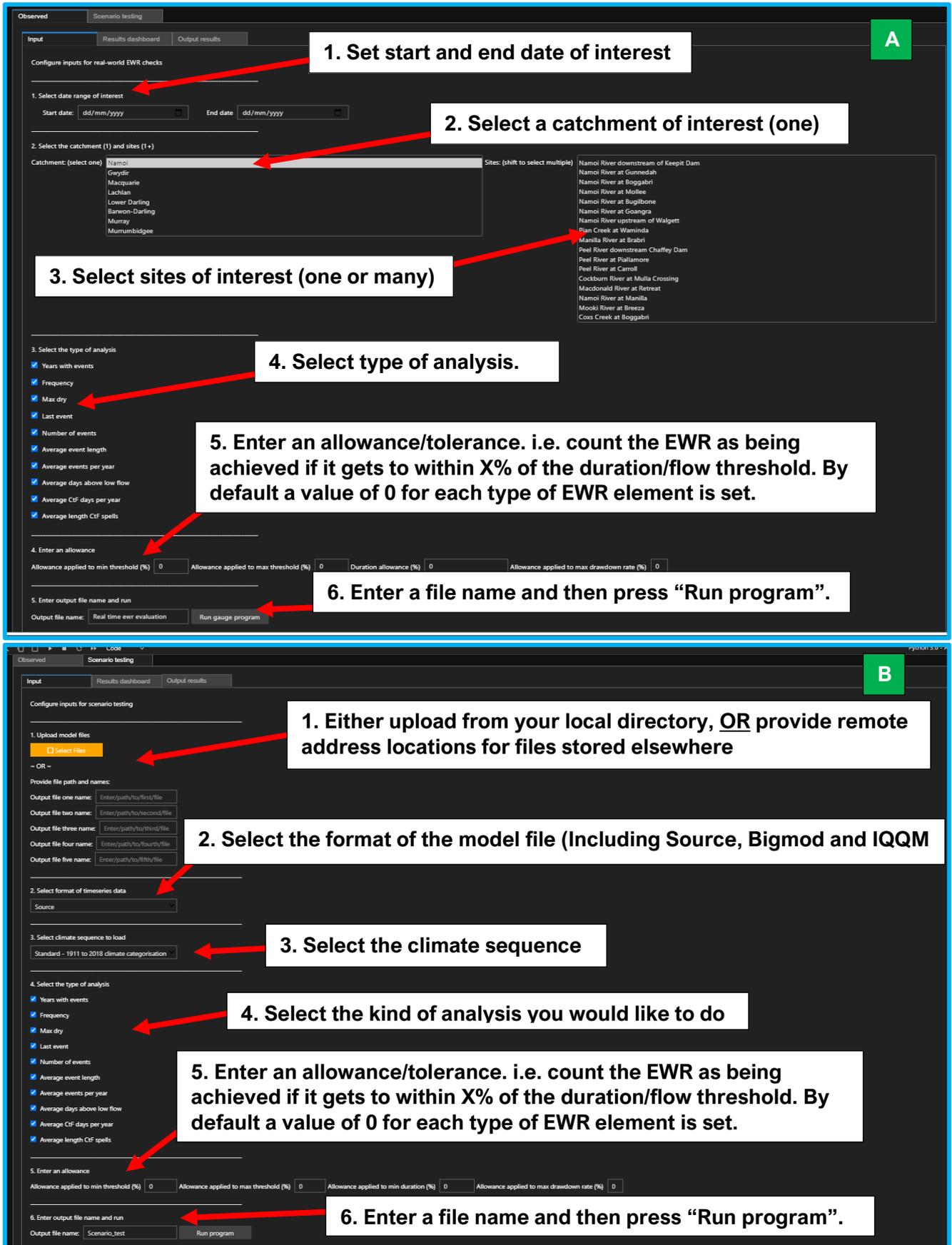


Figure 2 (A) - Top: Input tab for observed/operational flow EWR testing and descriptions for each section. Figure 2 (B) - Bottom: Input tab for scenario testing and descriptions for each section.

