NSW long-term water plans environmental water requirement assessment code description

Department of Climate Change,
Energy, the Environment and Water
and the Murray–Darling Basin Authority

NSW GOVERNMENT

Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

This resource may contain images or names of deceased persons in photographs or historical content.

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Introduction

In 2020 New South Wales published 9 long-term water plans (LTWPs) for the NSW portion of the Murray–Darling Basin. They bring together information from a range of planning material, scientific literature and expert knowledge. The plans contain long-term ecological objectives for 5-, 10- and 20-year timeframes relating to waterbirds, native fish, native vegetation, ecosystem functions and in some cases other species such as frogs. The plans also outline the environmental watering requirements (e.g. river flows) required to meet these objectives.

An environmental water requirement (EWR) for the purpose of NSW LTWPs, describes a set of recommended flow characteristics (flow threshold or volume, duration, timing, frequency, maximum inter-event period) at a certain location (river gauge) to meet a particular set of environmental objectives in a particular river reach and its associated floodplain (referred to as a planning unit in NSW LTWPs). A number of EWRs are defined for each river gauge location covering a range of flow categories including, but not limited to, cease-to-flows, baseflows, small and large freshes and overbank flows.

Since publishing the LTWPs EWRs have been used by different organisations to inform environmental water delivery and annual planning as well as broader water management policy, programs and projects. Detail on the development of LTWPs can be found in the 4 background documents (DPE EHG 2022a; DPE EHG 2022b; DPE EHG 2022c; DPE EHG 2022d) with greater detail on EWR development in the background document *NSW long term water plans: background information – A description of the development of the 9 LTWPs in NSW, Part C: Environmental water requirements* (DPE EHG 2022c).

The EWR assessment code (EWR_Tool) is a computer code in Python that assesses the occurrence of flow conditions that meet or partially meet the LTWP EWRs in observed or modelled flow time series. It was originally developed in Python by the Murray–Darling Basin Authority (MDBA) and further refined with input from the NSW Department of Climate Change, Energy, the Environment and Water's Biodiversity, Conservation and Science Group, who were responsible for the development of the LTWPs and their EWRs for New South Wales. The EWR_tool (assessment code) has been specifically developed to reflect detailed analysis used in the development of EWRs for NSW LTWPs; however, slight variations have been made to improve the assessment where appropriate. Although this may cause some misalignment of assessment methods, sensitivity testing indicates that this is minor. The EWR_tool is publicly available as an installable Python package, see 'More information' below. The codebase is also available, on Github, see 'More information'. Environment and Heritage Group have used this code to inform the NSW LTWP EWR dashboard, which is available for internal NSW Government stakeholders and others upon request.

This document provides an outline of the technical details of the EWR_tool (assessment code) and how the EWRs are evaluated.

Hydrological EWR assessment method

EWR_tool (assessment code) (py-ewr package)

Overview

The EWR_tool contains the standalone Python package called py-ewr. The package can be accessed using the steps outlined below under 'Accessing the EWR_tool (assessment code) Python package'.

This Python package takes daily flow data in the form of observed flows or modelled scenario flow data. It then accesses the EWR parameter sheet to look for all the EWRs available at the sites that were loaded in with the flow data and calculates the achievement of each applicable EWR using the supplied flow time series. This calculation involves a number of statistics outlined in the EWR assessment categories section of this document.

When using the installable py-ewr package or Jupyter interface, EWR results are provided via 6 Pandas dataframes. These are described in more detail below.

Accessing the EWR_tool (assessment code) Python package

The Python package can be installed on the command line using pip: 'pip install py-ewr'.

The code can be found on Github, see 'More information'.

If you find any issues with the package, please submit an issue on the Github issues repository.

This package provides the outputs outlined in the EWR_tool (assessment code) (py-ewr package) outputs section of this document.

Inputs

Hydrological data

1. Observed data: if using this option, the tool will fetch the observed data from relevant water data portals for the selected locations.
2. Modelled scenario or user-defined data: if using this option, the user will need to specify the locations of the modelled scenario data files. See Appendix A for formatting requirements of modelled scenario data. If the user has model formats (including variations of datetime formats) that fall outside of this, please contact the developers, listed on Github with the EWR_tool, as they will be able to amend the tool to ingest other formats. Failure to follow these formatting requirements could result in unexpected behaviour of the EWR_tool.

EWR parameter sheet

Each time the tool is run, it will read the parameter sheet data stored with the code. The parameter sheets include parameters defined in Part B of the NSW LTWPs (DPE EHG 2022b).

Within the tool

The package is made up of:

- 5 Python scripts (the tool)
- 7 Python test files
- modelled scenario data metadata for linking model nodes to gauges. If users notice model locations are not being evaluated, it may be because of missing relational links between nodes and gauges. This is updated regularly, by the MDBA, to add in any missing links.

Outputs

The tool outputs 6 Pandas dataframes:

- ewr_results
- yearly_ewr
- all_events
- all_successful_events
- all_inter_events
- all_successful_interevents.

These report on 5 elements of EWR achievement that are tracked in the tool:

- successful achievements – when all parts of the EWR are met, including multiple successful events in a single year
- successful events – when all parts of the EWR are met, excluding multiple events per year
- any event – any event that meets the flow/level/volume requirement and falls within the timing window irrespective of duration. This allows for partial duration successes to be reported, information that is important for water management
- inter-event periods between successful events
- inter-event periods between all events.

Interpreting EWR outcomes across different EWR assessment categories

The methods used to calculate the above elements vary among different types of EWRs. Outputs follow a standard format; however, their interpretation will change depending on the underlying calculation. Broadly speaking, baseflow EWRs are evaluated using the number of days each year above a flow threshold, whereas most other EWRs are evaluated as discrete events (the number of consecutive days above a flow, level or volume threshold). Table 1 provides a brief reference guide to the assessment approach by EWR flow category. Further detail is provided in the assessment rules in the 'EWR assessment categories' section.

Table 1 Outline for the interpretation of parameters for EWR flow categories

For further detail please see 'Assessment rules' under each EWR assessment category.

EWR flow category	Flow requirement	Duration requirement	Timing requirement	Frequency requirement	Max inter-event period requirement	Water year split and events (1 event per year required unless specified)
Cease-to-flow	Maximum flow threshold	Consecutive days, except for the Murrumbidgee (number of days in the water year)	Any time. LTWP EWR tables in Part B suggest natural timings	Ranges from 0–100% (also expressed as number of years out of 10)	NA	Event accrues across water year boundary
Low flows	Minimum flow threshold	Number of days in the water year	Any time	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	Water year boundary is a hard edge. Count of days occurs within the water year or timing window unless it crossed the boundary, then it reports in the finishing year
Baseflow	Minimum flow threshold	Number of days in the water year	Any time or with seasonal timing	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	Water year boundary is a hard edge. Count of days occurs within the water year or timing window unless it crossed the boundary, then it reports in the finishing year

EWR flow category	Flow requirement	Duration requirement	Timing requirement	Frequency requirement	Max inter-event period requirement	Water year split and events (1 event per year required unless specified)
Small fresh	Minimum flow threshold or volume	Consecutive days	Any time or with seasonal timing	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	Water year boundary is a hard edge and splits consecutive event. Currently small fresh 1 in the Murrumbidgee requires 2 events per year to be successful
Large fresh	Minimum flow threshold or volume	Consecutive days	Any time or with seasonal timing	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	Water year boundary is a hard edge and splits consecutive event
Anabranch and bankfull flows	Minimum flow threshold or volume	Consecutive days	Any time or with seasonal timing	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	Water year boundary is a hard edge and splits consecutive event
Wetland connecting and overbank flows	Minimum flow threshold or volume	Consecutive days with within event gap tolerances in some locations. Please see 'Standard Flows' for further detail	Any time or with seasonal timing	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	Water year boundary is a hard edge and splits consecutive event
Weir pool	Minimum flow threshold and weir level (mAHD)	Consecutive days	Seasonal timing	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	No water year split required at this time

EWR flow category	Flow requirement	Duration requirement	Timing requirement	Frequency requirement	Max inter-event period requirement	Water year split and events (1 event per year required unless specified)
Lake level	Minimum and maximum lake level (mAHD)	Consecutive days	Any time	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	Rules based. Please see 'Lake level' further down in this document
Nesting flows	Minimum flow threshold with assessment of rates of rise and fall	Consecutive days	Seasonal timing	Ranges from 0–100% (also expressed as number of years out of 10)	Period between successful events, expressed as years or days	No water year split required at this time

ewr_results dataframe

The ewr_results dataframe provides a summary of the results for each EWR over the entire period of the input time series. It also provides separate results for events that meet all EWR parameters and events that meet the EWR flow/level/volume threshold and timing requirements but not necessarily the duration requirements. Table 2 provides a description of ewr_results dataframe outputs.

Table 2 ewr_results dataframe output descriptions

Columns	Description	Example
Scenario	Type or name of the scenario	observed
Gauge	Gauge number	410001
PlanningUnit	Planning unit name	Willandra Creek
EwrCode	EWR code	BF1_a
Multigauge	Gauge number if there is a second gauge used for the EWR. Identifies the second gauge so flows from the 2 gauges can be combined. Is currently used only for 'multigauge' EWRs	454
EventYears	Count of event years (years where all annual EWR parameters are met, e.g. flow/level/volume threshold, duration timing, and events per year)	1
Frequency	Calculated frequency as % of years achieved (based on the number of successful vs total years in the input time series). Calculated for cease-to-flow using the maxRollingAchievement column from the yearly_ewr dataframe. All other EWRs use eventYears column from the yearly_ewr dataframe.	50
TargetFrequency	Target frequency specified in the LTWP as % of years	50
AchievementCount	Count of total achievements (how many times all EWR parameters, including multiple events per year requirements, were successfully met for the entire time series. Some EWRs require more than one successful event per year)	2
AchievementPerYear	AchievementCount divided by the total number of years in the input time series	0.5

Columns	Description	Example
EventCount	Sum of numEvents, from yearly_ewr dataframe, for successful EWR events that meet all flow/level/volume threshold, duration and timing requirements. When multiple events are required for the achievement of an EWR these are counted as individual events	1
EventCountAll	Sum of numEventsAll, from yearly_ewr dataframe (any event that has met the flow/level/volume threshold and timing requirements)	2
EventsPerYear	Average numEvents, from yearly_ewr dataframe, for successful EWR events that meet all EWR event requirements (threshold, duration and timing)	0.5
EventsPerYearAll	Average numEventsAll, from yearly_ewr dataframe, for any event that meets the flow/level/volume threshold and timing requirement	1
AverageEventLength	Average length in days of all events (any event that has met the threshold and timing requirements)	217
ThresholdDays	Number of days above the flow, volume or water level threshold of the EWR. Pulls from all_events dataframe (includes events that meet EWR flow/level/volume threshold and timing requirements but not necessarily duration requirements)	434
MaxInterEventYears	Target max inter-event length from the LTWP. (The longest inter-event period (in years) for the EWR)	0.065753
NoDataDays	sum of missingDays from hydrological data	1
TotalDays	sum of totalPossibleDays from the yearly_ewr dataframe	730

yearly_ewr dataframe

The yearly_ewr dataframe provides a yearly summary for each EWR and each water year included in the input data. Table 3 provides a description of yearly_ewr dataframe outputs.

Duration definition and subsequent calculation is different depending on the type of EWR:

- Very low flow and baseflow EWRs are the number of days within the water year and do not have to be consecutive. Cease-to-flows in the Murrumbidgee are also calculated as number of days in the water year.
- Cease-to-flow (CTF) (except for the Murrumbidgee), small fresh, large fresh, anabranch, wetland connecting, overbank, nesting flow and weir pool EWRs all require the duration to be consecutive days.