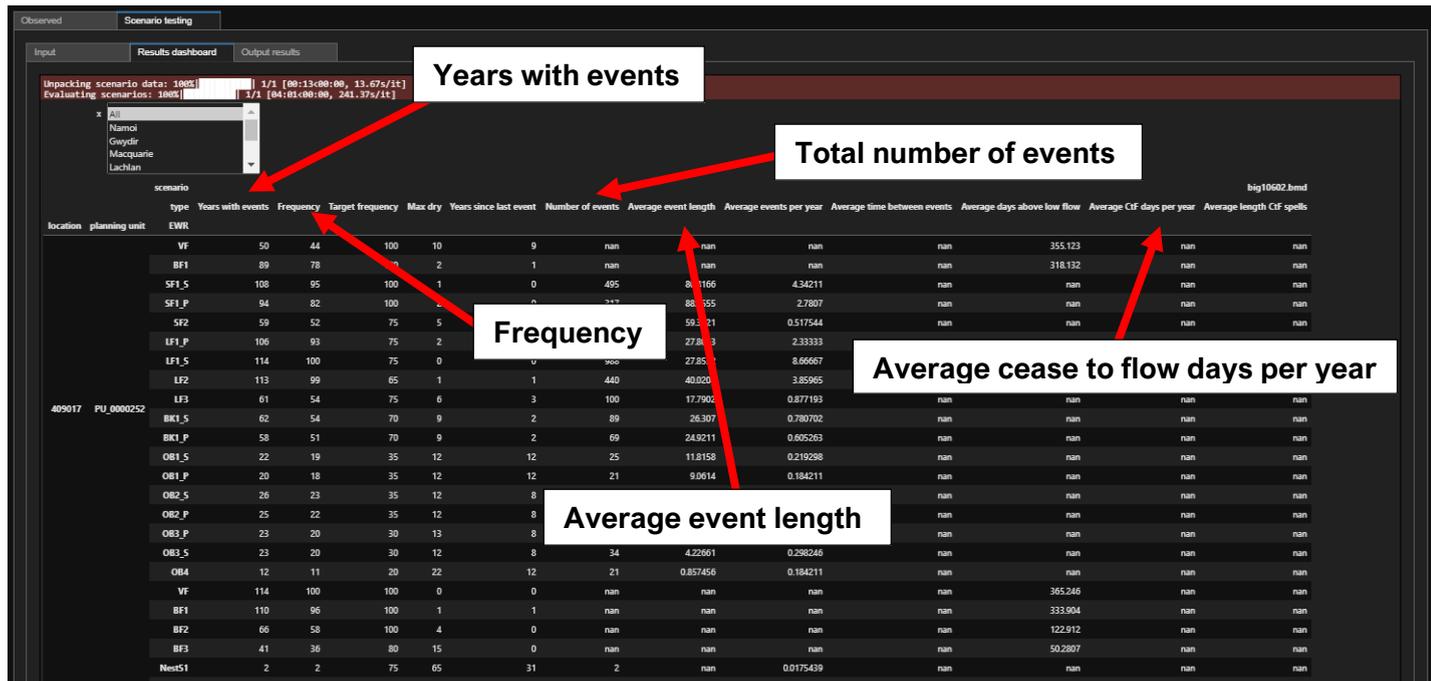


Figure 3 An example results summary table from the EWR tool

Conclusion/next steps

The focus of the development of the EWR tool so far has been in New South Wales catchments, with subsequent effort to be directed towards the Queensland, Victoria, and South Australian catchments. A Basin wide version of this tool will go a long way to addressing some of the issues discussed including transparency around decision making processes and having a universal approach to the interpretation and calculation of environmental water requirements. However, there is now substantial work to be done to work out how to effectively embed the results generated by the EWR tool into the science to policy framework to give the science real world impact.

During the development of the Basin Plan, approximately 100 environmental water requirements were used to anticipate the environmental outcomes that could be achieved under a variety of water sharing options. A manual process was applied to convert these metrics into overall findings for decision-makers — that is, metrics were scanned by eye, conclusions were drawn about the various trade-offs for different parts of the ecosystem or different environmental assets, and the results were communicated in word and graphical form. However, while this approach was possible for these 100 metrics, it is extremely difficult to apply for thousands of metrics. There will always be a need for information to be communicated to decision-makers in summary form (i.e. graphs, charts and concluding remarks), and there will always be a need for manual examination of the results to draw meaningful conclusions (“this metric has decreased, but what does that actually mean for the environment?”). However, it is likely that future water planning activities will need a new step that aggregates or combines the thousands of metrics analysed by this EWR tool using a scientifically robust approach. Aggregation of environmental scores was applied as part of the SDL adjustment determination (Overton et al. 2014).

At the MDBA we are currently experimenting with aggregation approaches, but these are still in early development. A key challenge we have run into is the relative weighting of metrics that is applied as part of the aggregation process. When forming part of the evidence base to inform water sharing decisions amongst different parts of the ecosystem and different sites, ‘weighting’ is often associated with ‘importance’ — providing a higher weighting to a specific environmental site will mean it is more influential in the decision-making process. Options for weighting already exist, such as by geographic area (i.e. metrics for large wetlands are weighted higher than those for small wetlands), or by ecosystem component (e.g. metrics are weighted such that birds, fish and vegetation all receive equal consideration), or by expert feedback. Ultimately, the weighting that is chosen will need to be both scientifically robust and capture the concept of ‘sustainability’.

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References

- NSW Department Of Planning, Industry & Environment (2020). Murray–Lower Darling Long Term Water Plan Part B: Murray–Lower Darling planning units
Retrieved from: <https://www.environment.nsw.gov.au/topics/water/water-for-the-environment/planning-and-reporting/long-term-water-plans/murray-lower-darling>
- NSW Department Of Planning, Industry & Environment (2020). Namoi Long Term Water Plan Part B: Namoi planning units
Retrieved from: <https://www.environment.nsw.gov.au/topics/water/water-for-the-environment/planning-and-reporting/long-term-water-plans/namoi>
- NSW Department Of Planning, Industry & Environment (2020). Murrumbidgee Long Term Water Plan Part B: Murrumbidgee planning units
Retrieved from: <https://www.environment.nsw.gov.au/topics/water/water-for-the-environment/planning-and-reporting/long-term-water-plans/murrumbidgee>
- Overton IC, Pollino CA, Roberts J, Reid JRW, Bond NR, McGinness HM, Gawne B, Stratford DS, Merrin LE, Barma D, Cuddy SM, Nielsen DL, Smith T, Henderson BL, Baldwin DS, Chiu GS and Doody TM (2014). Development of the MurrayDarling Basin Plan SDL Adjustment Ecological Elements Method. CSIRO