Table 3 yearly_ewr dataframe output descriptions

Columns	Description	Example
Year	Water year (1 July to 30 June), i.e. an event starting 24 October 2022 that finishes on 30 April 2023 will show the year 2022	2022
eventYears	1 if all parts of the EWR were achieved and 0 if not (all parts of the EWRs need to be met). CTFs (except ALT_CTF) will be given a 1 in this column if they exceed duration (do not meet LTWP requirements); however, if they span multiple water years a 1 will only be applied in the year that the event finishes. See maxRollingAchievement for annual reporting on CTFs that exceed maximum durations (given 1). This column aligns with original LTWP development and is best used for annual reporting	1
numAchieved	Count of EWR achievements in the year	2
numEvents	Count of individual successful events achieved in the year. Count 1 for each time an event exceeds the minimum required duration (successful EWR event, meets all threshold, duration and timing requirements). A count of greater than one can also be achieved for very low flow and baseflows if the number of days in the water year is exceeded more than once (e.g. duration requirement is 55	2

Columns	Description	Example
	days and 110 days occurs numEvents would be 2)	
numEventsAll	Count of events in the year. Count 1 for each irrespective if the minimum event requirement and duration are achieved	3
eventLength	Average length of all events for the year. This includes events that meet EWR threshold and timing requirements but not necessarily duration requirements	2
eventLengthAchieved	Average length of successful events for the year (i.e. those events that meet all threshold, duration and timing requirements)	2
totalEventDays	Total number of days of the events in the year (events that meet threshold and timing requirements but not necessarily duration requirements). In other words, the total number of days in the year that flows, or water levels, are above the EWR threshold during the required timing window	4
totalEventDaysAchieved	Total as above (totalEventDays) but excludes unsuccessful events (only includes events that meet all threshold, duration and timing requirements)	4
maxEventDays	Returns the maximum event length (days) of successful events within a given year	2
maxRollingEvents	Returns the maximum event length (days) of successful events up to the year boundary. If there is an event that crosses the year boundary the event total duration count (days) accumulates into the next year. This cumulative total is also reported in the next year if it is the maximum event length (used in the CTF frequency calculation)	420
maxRollingAchievement	Returns 1 if the maxRollingEvents duration is equal to or greater than the minimum calculated duration for CTF annually	1
missingDays	Days in the hydrological time series without data. Missing data arises when	0

Columns	Description	Example
	the tool filters out days with poor quality data. Currently, poor quality data is defined as those with quality codes 151, 152, 153, 155, 180, 201, 202, 204, 205, 207, 223, 255	
totalPossibleDays	Total days in the hydrological time series	365
ewrCode	EWR code	OB-S2
scenario	Type or name of the scenario	observed
gauge	Gauge number	410033
pu	Planning unit name	Willandra Creek
multigauge	gauge number if there is a multigauge in the EWR (second gauge)	
rollingMaxInterEvent	Returns the event with max inter-event days up to the water year boundary (365/366 days). If an event crosses the water year boundary the max inter-event days total continues to accumulate into the next year. Calculated off the all_successful_interevents table below	643
RollingMaxInterEventAchieved	1 if the number of inter-event days in a year is less than the target maximum inter-event days specified in the LTWPs and 0 if they are exceeded. This is calculated by comparing the rollingMaxInterEvent with the target maximum inter-event period specified yearly	1

all_events dataframe

The all_events dataframe details each individual event (an event that meets the timing and flow, volume or water level requirements) irrespective of any duration or minimum event requirements. That is, it will detail an event that meets the flow/level/volume threshold at the correct timing of year but does not check for the required minimum duration. Table 4 provides a description of all_events dataframe outputs.

Table 4 all_events dataframe output descriptions

Columns	Description	Example
scenario	Type or name of the scenario	observed
gauge	Gauge number	410033
pu	Planning unit name	Willandra Creek
ewr	EWR code	VF1_a
waterYear	Water year (1 July to 30 June), i.e. event starting 24 October 2022 that finishes on the 30 April 2023 will show the year 2022	2022
startDate	Start date of EWR event in format DD/MM/YYYY	1/07/2022
endDate	End date of EWR event in format DD/MM/YYYY	30/06/2023
eventDuration	Event duration in days. This is the number of days an EWR event goes for including the days that fall below the threshold when a 'within event gap tolerance' is specified. This column will be different to the eventLength column only when an EWR has a 'within event gap tolerance' that occurs throughout its duration	365
eventLength	Event length in days. This is the number of days an EWR event goes for excluding the days that fall below the threshold when a 'within event gap tolerance' is specified. This column will be different to the eventDuration column only when an EWR has a 'within event gap tolerance' that occurs throughout its duration and it will have less days	330
multigauge	Gauge number if there is a multigauge in the EWR (second gauge)	

all_successful_events

The all_successful_events is a version of the all_events dataframe that provides the same outputs but has filtered out all events that have durations less than the minimum required duration defined in the EWR tables in the LTWPs. For very low flow and baseflow EWR assessment categories where duration is number of days in the water year it still provides the event details for all events that fall within the timing window and above the flow threshold regardless if the number of days in the water year have been met. Table 5 provides a description of all_successful_events dataframe outputs.

Table 5 all_successful_events dataframe output descriptions

Columns	Description	Example
scenario	Type or name of the scenario	observed
gauge	Gauge number	410033
pu	Planning unit name	Willandra Creek
ewr	EWR code	VF1_a
waterYear	Water year	2022
startDate	Start date of EWR event in format DD/MM/YYYY	1/07/2022
endDate	End date of EWR event in format DD/MM/YYYY	30/06/2023
eventDuration	Event duration in days	365
eventLength	Event length in days	365
multigauge	gauge number if there is a multigauge in the EWR (second gauge)	

all_inter_events

The all_inter_events dataframe is the inverse of the all_events dataframe and provides the inter-event period between each individual event (an event that meets the timing and flow, volume or water level requirements) irrespective of any duration requirements. Table 6 provides a description of all_inter_events dataframe outputs.

Table 6 all_inter_events dataframe output descriptions

Columns	Description	Example
scenario	Type or name of the scenario	observed
gauge	Gauge number	410033
pu	Planning unit name	Willandra Creek
ewr	EWR code	VF1_a
startDate	Start date of EWR inter-event period in format DD/MM/YYYY	1/07/2022

Columns	Description	Example
endDate	End date of EWR inter-event period in format DD/MM/YYYY	30/06/2023
InterEventLength	Inter-event duration in days	365

all_successful_interevents

The all_successful_interevents dataframe is the inverse of the all_successful_events dataframe, providing the inter-event period between successful events. Table 7 provides a description of the all_successful_interevents dataframe outputs.

Table 7 all_successful_interevents dataframe output descriptions

Columns	Description	Example
scenario	Type or name of the scenario	observed
gauge	Gauge number	410033
pu	Planning unit name	Willandra Creek
ewr	EWR code	VF1_a
startDate	Start date of EWR inter-event period in format DD/MM/YYYY	1/07/2022
endDate	End date of EWR inter-event period in format DD/MM/YYYY	30/06/2023
InterEventLength	Inter-event duration in days	365

Missing hydrological data

The approach for handling missing hydrological input data is yet to be finalised and implemented. For online water data observations, the EWR_tool (assessment code) filters using hydstra quality codes (151, 152, 153, 155, 180, 201, 202, 204, 205, 207, 223 and 255) replacing them with a null. This replacement will end any ongoing EWR events as it is essentially treated as a flow of 0. Future versions of the tool will allow for the option to undertake gap filling on periods of missing data.

When processing modelled scenario data, you should check there are no missing values or duplicated dates in the time series. Deviations from the required format, outlined in Appendix A: Loading in model data, may cause erroneous results.

EWR assessment categories

There are many different types of EWRs throughout the LTWPs, including but not limited to, cease-to-flows, baseflows, freshes and overbank flows. For the purpose of the EWR assessment code, EWRs have been grouped into assessment categories that use the same method for calculating EWR achievement and other EWR_tool outputs. The assessment method and rules for each EWR assessment category are described below.

Cease-to-flows

CTFs occur across all LTWP areas. They largely describe the maximum periods of effective 'no flow' recommended for each planning unit. Some LTWPs also have CTFs that are ecologically required in the system (e.g. in the case of naturally ephemeral rivers and creeks). CTF thresholds can vary among gauge locations and in some cases are set higher than zero (e.g. 1 ML/d) to allow for uncertainty in the no flow threshold. The EWRs/EWR codes that fall within this assessment category are described in Table 8[1]. The split of EWR codes may not align with the representation of the CTF EWRs in the LTWPs but has been implemented in the EWR_tool to best reflect the original analysis used to inform them.

Table 8 Description of CTF EWR codes

EWR code	Description	LTWP area
CF/CF1	Mostly used when only a single CTF EWR applies to a planning unit. These tend to be zero duration CTF requirements (indicating CTF events should not occur in the river/creek) or CTF requirements informed by expert opinion	Most LTWP areas
CF_a/CF1_a	Specifies the maximum duration of CTF events in 'typical years', which is one of 2 durations specified in CTF EWRs in most LTWPs. In the development of LTWPs, this 'typical year' maximum CTF duration was informed by multiple lines of evidence including the 50th percentile CTF duration from select hydrological time series (modelled without development, modelled current and/or observed). For the purpose of testing CF_a / CF1_a achievement, the EWR_tool tests if the total number of days of CTFs in a given year is less than the maximum recommended duration for 'typical years'. No frequency is assigned to CF_a/CF1_a at this stage	Most LTWP areas

[1] CTF EWRs are only expressed in this split format (CF_a, CF_b and CF_c) in the Border Rivers LTWP. The duration requirements are expressed across all current plans. The Border Rivers format will be applied to all LTWP areas in the next LTWP review, for clarity.

EWR code	Description	LTWP area
CF_b/CF1_b	Specifies the maximum duration of CTF events in 'dry years', which is one of 2 durations specified in CTF EWRs in most LTWPs. In the development of LTWPs, this 'dry year' maximum CTF duration was informed by multiple lines of evidence including the 95th percentile CTF duration from select hydrological time series (modelled without development, modelled current and/ or observed). For the purpose of testing CF_b / CF1_b achievement, the EWR_tool tests if the total number of days of CTFs in a given year is less than the maximum recommended duration for 'dry years'. It also assesses the frequency	Most LTWP areas
CF_c/CF1_c	This CTF EWR specifies the proportion of years (expressed as a percentage) that CTF events of any duration should occur (maximum duration of 1 day or more). This aligns with the expressed CTF event frequency in the LTWPs	Most LTWP areas
CF1_d	This CTF EWR only occurs in one location in the Murrumbidgee LTWP. The duration aligns with the 75th percentile duration of CTF in the modelled without development flow time series for that gauge and should occur no more than 25% of the time (frequency)	Murrumbidgee
CF1_cool/CF1_hot	These CTF EWRs are present only in the Gwydir and are based on expert knowledge of the system due to low confidence in modelling for low flows. They represent the maximum range of CTF durations throughout seasons. This seasonality is currently not included in the tool and the range of EWRs are assessed across the whole year	Gwydir
ALT_CTF	This CTF is alternate to all other CF codes as it is documented differently. The duration and frequency are minimums not maximums as they are required to occur within the system. The logic of this CTF EWR aligns with the assessment method for standard EWRs assessment category and as the durations are less than 365 days it can be assessed using the assessment method for the standard flow EWR category. This CTF EWR is only encountered in the Murray–Lower Darling LTWP area	Murray–Lower Darling

Assessment rules

CTF EWRs utilise the following parameters:

- **Timing** – assessed for any time of year (July to June) within the assessment code (except for select EWRs in the Murray–Lower Darling). EWR tables in Part B of LTWPs present guidelines for the preferred seasons for CTF to occur. This

seasonality guidance is not included in the assessment tool. The majority of CTFs are assessed for any time of year as this reflects the original LTWP analysis.

- **Flow threshold** – aligns with LTWPs. Expressed as a flow threshold below which CTFs occur, e.g. 0 or 1 ML/d.
- **Duration** – events are consecutive days except for the Murrumbidgee LTWP area which is days above the threshold within the water year. This variation is accounted for in the code.
- **Frequency** – as expressed in Table 8. Ranges from 0–100% (also expressed in number of years out of 10).
- **Maximum inter-event period** – not applicable
- **Two methods for tracking CTF EWRs** (both shown in Table 9)
  - Method A:
    - The results of this method are shown in the all_events and all_successful_events dataframe tables above as well as the eventYears column in the yearly_ewr dataframe
    - Each CTF event is assigned to the year it is broken in (event is not split by the water year boundary).
  - Method B:
    - The results of this method are shown in MaxRollingEvents in the yearly_ewr dataframe. In this method, event accrual over water years is calculated as follows: If a CTF event crosses a water year boundary the event records firstly at the end of the water year. It then continues into the new water year and continues to accrue, including the days from the previous water year. The accounting of the event at the end the water year allows for frequency calculations to align with the original LTWP analysis.

Method B was developed to track the maximum cumulative event when crossing water years. This method was implemented to handle CTF events that span multiple years. If the above Method A was used, a CTF event spanning 3 years would only be assigned to a single year, and the other 2 years would report no CTF had occurred. Each CTF event is recorded throughout the water year and the event with the maximum duration is checked against the CTF requirements. This maximum event is what is displayed in annual tables for the NSW LTWP EWR Assessment Dashboard.

The 2 methods were required to calculate the various statistics required to support the analysis; for example, when calculating the number of days for events, Method A is used to avoid any double counting that would happen if Method B was used. For calculating the annual achievement, Method B is used.

Table 9 **Visualisation of CTF duration calculation methods**

Month, water year	June 2019–20											July 2020–21					
Day of the month	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6
Flow (ML/d)	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Calculated CTF events (number of days)	NA	NA	NA	1	2	3	4	5	6	7	8	9	10	11	12	13	NA
Method A																13 days	
Method B (max rolling events)										8 days						13 days	

Low flows

Low flows comprise several EWR flow categories, primarily very low flows and baseflows, that fall across all LTWP areas. Very low flows (VF/VL)[2] are a flow category that join river pools, thus providing partial or complete connectivity in a reach. Baseflows (BF)[2] provide connectivity between pools and riffles and along channels. They provide sufficient depth for fish movement along reaches and the seasonality of BF2 targets native fish recruitment.

Low flow EWR codes are described in Table 10 and the assessment methods for testing their achievement are outlined below in the 'Assessment rules' section.

Table 10 Low flow EWR codes

Category	EWR code	Description	LTWP area
Very low flow	VF/ VF1	Used where a single very low flow requirement is assigned to a planning unit in the LTWP. Parameter information is based on percentiles and/or expert advice	Macquarie–Castlereagh, Murray–Lower Darling
Very low flow	VF_a/ VF1_a/ VL_a	Specifies the minimum required number of days per water year where the very low flow threshold is exceeded. This number of days should be met in at least 50% of years over the long term. This aligns with 'typical year' minimum durations for very low flows expressed in LTWPs. The minimum required number of days was informed by multiple lines of evidence including the 50th percentile annual very low flow days from select hydrological time series (modelled without development, modelled current and/ or observed), at the relevant gauge. The exception to this method is the Gwydir LTWP, where the duration requirements for very flow flows are largely based on expert knowledge of the system due to low confidence in the modelling of low flows. The minimum required frequency for this EWR is 50% of years	Most LTWP areas
Very low flow	VF_b/ VF1_b/ VL_b	Specifies the minimum required number of days per water year where the very low flow threshold is exceeded. This number of days should be met in 100% of years over the long term. This aligns with	Most LTWP areas

[2] Low flow EWRs are only expressed in the a and b split format in the Border Rivers LTWP; however, duration requirements are expressed within all current plans. The Border Rivers format will be applied to all LTWP areas in the next LTWP review, for clarity.

Category	EWR code	Description	LTWP area
		'dry year' minimum durations for very low flows expressed in LTWPs. The minimum required number of days was determined from multiple lines of evidence including the 5th percentile annual very low flow days from select hydrological time series (modelled without development, modelled current and/ or observed), at the relevant gauge. The exception to this method is the Gwydir LTWP, where the duration requirements for very flow flows are largely based on expert knowledge of the system due to low confidence in the modelling of low flows. The minimum required frequency for this EWR is 100% of years	
Baseflow 1	BF1	Used where a single baseflow requirement is assigned to a planning unit. Parameter information is based on percentiles and/or expert opinion	Macquarie–Castlereagh, Murray–Lower Darling
Baseflow 1	BF1_a	Specifies the minimum required number of days per water year where the baseflow threshold should be exceeded. Should occur in at least 50% of years. This aligns with 'typical year' minimum durations for baseflow 1 (BF1) flows expressed in LTWPs. The minimum number of days per year is determined from multiple lines of evidence including the 50th percentile annual number of days for baseflows (BF1 magnitude flows) from select hydrological time series (modelled without development, modelled current and/ or observed), at the relevant gauge. The exception to this method is the Gwydir LTWP, where minimum duration requirements for baseflows are based on expert knowledge of the system due to low confidence in the modelling of low flows. The minimum required frequency for BF1_a is 50% of years. Baseflow 1 flows (BF1, BF1_a and BF1_b) mostly have no seasonal restriction (can occur any time during the year), unlike baseflow 2 (BF2) EWRs, which typically have a seasonal restriction	Most LTWP areas
Baseflow 1	BF1_b	Specifies the minimum required number of days per water year where baseflow threshold should	Most LTWP areas

Category	EWR code	Description	LTWP area
		be exceeded. This aligns with 'dry or very dry year' minimum durations for baseflows expressed in LTWPs. The required frequency of this EWR is 100% of years to ensure the required minimum baseflow days are met in the dry and very dry years. The minimum number of days per year is determined from multiple lines of evidence including the 5th percentile annual number of days for baseflows (BF1 magnitude flows) from select hydrological time series (modelled without development, modelled current and/ or observed), at the relevant gauge. The exception to this method is the Gwydir LTWP, where minimum duration requirements for baseflows are based on expert knowledge of the system due to low confidence in the modelling of low flows. Baseflow 1 flows (BF1, BF1_a and BF1_b) mostly have no seasonal restriction (can occur any time during the year), unlike baseflow 2 (BF2) EWRs, which typically have a seasonal restriction	
Baseflow 1	BF1a/ BF1b	Only in the Murray–Lower Darling LTWP. BF1a and BF1b are different to BF1_a and BF1_b and represent 2 different seasons (timings) that the BF1 EWR should occur at	Murray–Lower Darling
Baseflow 2	BF2	Used where a single baseflow 2 requirement is assigned to a planning unit. Parameter information is based on percentiles and/or expert opinion	Lachlan, Macquarie–Castlereagh, Murray–Lower Darling
Baseflow 2	BF2_a	Specifies the minimum required number of days per year where baseflow threshold should be exceeded. Should occur in at least 50% of years. This aligns with 'typical year' minimum durations for baseflow 1 (BF2) flows expressed in LTWPs. BF2_a has a seasonal restriction (needs to occur at a certain time of year). The minimum number of days per year is determined from multiple lines of evidence including the 50th percentile annual number of days of baseflows (BF2 magnitude flows) from select hydrological time series (modelled without development, modelled current and/ or observed), at the relevant gauge.	Most LTWP areas

Category	EWR code	Description	LTWP area
		The exception to this method is the Gwydir LTWP, where minimum duration requirements for baseflows are based on expert knowledge of the system due to low confidence in the modelling of low flows. The minimum required frequency for BF2_a is 50% of years	
Baseflow 2	BF2_b	Specifies the minimum required number of days per year where baseflow threshold should be exceeded. Should occur in 100% of years. This aligns with 'dry or very dry year' minimum durations for baseflows expressed in LTWPs. BF2_b has a seasonal restriction (needs to occur at a certain time of year). The required frequency of this EWR is 100% of years to ensure the required minimum baseflow durations are met in the dry and very dry years. The minimum number of days per year is determined from multiple lines of evidence including the 5th percentile annual number of days of baseflows (BF2 magnitude flows) from select hydrological time series (modelled without development, modelled current and/ or observed), at the relevant gauge. These EWRs vary slightly in the Macquarie, where the minimum required number of days per year is based on the 25th percentile number of days of baseflows in the modelled 'without development' flow time series at the relevant gauge and should occur 75% of the time (frequency) to avoid extreme events. They also vary in the Gwydir LTWP, where they are based on expert knowledge of the system due to low confidence in the modelling of low flows	Most LTWP areas
Baseflow 2	BF2a/ BF2b/ BF2c	Used only in the Murray–Lower Darling LTWP. BF2a, BF2b and BF2c are different to BF2_a and BF2_b and represent 3 different seasonalities (timings) that the BF2 EWR should occur at. These are based on expert understanding of the system	Murray–Lower Darling
Baseflow 3	BF3	Baseflow 3 is used in some LTWPs when the parameters of baseflows 1 and 2 do not cover the flow requirements to meet the ecological needs of a system and an additional baseflow EWR is needed. Duration requirements are expressed as number of days per year and are assessed under the low flow methodology	Macquarie–Castlereagh, Murray–Lower Darling

Category	EWR code	Description	LTWP area
Baseflow 3	BF3_P	Used when baseflow 3 specifies a timing window or 'any time'. BF3_P assesses the BF3 EWR with the preferred timing window. Baseflow 3 is introduced when the parameters of baseflows 1 and 2 do not cover the requirements of a system. Duration requirements are expressed as number of days per water year and are assessed under the low flow methodology	Murray–Lower Darling
Baseflow 3	BF3_S	Used when baseflow 3 specifies a timing window or any time. BF3_S assesses the BF3 EWR for 'any time' during the year. Baseflow 3 is introduced when the parameters of baseflows 1 and 2 do not cover the requirements of a system. Duration requirements are expressed as number of days per water year and are assessed under the low flow methodology	Macquarie–Castlereagh, Murray–Lower Darling
De-stratifying flow	DSF/DSF1	De-stratifying EWR (flow) required to de-stratify refuge pools during periods of identified high risk. Present in the Macquarie–Castlereagh and Murrumbidgee. These are not assessed in the tool as they are guidelines for complex event-based actions for water managers	Murrumbidgee

Assessment rules

Low flow EWRs utilise the following parameters:

- **Timing** – expressed as months of the year and is either any time of the year or a seasonal timing window expressed in the EWR tables in Part B of the LTWPs. The timing window is seen as a 'hard edge' in the assessment code and will end an EWR event.
- **Flow threshold** – aligns with flow thresholds presented in EWR tables in Part B of the LTWPs. It is the minimum flow that needs to be exceeded or equalled; for example, a flow greater than or equal to 10 ML/d (expressed as ≥10 ML/d). Although calculated as greater than (>) for low flows in the original LTWP EWR analysis, the implementation of greater than or equal to in the assessment code brings the calculation in line with standard EWR assessment calculations and has minimal impact on results.
- **Duration** – events are non-consecutive days expressed and calculated as days above the flow threshold within the water year, i.e. a low flow EWR with a duration requirement of 50 days can be achieved from 50 1-day events or one 50-day event.
- **Frequency** – as expressed in Table 8 of this document. Ranges from 0–100% (also expressed in number of years out of 10).

- **Maximum inter-event period** – expressed in years within the EWR tables in Part B of the LTWPs and reported in days in the dataframe outputs. It is the period between successful EWR events, when flow exceeds the minimum threshold and meets other parameter requirements such as seasonality and duration.
- **Event accrual and water year split** – the number of events per year is automatically set to one day in the parameter sheets for low flow EWRs due to them being non-consecutive days above the threshold.

  The water year boundary is seen as a hard edge for the low flows EWR assessment if the EWR has no other specified seasonality (timing). In order to fully achieve these low flow EWRs, flows must meet the minimum number of days above the flow threshold within the window (e.g. July to June for any time of year or September to March for some seasonal low flows).

Standard flows

Standard flows fall into 4 broad flow categories: small fresh, large fresh, bankfull/ anabranch connecting flow and overbank/ wetland connecting flow. The differing EWR codes that represent these are outlined in Table 11, Table 12, Table 13 and Table 14. They aim to achieve a multitude of environmental objectives, which are outlined in the relevant LTWPs in Part A.

Table 11 Standard flow small fresh EWR codes

EWR code	Description	LTWP area
SF1/ SF1_P/ SF1_S/ SF1_a_S/ SF1_b_S	Small fresh 1 (SF1) applies to all LTWP areas. SF1 applies on its own (without SF1_P, SF1_S, etc.) when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when SF1 has a 'preferred' seasonal timing (_P) or can occur any time that is considered 'satisfactory' (_S). For example, SF1_P and SF1_S are applied when the required timing of an SF1 EWR is 'Aug–May or any time'. The SF1 a/b split is in NSW Border Rivers only and represents 2 different durations for SF1	All LTWP areas
SF2/ SF2_P/ SF2_S	Small fresh 2 (SF2) applies to all LTWP areas. SF2 applies on its own (without SF2_P, SF2_S etc) when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when SF2 has a 'preferred' seasonal timing (_P) or can occur any time that is considered 'satisfactory' (_S). For example, SF2_P and SF2_S are applied when the required timing of an SF2 EWR is 'Aug–May or any time'	All LTWP areas
SF3/ SF3_P/ SF3_S	Small fresh 3 (SF3) is used in some LTWPs when SF1 and SF2 do not cover all small fresh needs. SF3 applies on its own when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when SF3 has 'preferred' seasonal timing (_P) or any time that is satisfactory (_S)	Gwydir, Intersecting Streams, Lachlan, Macquarie–Castlereagh, Murray–Lower Darling, Murrumbidgee

Table 12 Standard flow large fresh EWR codes

EWR code	Description	LTWP area
LF1/ LF1_P/ LF1_S	Large fresh 1 (LF1) applies to all LTWP areas. LF1 applies on its own (without _P and _S) when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when LF1 has a 'preferred' seasonal timing (_P) or can occur any time that is considered 'satisfactory' (_S)	All LTWP areas
LF2/ LF2_P/ LF2_S	Large fresh 2 (LF2) applies to all LTWP areas. LF2 applies on its own when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when LF2 has a 'preferred' seasonal timing (_P) or can occur any time that is considered 'satisfactory' (_S)	All LTWP areas
LF3/ LF3_P/ LF3_S	Large fresh 3 (LF3) is used in some LTWPs when LF1 and LF2 do not cover all large fresh needs. LF3 applies on its own (without _P and _S) when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when LF3 has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Gwydir, Intersecting Streams, Lachlan, Murray–Lower Darling, Murrumbidgee, Namoi, NSW Border Rivers
LF4/ LF4_P/ LF4_S	Large fresh 4 (LF4) is used in some LTWPs when LF1, LF2 and LF3 do not cover all large fresh needs. LF4 applies on its own (without _P and _S) when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when LF4 has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Gwydir, Murray–Lower Darling
LF5/ LF5_P/ LF5_S	Large fresh 5 (LF5) is used in the Gwydir LTWP when LF1 to LF4 do not cover all large fresh needs. LF5 applies on its own (without _P and _S) when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when LF5 has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Gwydir
W-LF4_P/ W-LF4_S	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh flows (i.e. larger magnitude than LF1 and LF2 flows). These flows connect the river to anabranches and wetlands but remain below bankfull level. These EWRs are referred to as 'wetland-connecting large fresh' flows. The EWR group W-LF4 has 2 timings specified in the EWR table in Part B of the LTWPs. The 'preferred' seasonal timing is assessed using W-LF4_P and the 'any time' timing as W-LF4_S	Murrumbidgee

EWR code	Description	LTWP area
W-LF5	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh EWRs. These flows connect to anabranches and wetlands but remain below bankfull level. The EWR W-LF5 only has one timing applied, as in the EWR tables in Part B of the Murrumbidgee LTWP	Murrumbidgee
W-LF6_P/W-LF6_S	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh EWRs. These flows connect to anabranches and wetlands but remain below bankfull level. The EWR W-LF6 has 2 timings specified in the EWR tables in Part B of the Murrumbidgee LTWP. The 'preferred' seasonal timing is assessed using W-LF6_P and the 'any time' timing as W-LF6_S	Murrumbidgee
W-LF7	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh EWRs. These flows connect to anabranches and wetlands but remain below bankfull level. The EWR W-LF7 only has one timing applied, as in the EWR tables in Part B of the Murrumbidgee LTWP	Murrumbidgee
W-LF8	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh EWRs. These flows connect to anabranches and wetlands but remain below bankfull level. The EWR group W-LF8 only has one timing applied, as in the EWR tables in Part B of the Murrumbidgee LTWP	Murrumbidgee

Table 13 Standard flow bankfull and anabranch connection EWR codes

EWR code	Description	LTWP area
BK1/ BK1_P/ BK1a_P/ BK1b_P/ BK1_S	This group includes several variations of bankfull 1 (BK1) EWRs. BK1 applies when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when BK1 has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S). The split of a and b occurs in the Murray–Lower Darling LTWP where there are 2 separate seasonal timings required as per the EWR tables in Part B of the LTWP	Barwon–Darling, Gwydir, Lachlan, Murray–Lower Darling, Namoi, NSW Border Rivers

EWR code	Description	LTWP area
BK1_ds/ BK1_us/ BK2_ds/ BK2_us	The _ds and _us split of bankfull EWRs occurs in the NSW Border Rivers LTWP and is to account for different parameter requirements (including flow threshold) for bankfull flows upstream (_us) and downstream (_ds) of the gauge used. This occurs for both BK1 and bankfull 2 (BK2) EWRs and can be found in the EWR tables in Part B of the LTWP	NSW Border Rivers
BK2/ BK2_P/ BK2_S	BK2 often has the same threshold but a different timing to BK1. BK2 applies when there is only one timing specified in the EWR tables in Part B of the LTWPs. The addition of _P and _S occurs when BK2 has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Murray–Lower Darling, Namoi, NSW Border Rivers
AC1/AC1_P/ AC1_S AC2	Anabranch connecting EWRs (AC1 and AC2) represent flows that begin to inundate off-channel habitats including anabranches, some flood runners and low-lying wetlands. AC1 or AC2 applies when there is only one timing specified in the EWR tables in Part B of the LTWPs. The addition of _P and _S occurs when AC1 has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Namoi

Table 14 Standard flow overbank and wetland connection EWR codes

EWR code	Description	LTWP area
WL1/WL1_P/ WL1_S WL2/WL2_P/ WL2_S WL3/WL3_P/ WL3_S WL4	These EWR codes represent a range of wetland inundation flow EWRs that provide broadscale lateral connectivity. The WL set of codes are only used in the Lachlan LTWP although there are other wetland flow EWRs in other catchments that use alternative codes. These can all be found in the EWR tables in Part B of the LTWPs. WL** applies when there is only one timing applied. The addition of _P and _S occurs when WL** has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Lachlan
OB_WS2/ OB_WS2_P/ OB_WS2_S/ OB_WS3/ OB_WS3_P/ OB_WS3_S/ OB_WS4/ OB_WS4_P/ OB_WS4_S OB_WM/ OB_WM_P/ OB_WM_S OB_WL/ OB_WL_P/ OB_WL_S	These EWR codes represent a range of overbank/ wetland inundating flow EWRs that provide broadscale lateral connectivity. They range from small (OBWS*) to large (OBWL*) overbank/ wetland inundating flows. This code is only used in the Macquarie–Castlereagh LTWP although there are other wetland flows in other catchments. These can all be found in the EWR tables in Part B of the LTWPs. OB/*** applies when there is only one timing applied. The addition of _P and _S occurs when OB/*** has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Macquarie–Castlereagh
OB1/ OB1_P/ OB1_S	These EWR codes represent a range of overbank flow EWRs that provide lateral connection within the planning units they are applied to. The split of a and b occurs in the Murray–Lower Darling LTWP only, where there are multiple seasonal timings required for OB2 as outlined in the EWR tables in Part B of the LTWP. The addition of _P and _S occurs when OB** has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Almost all LTWP areas
OB2/ OB2_P/ OB2_S		Almost all LTWP areas
OB2a_P/ OB2a_S/ OB2b_P/ OB2b_S		Murray–Lower Darling
OB2_WHA_P/ OB2_WHA_S	These EWR codes represent a specific overbank EWR, OB2_Whalan, in the NSW Border Rivers LTWP for the 'Macintyre River floodplain upstream of Boomi River' planning unit. They assist in the achievement of EWRs within the adjoining planning unit, Whalan Creek. The 'preferred' seasonal timing is assessed using OB2_WHA_P and the 'any time' timing, which is satisfactory, as OB2_WHA_S	NSW Border Rivers

EWR code	Description	LTWP area
OB3/ OB3_P/ OB3_S/ OB3a_P/ OB3a_S/ OB3b_P/ OB3b_S	These EWR codes represent additional overbank flow EWRs when standard OB1 and OB2 do not cover the range of lateral connectivity encountered in the planning unit. The addition of _P and _S occurs when OB** has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Barwon–Darling, Gwydir, Intersecting Streams, Lachlan, Murray–Lower Darling, Namoi
OB4/ OB4_P/ OB4_S		Gwydir, Intersecting Streams, Lachlan, Murray–Lower Darling, Namoi
OB5/ OB5_P/ OB5_S		Gwydir, Lachlan, Murray–Lower Darling, Namoi
OB6_P/ OB6_S OB7_P/ OB7_S OB8_P/ OB8_S OB9 OB10		Murray–Lower Darling
OB-S1 OB-S2/ OB-S2_P/ OB-S2_S OB-L1/ OB-L1_P/ OB-L1_S	These EWR codes represent a range of overbank flow EWRs that provide broadscale lateral connectivity in the Murrumbidgee. They range from small (OB-S1) to large (OB-L1) overbank flows. These codes are only used in the Murrumbidgee LTWP although there are other overbank flows in other catchments (see EWR tables in Part B of the LTWPs). OB-*** applies when there is only one timing applied. The addition of _P and _S occurs when OB-** has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Murrumbidgee

Assessment rules

Standard flow EWRs are assessed using the following parameters found in the EWR tables in Part B of the LTWPs:

- **Timing** – expressed as a range of months of the year in which the flow event is required or preferred to occur. This is either any time of the year (July – June) or a seasonal timing window expressed in the EWR tables in Part B of the LTWPs. Days within the timing months are inclusive, meaning the window begins on day 1 of the start month and ends on the last day of the end month. The timing window is seen as a hard edge in the assessment code and will end an EWR event.
- **Flow threshold** – aligns with EWR tables in Part B of the LTWPs. It is the minimum flow that needs to be exceeded or equalled; for example, a flow greater than or equal to 10,000 ML/d (expressed as ≥10,000 ML/d).

- **Duration** – events are consecutive days and the minimum duration specified in the EWR tables in Part B of the LTWP must be met for an EWR to be successful (note some EWRs have within event gap tolerances).
- **Within event gap tolerance** – only found in the Murray–Lower Darling and Murrumbidgee LTWPs. This is a maximum number of consecutive days that the flow can fall below the flow threshold assigned to the EWR and still be considered a continuous event. The EWR has to start above the required flow threshold before it can drop below it. See example in Table 15a–c below, which has a minimum duration of 7 days and a within event gap tolerance of 3 days.

Table 15 Example of within event gap tolerance

a) EWR not achieved, b) EWR achieved and c) EWR not achieved. EWRs: minimum duration 7 days, within event gap tolerance 3 days.

a. EWR not achieved. Flow dips below the flow threshold for only 3 days on days 3–5, but it does not have the total of 7 days above the flow threshold required by the EWR.

Day	1	2	3	4	5	6	7	8	9	10	11	12
Flow threshold pass/fail	↑	↑	↓	↓	↓	↑	↑	↓	↓	↓	↓	↓

b. EWR achieved (days 1–12). The event dropped below the flow threshold for 3 and then 2 days, but it had 7 days above the flow threshold.

Day	1	2	3	4	5	6	7	8	9	10	11	12
Flow threshold pass/fail	↑	↑	↓	↓	↓	↑	↑	↓	↓	↑	↑	↑

c. EWR not achieved. Event exceeds the within event gap tolerance threshold of 3 days.

Day	1	2	3	4	5	6	7	8	9	10	11	12
Flow threshold pass/fail	↑	↑	↑	↑	↑	↑	↓	↓	↓	↓	↑	↑

- **Frequency** – ranges from 0–100% and can be found in the EWR tables in Part B of the LTWP. It is also expressed in number of years out of 10. Some EWRs have an individual frequency target based on the long-term average (e.g. baseflow EWRs), others present a range with the long-term average in brackets, where frequencies

have been defined using one or more ecological requirements. The base EWR_tool (assessment code) only assesses against the long-term average, the percentage often expressed in brackets in the EWR tables following the frequency expressed as number of years in 10 (e.g. 5 out of 10 years (50% – this 50% is the long-term average)). Frequency ranges are presented in the NSW LTWP EWR Assessment Dashboard and the targets within the plan and are included within the parameter sheets.

- **Maximum inter-event period** – expressed in years within the EWR tables in Part B of the LTWPs and reported as days in the dataframe outputs. It is the period between successful EWR events, when flow exceeds the minimum threshold and meets other parameter requirement such as seasonality and duration.
- **Event accrual and water year split** – for the majority of EWRs, one event is required per year; however, there are some EWRs that require multiple events per year. These are documented in the EWR tables in Part B of the LTWPs and at this time occur only in the Murrumbidgee. For these EWRs, unless the multiple events occur, the EWR is not achieved for that water year.

  The water year boundary is seen as a hard edge. A hybrid method of using the 2 approaches from the LTWP analysis and the original MDBA code has been adapted in the revised code. This uses the water year boundary as a hard edge and splits an ongoing event that crosses this boundary. The events either side must meet the EWR duration requirement individually to be counted as successful events in each year. Sensitivity testing indicates the hybrid approach does not significantly impact the calculated event frequencies.

Volumetric

Volumetric EWRs consist of large fresh, wetland inundating and overbank EWRs that are expressed as the volume of flow at a gauge over a period of time rather than a daily flow threshold as in the standard flow EWRs. Table 16 provides a description of the codes used and what they represent. These EWRs can be found in the EWR tables of Part B of the LTWPs.

Table 16 Volumetric EWR codes

EWR Category	EWR code	Description	LTWP area
Large fresh	LF6/ LF6_P/ LF6_S	These EWR codes represent volumetric large fresh EWRs. The addition of _P and _S occurs when LF6 has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Gwydir
Wetland inundating	WL1/ WL2/ WL2_P/ WL2_S/ WL3/ WL4/ WL4_P/ WL4_S	These EWR codes represent wetland inundating large fresh EWRs that specify the volume required to achieve a range of lateral wetland connectivity. The addition of _P and _S occurs when WL* has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Gwydir, Intersecting Streams
Overbank	OB_WL_P/ OB_WL_S/ OB_WM_P/ OB_WM_S/ OB_WS1_P/ OB_WS1_S/ OB_WS4_P/ OB_WS4_S	These EWRs are a range of volumetric overbank EWRs that specify the volume required to achieve small (e.g. OB/WS1_P) to large (e.g. OB/WL_P) lateral inundation. The addition of _P and _S occurs when an OB/W** or OB** has 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Macquarie–Castlereagh
Overbank	OB1_P/ OB1_S/ OB2_P/ OB2_S/ OB3_P/ OB3_S/ OB5	These EWRs are a range of volumetric overbank EWRs that specify the volume required to achieve small (e.g. OB/WS1_P) to large (e.g. OB/WL_P) lateral inundation. The addition of _P and _S occurs when an OB/W** or OB** has 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)	Gwydir

Assessment rules

Volumetric EWRs follow similar rules to the standard flow EWRs method; however, instead of meeting a minimum flow threshold for a minimum duration, a specified minimum volume of flow must move past the gauge within a specified period of time, whilst also meeting the other required EWR parameters such as timing. These details can be found in the EWR tables in Part B of the LTWPs. The volumetric requirement, i.e. flow volume that has passed in the specified time period, is checked daily along with the other

standard parameters such as a seasonal timing window. It should be noted that some volumetric EWRs will not begin to be calculated until a minimum flow threshold is met.

Volumetric flow EWRs utilise the following parameters:

- **Timing** – expressed as months of the year. This is either any time of the year (July – June) or a seasonal window expressed in the EWR tables in Part B of the LTWPs. Days within the timing months are inclusive, meaning the window begins at day 1 of the start month and ends on the last day of the end month. The timing window is seen as a hard edge in the assessment code and will end an EWR event.
- **Flow threshold** – can be found in the EWR tables in Part B of the LTWPs. Expressed as a minimum threshold that needs to be exceeded. This can still apply to some volumetric EWRs, and volume will not start to accrue unless the minimum flow threshold is met. For most volumetric EWRs this is not defined and therefore assumed to be 0 ML/day (thereby all flows can contribute to the volume target).
- **Flow volume** – volume in ML that must be met over a specific period (accumulation period) to achieve desired flow outcome (either longitudinal or lateral).
- **Accumulation period (days)** – often presented in the duration column in the EWR tables in Part B of the LTWPs, this is the period in days that the flow volume must accrue in to be achieved. When ranges are presented the conservative option of the maximum period has been entered into the parameter sheet for the EWR_tool (assessment code).
- **Duration** – volumetric EWRs have an accumulation period during which flow must accumulate and there is no minimum duration requirement in days (e.g. a minimum number of days where all EWR parameters must be met for the EWR to be considered achieved). Therefore, minimum duration is set as 0 days for all volumetric EWRs in the parameter sheet.

  Reporting of event duration outcomes only starts when all the requirements have been met, not from the first day that the volumetric flow requirements are met (must meet timing and volumetric EWRs). This may lead to some unexpected results for the duration; however, this is intentional. In Table 17 and Table 18 you can see in the first event the tool reports the duration as being 3 days long – this is because the volume requirement was only met for 3 days (days 3, 4 and 5).
- **Frequency** – ranges from 0–100% and can be found in the EWR tables in Part B of the LTWP. It is also expressed in number of years out of 10. Some EWRs have an individual frequency target based on the long-term average (e.g. baseflow EWRs), others present a range with the long-term average in brackets, where frequencies have been defined using one or more ecological requirements. The base EWR_tool (assessment code) only assesses against the long-term average, the percentage often expressed in brackets in the EWR tables following the frequency expressed as number of years in 10 (e.g. 5 out of 10 years (50% – this 50% is the long-term average)). Frequency ranges are presented in the NSW LTWP EWR Assessment Dashboard and the targets within the plan and are included within the parameter sheets.
- **Maximum inter-event period** – expressed in years within the EWR tables in Part B of the LTWPs and reported in days in the dataframe outputs. It is the period

between successful EWR events, when flow volume exceeds the minimum volume and meets other parameter requirements such as seasonality and duration.

- **Event accrual and water year split** – for the majority of EWRs, one event is required per year; however, there are some EWRs that require multiple events per year. These are documented in the EWR tables in Part B of the LTWPs and at this time primarily occur in the Murrumbidgee. For these EWRs, unless the multiple events are met, the EWR is not achieved for that water year.

  The water year boundary is seen as a hard edge. A hybrid method of 2 approaches between the LTWP analysis and the original MDBA code approach has been adapted in the code. This uses the water year boundary as a hard edge and splits an ongoing event that crosses this boundary. The events either side must meet the EWR duration requirement individually to be counted as a successful event in each year.

Table 17 Volumetric EWR example parameters

EWR parameter	Figure
Min flow threshold	5 ML/d
Max flow threshold	10 ML/d
Accumulation period	3 days
Min duration	0 days
Min volume	15 ML

Table 18 Volumetric EWR example

Water year	2010										2011										2012										2013									
Days	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Flow rate	5	5	5	5	5	0	5	5	5	5	5	5	5	0	0	0	5	5	5	5	5	5	0	0	5	0	0	5	5	0	0	0	0	0	5	0	0	5	5	5
Event count	Event 1 Volume 25 ML						Event 2 Volume 20 ML				Event 3 Volume 15 ML						Event 4 Volume 20 ML																						Event 5 Volume 15 ML			
Event duration	Duration: 3 days						Duration: 2 days				Duration: 1 day						Duration: 2 days																						Duration: 1 day			

Multigauge

Multigauge EWRs occur at combined gauges 421090/421088 and 423001/ 423002 in the Macquarie and Intersecting Streams respectively, at this time. Descriptions for the EWR codes can be found in Table 19. They follow the logic of the EWRs assessment category that the EWR flow category occurs in but are the combined volume at 2 select gauges specified in the EWR tables in Part B of the LTWPs. The requirement for 2 gauges is identified through the main gauge column in the parameter sheet and an additional multigauge column that lists the second gauge to be considered. Full details of these EWRs can be found in the EWR tables in Part B of the LTWPs.

Table 19 Multigauge EWR codes

EWR code	Description	LTWP area
OB_WS1_P/ OB_WS1_S/ OB_WS4_P/ OB_WS4_S/ OB_WM_P/ OB_WM_S/ OB_WL_P/ OB_WL_S	These EWR codes represent a range of volumetric overbank and wetland inundating EWRs that specify the combined volume of flow at 2 gauges required to achieve small (e.g. OB/WS1_P, WL1) to large (e.g. OB/WL_P, WL4) lateral inundation. The addition of _P and _S occurs when the EWR has a 'preferred' seasonal period (_P) or can occur any time that is satisfactory (_S)	Macquarie–Castlereagh
WL1/ WL2/ WL3/ WL4	These EWR codes represent a range of volumetric overbank and wetland inundating EWRs that specify the combined volume of flow at 2 gauges required to achieve small (e.g. OB/WS1_P, WL1) to large (e.g. OB/WL_P, WL4) lateral inundation. The addition of _P and _S occurs when the EWR has a 'preferred' seasonal period (_P) or can occur any time that is satisfactory (_S)	Intersecting Streams

Assessment rules

Assessment rules align with volumetric flows rules and the aligning type of standard EWR (e.g. overbank or large fresh). Please see assessment rules in the respective sections for details.

Weir pool

Weir pool EWRs have been developed for reaches of the Murray River influenced by weir pools. Table 20 provides a description of the EWR codes. WP3 and WP4 are the only EWRs that have a post processing stage, which is a second assessment step after the initial EWR analysis that looks at the occurrence of 2 EWRs (small and large freshes) relevant to the overall EWR outcome. The EWR codes SF_WP/WP3 and LF2_WP/WP4 present the final results for the WP3 and WP4 EWR in each year.

Table 20 Weir pool EWR codes

EWR code	Description	LTWP area
WP1	The weir pool drawdown EWR for summer to autumn	Murray–Lower Darling
WP2	The weir pool raising EWR for winter, spring and early summer	Murray–Lower Darling
WP3	The weir pool drawdown EWR for winter spring. Only required under extended dry periods as a partial surrogate for small freshes (SF1,2). Should not be considered in isolation and must consider the occurrence of SF_WP	Murray–Lower Darling
WP4	The weir pool drawdown EWR for spring to early summer. Should not be considered isolation and must consider the occurrence of LF2_WP	Murray–Lower Darling
SF_WP	A specific small fresh EWR that has the seasonal timing requirements of small freshes that link to stage 2 in the weir pool assessment for WP3. Should not be considered in isolation and must consider the occurrence of WP3	Murray–Lower Darling
SF_WP/WP3	This is the EWR code used to represent the post processing results for WP3. It shows the final outcomes for WP3, considering the occurrence (or not) of small freshes (SF_WP) and weir pool lowering (WP3). SF_WP/WP3 is successful when the full requirements of the WP3 EWR as described in the EWR tables in Part B of the LTWP have been met (see Table 23 for details of the assessment logic)	Murray–Lower Darling
LF2_WP	The specific large fresh 2 EWR that has the seasonal timing requirements of large fresh 2 that link to stage 2 in the weir pool assessment for WP4. Should not be considered in isolation and must consider the occurrence of WP4	Murray–Lower Darling

EWR code	Description	LTWP area
LF2_WP/WP4	This is the EWR code used to represent the post processing for WP4. It shows the final outcomes for WP4 considering the occurrence (or not) of large freshes (LF2_WP) and weir pool lowering. LF2_WP/WP4 is successful when the full requirements of the WP4 EWR as described in the EWR tables in Part B of the LTWP have been met (see Table 23 for details of the assessment logic)	Murray–Lower Darling

Assessment rules

The EWR parameter requirements are checked daily and if all are met on an individual day the day is counted towards the EWR duration requirement. When the consecutive day duration requirements are met the individual EWR event is considered successful. Both frequency and max inter-event period requirements need to be met throughout time for the EWR to be considered completely successful. For WP3 and WP4, a second stage of assessment must be completed that considers the occurrence of other EWRs that meet the same ecological requirements. Stage 1 and stage 2 are outlined below.

Weir pool EWRs utilise the following parameters:

- **Duration** – events are consecutive days and the minimum duration specified in the EWR tables in Part B of the LTWP must be met for an EWR to be successful.
- **Timing window** – expressed as months of the year. For weir pool EWRs this is primarily a seasonal window expressed in the EWR tables in Part B of the LTWPs. Days within the timing months are inclusive, meaning the window begins at day 1 of the start month and ends on the last day of the end month. The timing window is seen as a hard edge in the assessment code and will end an EWR event.
- **Threshold** – these EWRs have multiple thresholds to meet, the weir pool level threshold (mAHD) at the specified weir pool gauge and the flow threshold at the specified flow gauge (ML/d).
- **Weir pool gauge number** – as well as a flow gauge number (all EWRs except lake level EWRs have this) the weir pool EWRs specify a weir pool gauge number that weir pool levels should be assessed at.
- **Weir pool raising or drawdown (lowering) level**
  - Weir pool raising – the water level in the weir pool needs to be at or above the minimum specified level. When a value is given for minimum level in the parameter sheet it indicates a weir pool raising EWR. WP2 is a weir pool raising EWR.
  - Weir pool drawdown (lowering) – the water level in the weir pool needs to be at or below the minimum specified level. When a value is given for the maximum level in the parameter sheet it indicates a weir pool drawdown. WP1, WP3 and WP4 are weir pool drawdown EWRs.

  The weir pool lowering and raising level targets in the Murray–Lower Darling LTWP currently align with the operational limits of the weir pools and it is not possible to exceed them. For this reason, the value for minimum and maximum weir pool levels

within the parameter sheet is slightly below the expressed targets to allow success to be measured (Table 21, Table 22). The EWR_tool (assessment code) views success of this parameter as exceedance of greater than or equal to this value for raising weir pool levels and equal to or less than the level for lowering levels. This figure was agreed upon by the Murray–Lower Darling LTWP planner and other experts.

Table 21 Lowering weir pool level thresholds for WP1, WP3 and WP4 for parameter sheet

Gauge and full supply level (FSL) (mAHD)	LTWP target lowering level (mAHD)	Maximum level threshold[3] for measuring EWR success (mAHD) in parameter sheet	Operational limit (mAHD)
Murray River upstream Euston (414209) FSL: 47.6	47.3 (0.3 below FSL)	47.4 (0.2 below FSL)	47.3 (0.3 below FSL)
Murray u/s Lock 9 (4260501) FSL: 27.4	27.3 (0.1 below FSL)	27.35 (0.05 below FSL)	27.3 (0.1 below FSL)
Murray u/s Lock 8 (4260506) FSL: 24.6	24.1–23.6 (0.5–1.0 below FSL)	24.2 (0.4 below FSL)	24.1–23.6 (0.5–1.0 below FSL)
Murray u/s Lock 7 (4260508) FSL: 22.1	21.6–21.1 (0.5–1.0 below FSL)	21.7 (0.4 below FSL)	21.6–21.1 (0.5–1.0 below FSL)

[3] Weir pool level has to be at or below this level for a successful lowering event (WP1, WP3 and WP4).

Table 22 Raising weir pool level thresholds for WP2 for parameter sheet

Gauge and full supply level (FSL) (mAHD)	LTWP target raising level (mAHD)	Minimum level threshold[4] for measuring EWR success (mAHD) in parameter sheet	Operational limit (mAHD)
Murray River upstream Euston (414209) FSL: 47.6	48.2 (0.6 above FSL)	48.05 (0.45 above FSL)	48.2 (0.6 above FSL)
Murray u/s Lock 9 (4260501) FSL: 27.4	27.91 (0.24 above FSL)	27.5 (0.1 above FSL)	27.91 (0.24 above FSL)
Murray u/s Lock 8 (4260506) FSL: 24.6	25.2-25.4 (0.6–0.8 above FSL)	25.05 (0.45 above FSL)	25.2-25.4 (0.6–0.8 above FSL)
Murray u/s Lock 7 (4260508) FSL: 22.1	22.7-22.9 (0.6–0.8 above FSL)	22.55 (0.45 above FSL)	22.7-22.9 (0.6–0.8 above FSL)

- **Frequency** – ranges from 0–100% and can be found in the EWR tables in Part B of the LTWP. It is also expressed in number of years out of 10. Some EWRs have an individual frequency target based on the long-term average (e.g. baseflow EWRs), others present a range with the long-term average in brackets, where frequencies have been defined using one or more ecological requirements. The base EWR_tool (assessment code) only assesses against the long-term average, the percentage often expressed in brackets in the EWR tables following the frequency, expressed as number of years in 10 (e.g. 5 out of 10 years (50% – this 50% is the long-term average)). Frequency ranges are presented in the NSW LTWP EWR Assessment Dashboard and the targets within the plan and are included within the parameter sheets.

  Frequency results are reported but do not factor into the event calculation. Frequency does however need to be met for the EWR to be considered successful.
- **Maximum rate of drawdown** (cm/day) – although the assessment tool has the capacity to calculate drawdown rate success this has not been included in the

[4] Weir pool level has to be at or above this level for a successful raising event (WP2).

current assessment. This is done by not entering a drawdown rate target in the parameter sheet. This is because the drawdown rates are considered a guideline and not a failing factor of the EWR; however, if the maximum drawdown rate is exceeded the EWR cannot be expected to achieve its greatest ecological outcomes.

- **Max inter-event period** – expressed in years within the EWR tables in Part B of the LTWPs and reported as days in the dataframe outputs. It is the period of time between successful EWR events, when weir pool levels exceed or are below the required minimum and maximum thresholds, respectively, and meet other parameter requirement such as seasonality and duration.
- **Event accrual and water year split** – the minimum event requirement per year is one unless specified in the EWR tables in Part B of the LTWPs.

  There are currently no weir pool EWRs with an 'any time' of the year timing window and therefore the water year boundary and how it impacts that assessment of the EWR does not need to be considered.

Assessment stages

Stage 1

This first stage assesses the parameters of the weir pool EWR itself and if they are being met. For WP1 and WP2 this is the only assessment that is required. EWR codes WP3 and WP4 also include the second post processing step (stage 2 outlined below). Stage 1 requires flows at one gauge and level readings at another and the check is made daily. If all parameter requirements are met on that day it counts towards the event, where the days must be consecutive.

The assessment checks:

- timing
- the flow at flow gauge to check it is above the minimum flow threshold
- if water levels in the weir pool are within the required range. If the weir pool EWR is a 'raising' requirement, it checks to see if the weir pool water level is above the minimum required level, and if the weir pool EWR is a drawdown or 'lowering' requirement, it checks to see if the weir pool water level is below the maximum level
- if the number of successful consecutive days meets the minimum duration requirement, in which case the EWR event is marked as successful.

The ability to assess drawdown rate is also incorporated into this assessment through the drawdown rate column in the parameter sheet. This would occur whilst checking weir pool levels and exceedance would fail the EWR; however, as they are currently presented as operational guidelines in the LTWP, these rates are not incorporated in the assessment (parameter sheet column is blank). Although the drawdown rate is considered a guideline it should be noted that if the maximum drawdown rate is exceeded the expected ecological outcomes in response to the EWR will be less than if it is followed.

Stage 2

Stage 2 is a post processing assessment and is the final stage in assessing the outcome of WP3 and WP4 (Table 23). These 2 EWRs represent the manipulation of weir pools to create a partial representation of hydrodynamic conditions that may be lacking if other EWRs (small and large freshes) do not occur.

Table 23 Stage 2 weir pool post processing logic

EWR	When is it required?	Assessment logic
WP3	Only required under extended dry periods as a partial surrogate for small freshes (SF1,2)	• If SF_WP (in Sep–Dec) is successful and WP3 is successful, then 'SF_WP/WP3' is successful • If SF_WP (in Sep–Dec) is successful and WP3 is failing, then 'SF_WP/WP3' is successful • If SF_WP is unsuccessful and WP3 is successful, then SF_WP/WP3 is successful • If SF_WP is failing and WP3 is failing, then SF/WP3 is failing
WP4	Partial surrogate for LF2 if flows are below 20,000 ML/d. Would improve flow velocities in weir pools and therefore likely support native fish spawning and movement in the Murray channel and functional connectivity along the river	Check annually (by water year) • If LF2_WP is successful and WP4 is successful, then LF2_WP/WP4 is successful • If LF2_WP is successful and WP4 is failing, then LF2_WP/WP4 is successful • If LF2_WP is failing and WP4 is successful, then LF2_WP/WP4 is successful • If LF2_WP is failing and WP4 is failing, then LF2_WP/WP4 is failing

Lake level

Lake level EWRs occur primarily in the Murray–Lower Darling; however, there is also a single lake level EWR for Lake Cargelligo in the Lachlan. Table 24 provides the EWR code descriptions. They achieve a range of ecological objectives that are specific to each location and aim to achieve these ecological objectives whilst meeting operational requirements within the lakes.

Table 24 Lake level EWR codes

EWR code	Description	LTWP area
LLLF	Low level lake fill	Murray–Lower Darling
MLLF	Mid level lake fill	Murray–Lower Darling
HLLF	High level lake fill. This EWR has a maximum duration as well as a minimum duration	Murray–Lower Darling
VHLL	Very high level lake fill. This EWR has a maximum duration as well as a minimum duration	Murray–Lower Darling
WL3_S/ WL3_P	Wetland EWR that is lake level for Lake Cargelligo planning unit. The '>65% full' volume requirement has been converted to a level in mAHD via percent full and lake level data from NSW Realtime Water Data for purposes of assessment. The addition of _P and _S occurs when WL3 has 'preferred' timing (_P) or any time that is satisfactory (_S)	Lachlan

Assessment rules

EWRs from the EWR tables in Part B of the LTWPs are checked daily and if all are met the individual day is counted. When the consecutive day duration requirements are met the individual EWR event is considered successful. Both frequency and max inter-event period requirements also need to be met for the EWR to be considered completely successful.

Lake level EWRs utilise the following parameters:

- **Minimum lake level** (mAHD) – in the EWR tables in Part B of the LTWPs, there are up to 3 lake threshold units – mAHD, approximate volume, and approximate depth. For the purposes of consistency and accuracy of data, mAHD was selected as the unit of measurement within the tool. The EWR parameter sheet therefore only has lake level thresholds in mAHD.
- **Maximum lake level** (mAHD) – the maximum lake level in mAHD.
- **Timing window** – expressed as months of the year. This is any time (July – June) for all lake level EWRs.
- **Minimum duration** – the minimum duration is a consecutive days requirement.

- **Maximum duration** – the maximum duration is a consecutive days requirement. Only HLLF and VHLLF in the Menindee Lakes planning unit have maximum duration requirements.
- **Frequency** – ranges from 0–100% and can be found in the EWR tables in Part B of the LTWP. It is also expressed in number of years out of 10. Some EWRs have an individual frequency target based on the long-term average (e.g. baseflow EWRs), others present a range with the long-term average in brackets, where frequencies have been defined using one or more ecological requirements. The base EWR_tool (assessment code) only assesses against the long-term average, the percentage often expressed in brackets in the EWR tables following the frequency expressed as number of years in 10 (e.g. 5 out of 10 years (50% – this 50% is the long-term average)). Frequency ranges are presented in the NSW LTWP EWR Assessment Dashboard and the targets within the plan and are included within the parameter sheets.
- **Maximum rate of drawdown** (either cm/day or % of change in flow per day) – although the assessment tool has the capacity to calculate drawdown rate success this has not been included (via the parameter sheet). This is because the drawdown rates are considered a guideline and not a failing factor of the EWR. Although the drawdown rate is considered a guideline it should be noted that if the maximum drawdown rate is exceeded the expected ecological outcomes in response to the EWR will be less than if it is followed.
- **Maximum inter-event period** – expressed in years within the EWR tables in Part B of the LTWPs and reported as days in the dataframe outputs. It is the period between successful EWR events, when lake level exceeds the minimum threshold and meets other parameter requirement such as seasonality and duration.
- **Event accrual and water year split** – the minimum event requirement per year is one unless specified in the EWR tables in Part B of the LTWPs.

The allocation of EWR events that cross the water year boundary follows rules that have been implemented to best represent the original LTWP analysis methods:

- If a water year has a lake level EWR event that meets the minimum duration requirements within the boundaries of the year, then it will be assigned an event year count.
- If the lake level EWR event continues into a second year (or into future years beyond that) it accumulates days from the previous year. If the additional duration in the subsequent years surpasses the minimum duration requirement in the EWR tables in Part B of the LTWPs then that year will be assigned an event count. If the additional duration in the second year is less than the minimum duration requirements in the EWR tables in Part B of the LTWPs, an event year account will be assigned to the previous year.

A visual representation of these rules can be seen in Table 26, Table 27 and Table 28, with example lake level EWR parameters in Table 25.

Table 25 Lake level conditions for water year boundary event calculation example

Example lake level EWRs	
Min level (mAHD)	5
Max level (mAHD)	10
Minimum duration (days)	3
Maximum duration (days)	22
Max inter-event period (days)	2

Table 26 Example of lake level EWR event calculation when crossing the water year boundaries with short events

Note: This is just an example and for visual purposes each year is presented with only 10 days.

Water year	2009–10										2010–11										2011–12										2012–13										
Days	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	
Lake level (mAHD)	5	5	5	5	5	0	5	5	5	5	5	5	5	0	0	0	5	5	5	5	5	5	0	0	5	0	0	0	5	5	5	5	0	0	0	0	0	5	5	5	Event count
	Event 1						Event 2										Event 4												Event 6										Event 7				7
							Event 3										Event 5																										Event years
Event years count	1 event (5 days)						1 event (4 days)				1 event (7 days, days from 2009/10 included)						2 events event 4 (4 days) Event 5 (7 days, days from 2011–12 included)												1 event (4 days, days from 2011–12 incl-uded)										1 event (3 days)				3

Table 27 Example of lake level EWR event calculation when crossing the water year boundaries multiyear event

Note: This is just an example and for visual purposes each year is presented with only 10 days.

Water year	**2009–10**										**2010–11**										**2011–12**										**2012–13**										
Days	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	
Lake level (mAHD)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	5	0	0	0	5	5	5	5	0	0	0	0	0	5	5	5	Event count
	Event 1																																								4
	Event 2																								Event 3										Event 4						
	Unsuccessful event																																								Event years
Event years count	Event 1 (10 days)										Event 2 (20 days, days from 2009–10 included) Unsuccessful event not counted as 23 days exceeds max duration														Event 3 (4 days)										Event 4 (3 days)						3

Table 28 Example of lake level EWR event calculation when crossing the water year boundaries multiyear event 2

Note: This is just an example and for visual purposes each year is presented with only 10 days.

Water year	**2009–10**										**2010–11**										**2011–12**										**2012–13**										
Days	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	
Lake level (mAHD)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	5	5	5	5	0	0	0	0	0	5	5	5	Event count
	Event 1																												Event 3									Event 4			4
	Event 2																																								
	Unsuccessful event																																								Event years
Event years count	Event 1 (10 days)										Event 2 (20 days)										Event 3 (25 days) Unsuccessful event not counted as 25 days exceeds max duration										Event 3 (4 days)									Event 4 (3 days)			3

Nesting flows

Nesting flow EWRs are a seasonal period of flow during which unnaturally rapid changes in water levels are avoided. This is timed during the predictable spring breeding season for nesting river specialists (e.g. Murray cod, freshwater catfish) to avoid the stranding or abandonment of nests. The assessment method has been developed to best represent the intent of these EWRs from the *Fish and flows in the southern Murray-Darling Basin* documentation by Ellis et al. (2022). These EWRs occur at both flow gauges and in weir pools and have been split as such with slightly different assessment methods. Table 29 provides the EWR code descriptions.

Table 29 Nesting flow EWR codes

EWR code	Description	LTWP area
NestS1	Standard nesting flow EWR code when only one set of parameters is present (e.g. not 2 different timing windows or flow thresholds)	Murray–Lower Darling, Murrumbidgee
NestS1_mc	Specific timing window for Murray cod	Murrumbidgee
NestS1_tcmc	Specific timing window for trout cod and Murray cod	Murrumbidgee
NestS1a/ NestS1b	Weir pool nesting flow EWRs in Murray River – Lock 15 weir pool to Lock 10 that has 2 different minimum thresholds; presented as a and b	Murray–Lower Darling

Assessment rules

Nesting flows at flow gauges and nesting flows in weir pools follow similar assessment logic except nesting flows in weir pools can be triggered at any time within the timing window. A daily check is done once the EWR is triggered to determine if all the EWR parameters specified in the EWR tables in Part B of the LTWP are being met. If all requirements are met on that day, then the individual day is counted towards the duration. When the consecutive day duration requirements are met the individual EWR event is considered successful. Both frequency and max inter-event period need to be met throughout time for the EWR to be considered completely successful.

Nesting flow EWRs utilise the following parameters:

- **Minimum flow threshold** – the flow has to be above the minimum flow threshold at the flow gauge specified in the EWR tables in Part B of the LTWPs to both trigger/ start the EWR event and then stay above the minimum threshold for the duration of the EWR, to be successful.
- **Maximum flow threshold** – this is upper flow threshold band at the flow gauge for rate of fall/ drawdown rate assessment, as specified in the EWR tables in Part B of the LTWPs. Exceedance of this threshold will not fail the EWR. Higher flows are

acceptable in the lowland Murray–Lower Darling and Murrumbidgee as lowland rivers are not expected to produce extreme velocities at these higher thresholds, so the risk of nests being damaged at higher flows is only moderate and there are additional benefits for flows at this level. It is acknowledged that this varies slightly from how information is presented in the 2019 LTWPs and this will be updated in the 5-year LTWP review.

- **Timing window** – expressed as months of the year, sometimes having day included, e.g. 15 Sep to 15 Nov. This timing window is a hard edge that will interrupt an EWR and the EWR will not apply outside this period. Days within the timing months are inclusive, meaning the window begins at day 1 of the start month and ends on the last day of the end month.
- **Minimum duration** – events are consecutive days and minimum event duration must be met for the individual event to be successful. For an individual day to be counted all other parameters must be met (be above the minimum flow threshold, within the timing window and meet rate of fall). Days that fall above the maximum flow threshold will be counted towards the event duration.
- **Frequency** – ranges from 0–100% and can be found in the EWR tables in Part B of the LTWP. It is also expressed in number of years out of 10. Some EWRs have an individual frequency target based on the long-term average (e.g. baseflow EWRs), others present a range with the long-term average in brackets, where frequencies have been defined using one or more ecological requirements. The base EWR_tool (assessment code) only assesses against the long-term average, the percentage often expressed in brackets in the EWR tables following the frequency expressed as number of years in 10 (e.g. 5 out of 10 years (50% – this 50% is the long-term average)). Frequency ranges are presented in the NSW LTWP EWR Assessment Dashboard and the targets within the plan and are included within the parameter sheets.
- **Maximum inter-event period** – expressed in years within the EWR tables in Part B of the LTWPs and reported as days in the dataframe outputs. It is the period between successful EWR events.
- **Maximum rate of drawdown/ fall** – percentage change in flow per day at flow gauges for flow gauge nesting flow EWRs. For weir pool nesting flow EWRs this is the weekly fall rate in cm/week. This rate of fall is applied only within the flow threshold band (specified by min and max flow thresholds) and exceeding it will fail the EWR.
- **Associated weir pool gauge number** – this is relevant for nesting flow EWRs **–** weir pool, and identifies the relevant weir pool to calculate the weekly drawdown rate when the flow gauge minimum threshold requirements are met and the EWR starts to be assessed.
- **Trigger day (day and month)** – date specified in the EWR tables in Part B of the LTWPs or start of the timing window for nesting flow EWRs at flow gauges only.
- **Event accrual and water year split** – one event per year is required unless specified in the EWR tables in Part B of the LTWPs. No water year split is required for nesting flow EWRs as they do not cross the water year boundary.

Nesting flow EWR – flow gauge

A nesting flow – flow gauge EWR event is successful if all of the following conditions are met (see example in Figure 1 using example in Table 30):

- flow is above the minimum flow threshold from the trigger date (beginning of the timing window) or within a 2-week grace period from the start date
- flow remains above the minimum flow threshold for the required minimum duration
- flow does not fall more quickly than specified rate of fall when within the specified flow band described by min and max flow thresholds.

Alternately, a nesting flow – flow gauge EWR event fails if any of the following occur (Figure 2 using example in Table 30):

- flow falls below the minimum flow threshold requirement before the required minimum duration is met
- the rate of fall exceeds the specified requirements when within the described flow band
- the end of the timing window is reached before the minimum duration is met.

Table 30 EWR parameters for example nesting flow – flow gauge

Example nesting flow EWR – flow gauge	
Min threshold	300 ML/d
Max threshold	1,400 ML/d
Daily rate of fall (max)	13%
Min duration	25 days
Trigger date	15 Sep
Timing window	15 Sep – 15 Oct

Nesting flow EWR – weir pool

A nesting flow – weir pool EWR event is successful if all of the following conditions are met:

- flow is above the minimum flow threshold at the flow gauge. This can be at any time within the timing window
- flow remains above the minimum flow threshold for the required duration
- flow does not fall more quickly than weekly drawdown rate at the specified weir pool gauge when in the flow band at the flow gauge (rate of rise is not an issue and rate of fall is not an issue if the flow is above maximum flow threshold at the flow gauge).

Alternatively, a nesting flow – weir pool EWR event fails if any of the following occur:

- flow falls below the minimum flow threshold requirement before the required minimum duration is met

- the rate of fall exceeds the specified requirements when within the described flow band
- the end of the timing window is reached before the minimum duration is met.

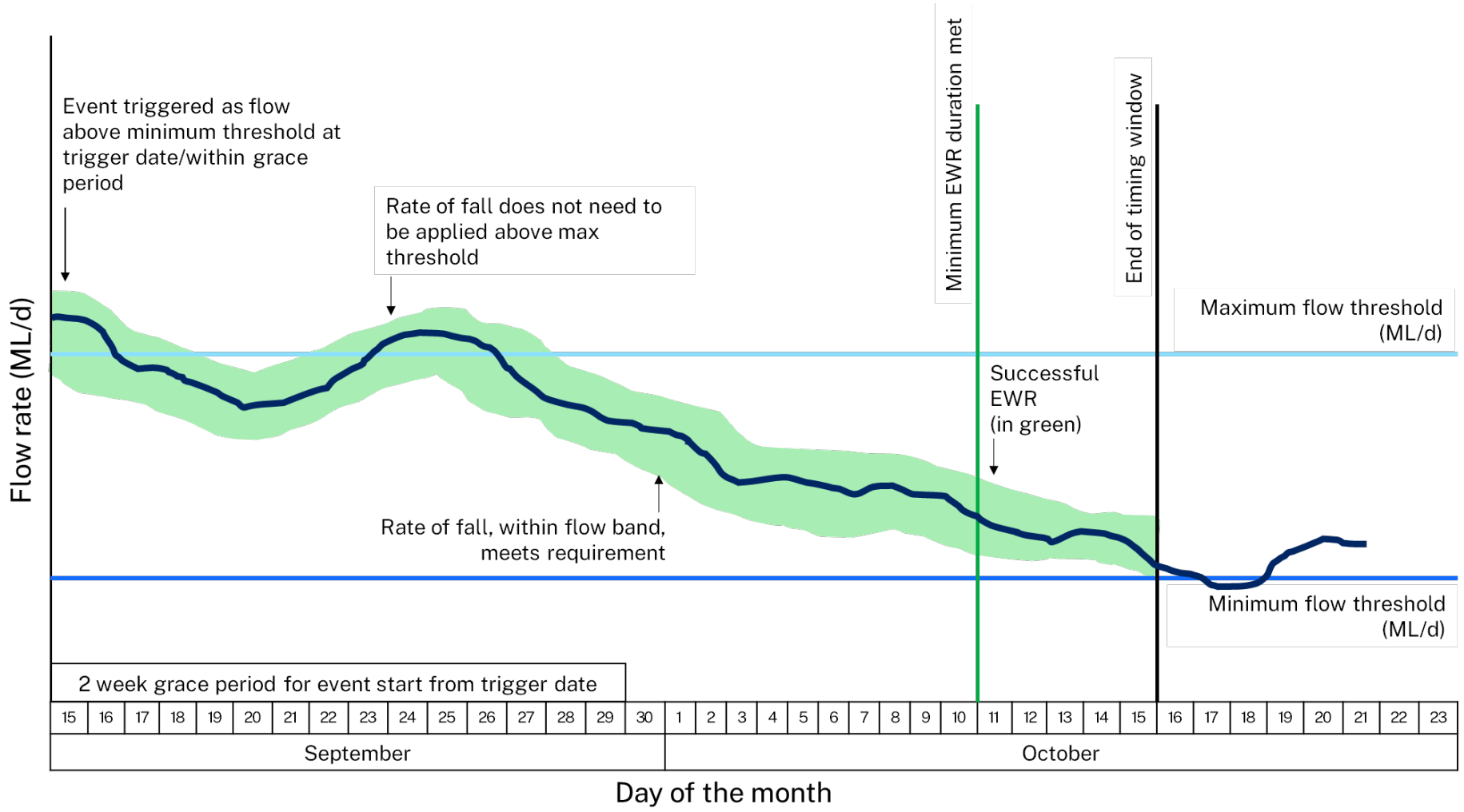

Figure 1 **Example of successful nesting flow EWR at a flow gauge**

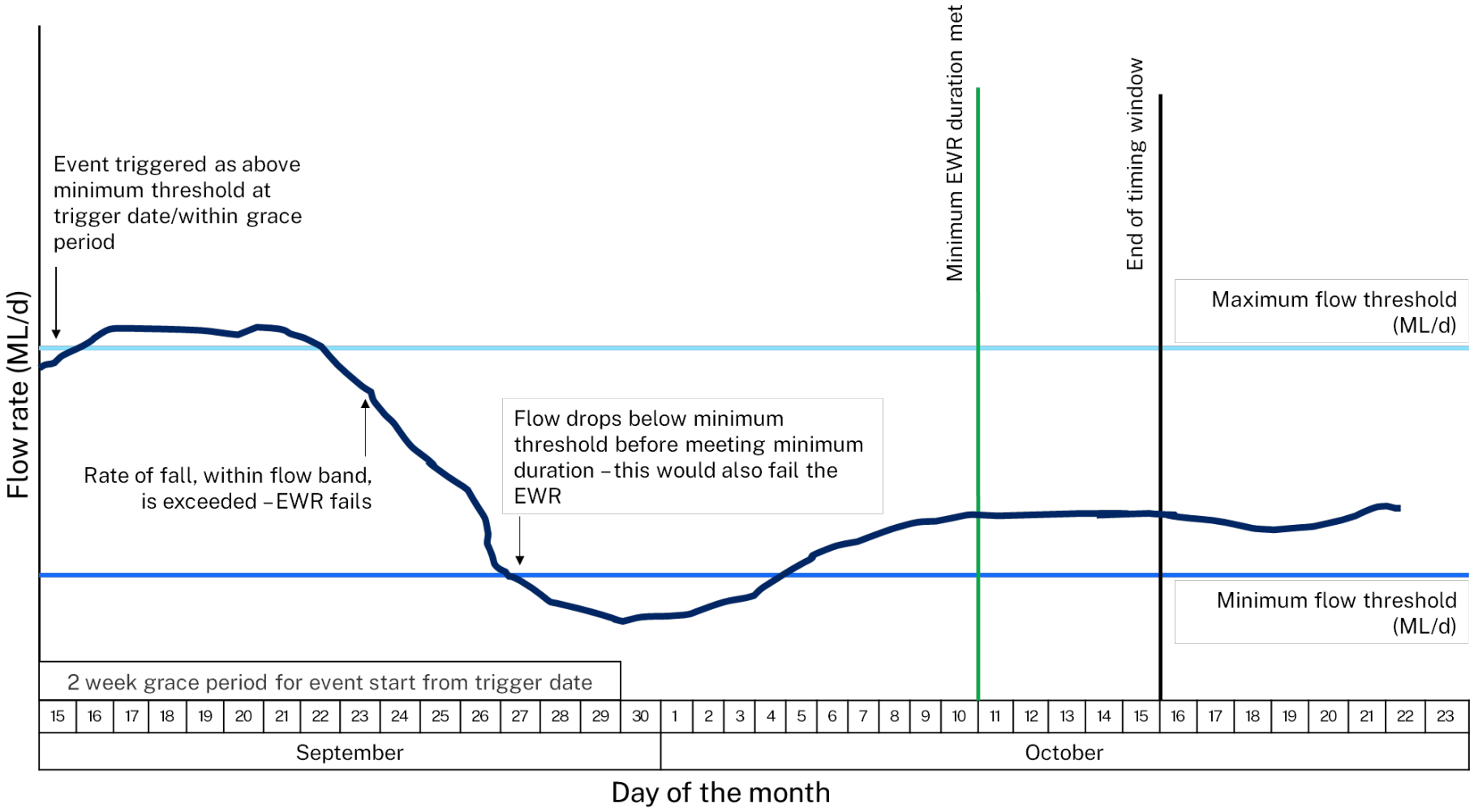

Figure 2 **Example of failing nesting flow EWR at a flow gauge**

References

DPE EHG (Department of Planning and Environment, Environment and Heritage Group) (2022a) NSW long term water plans: background information – A description of the development of the 9 LTWPs in NSW, Part A: Introduction, NSW Department of Planning and Environment.

DPE EHG (2022b) NSW long term water plans: background information – A description of the development of the 9 LTWPs in NSW, Part B: Objectives and targets, NSW Department of Planning and Environment.

DPE EHG (2022c) NSW long term water plans: background information – A description of the development of the 9 LTWPs in NSW, Part C: Environmental water requirements, NSW Department of Planning and Environment.

DPE EHG (2022d) NSW long term water plans: background information – A description of the development of the 9 LTWPs in NSW, Part D: Appendices, NSW Department of Planning and Environment.

Ellis I, Cheshire K and Townsend A (2022) *Fish and flows in the southern Murray–Darling Basin* (condensed summary), NSW Department of Primary Industries, Buronga.

More information

Please click to be taken to the relevant page.

- The EWR_tool contains the standalone Python package called py-ewr. This can be found here py-ewr link
- The EWR_tool code package can be found on Github here EWR codebase
- If you find any issues with the EWR_tool, please submit an issue on the Github issues repository here Github issues repository

Appendix A: Loading in model data

Current compatible formats

The py_ewr package is currently compatible with 3 formats:

- BigMod – MDBA
- Source – NSW (res.csv)
- Standard time-series.

If you have other scenario modelled data formats that are not covered here please contact the MDBA at dataservices@mdba.gov.au and they will be able to amend the code to make it compatible with other model formats.

BigMod – MDBA format

An example of the MDBA BigMod format time series formatting (colours shown for emphasis in this manual only) is in Figure 3. The orange value (cell A6) contains the number of sites in the dataset – it is important this is accurate, so if time series are modified this should be updated too.

The tool ingests the header data (in this example rows 1 to 8 inclusive), and then the flow data (rows 9 inclusive and onwards). The header data is used to construct new column headings using the site-measurand-quality information highlighted below. This is the key information used later in the tool. The list of newly constructed header data then replaces the current headings loaded in. This is critical when manipulating BigMod time series, because if you delete header data but not the matching column, the header data list will not match the columns and you could get erroneous results.

	A	B	C	D	E	F	G	H	I	J	K
1	6.104.1 24/03/2010 12:50:53.51										
2	\Output\11_mbidg\River_modelling\BIDG_BIDG_B0H000\BIDG.sqq										
3	IQQM v6.104.1 compiled at 2007-09-28 15:46:09										
4	1/07/1895 ########										
5	Field	Precision	Infill	Last mont	Site	Measuran	Quality	Name			
6	EOC										
7	5										
8	1	4	0	0	424202A	1	9	424202A	"424202 – Paroo@Yarronvale"		
9	2	4	0	0	424201A	1	9	424201A	"424201 – Paroo@Caiwarro"		
10	3	4	0	0	424002_	1	9	424002_	"424002 – Paroo@Willara"		
11	4	4	0	0	424001_	1	9	424001_	"424001 – Paroo@Wanaaring"		
12	5	4	0	0	423204_	1	9	423204_	"423204 – Warrego@Augathella"		
13	Dy	Mn	Year	424202A	424201A	424002_	424001_	423204_			
14	EOH			1	2	3	4	5			
15	1	7	1895	0	111	1128	586	0			
16	2	7	1895	0	147	584	935	0			
17	3	7	1895	0	97	377	735	0			
18	4	7	1895	0	67	217	411	0			
19	5	7	1895	0	50	164	265	0			
20	6	7	1895	0	37	127	150	0			
21	7	7	1895	0	30	96	106	0			
22	8	7	1895	0	22	73	79	0			
23	9	7	1895	0	15	58	60	0			
24	10	7	1895	0	12	45	45	0			
25	11	7	1895	0	10	35	35	0			
26	12	7	1895	0	6	28	26	0			
27	13	7	1895	0	3	22	19	0			
28	14	7	1895	0	2	17	15	0			
29	15	7	1895	0	0	13	14	0			
30	16	7	1895	0	0	9	11	0			
31	17	7	1895	5	0	7	8	0			
32	18	7	1895	207	0	4	6	0			
33	19	7	1895	0	0	3	4	0			

Figure 3 Format for BigMod model data

Source – NSW (res.csv) format

Figure 4 shows an example of res.csv output (noting the highlighting is for the purposes of this manual only). Some key elements of this layout include the EOC value of 5 (shaded orange), representing 5 sites with data. The tool will take a list of the header data 'Name' column, and save this to the flow data headings (as demonstrated with the shading, the top value in the name column will be saved to the left most flow heading, and so on). These flow data headings are then matched with their respective gauges using the 'SiteID_NSW.csv' file in the model_metadata folder and checked against any EWRs in the database for that location.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	File version	2													
2	Missing data value	-9999													
3	EOM														
4	Project name														
5	Source version	1.0.0.0													
6	Latest result run time	#######													
7	Simulation time	2015-01-01 - 2015-12-31													
8	Field	Units	RunName	ScenarioN	ScenarioIr	Name	Site	ElementN	WaterFea	ElementTy	Structure	Custom			
9	EOC														
10	5														
11	1	m^3.s^-1				Gauge: YCE	YCB_4100	Downstre	Gauge	Node	Downstre	a1a37714-6272-4e47-a0e6-bb333328b722			
12	2	m^3.s^-1				Gauge: YCE	YCB_4100	Downstre	Gauge	Node	Downstre	a1a37714-6272-4e47-a0e6-bb333328b722			
13	3	m^3.s^-1				Gauge: YCE	YCB_4100	Downstre	Gauge	Node	Downstre	a1a37714-6272-4e47-a0e6-bb333328b722			
14	4	m^3.s^-1				Gauge: YCE	YCB_4100	Downstre	Gauge	Node	Downstre	a1a37714-6272-4e47-a0e6-bb333328b722			
15	5	m^3.s^-1				Gauge: YCE	YCB_4101	Downstre	Gauge	Node	Downstre	a1a37714-6272-4e47-a0e6-bb333328b722			
16	Date	1>YCB_41	2>YCB_41	3>YCB_41	4>YCB_41	5>YCB_410134_BillabongCreek@Darlot>Downstream Flow									
17	EOH														
18	1/01/2015	11.8907	0.80219	0.29138	0	0									
19	2/01/2015	11.952	2.80306	1.23526	0	0									
20	3/01/2015	12.1753	4.07148	3.40681	0	0									
21	4/01/2015	12.2983	4.53965	5.31521	0	0									
22	5/01/2015	12.1148	5.26931	5.61859	0	1.12E-11									
23	6/01/2015	12.0586	5.60807	5.6501	0.00034	0.021283									
24	7/01/2015	12.3957	5.62302	5.65112	0.00117	0.054069									
25	8/01/2015	12.7022	5.63535	5.68861	0.10895	0.158366									
26	9/01/2015	12.5556	5.72398	5.76058	0.46296	0.422778									

Figure 4 Format for Source model data

Standard time-series

The Standard time-series handling has been set-up to allow users to load in simple customised model scenarios, it is not integrated with any specific hydrology model outputs. Figure 5 gives an example of the file format required. This option takes a '.csv' file, and is required to have a 'Date' column and at least one column titled with a text string that contains a gauge and specifies if the data are either 'level' or 'flow' (highlighted blue here for display purposes).

	A	B	C
1	Date	409025_flow	409025_level
2	0105-07-01	586	146.5
3	0105-07-02	935	233.75
4	0105-07-03	735	183.75
5	0105-07-04	411	102.75
6	0105-07-05	265	66.25
7	0105-07-06	150	37.5
8	0105-07-07	106	26.5
9	0105-07-08	79	19.75
10	0105-07-09	60	15
11	0105-07-10	45	11.25
12	0105-07-11	35	8.75
13	0105-07-12	35	8.75
14	0105-07-13	26	6.5

Figure 5 **Format for Standard time-series model data**