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Acknowledgement of the Traditional Owners of the Murray–Darling Basin
The Murray–Darling Basin Authority pays respect to the Traditional Owners and their Nations of the Murray–Darling Basin. We acknowledge their deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

The guidance and support received from the Murray Lower Darling Rivers Indigenous Nations, the Northern Basin Aboriginal Nations and our many Traditional Owner friends and colleagues is very much valued and appreciated.

Aboriginal people should be aware that this publication may contain images, names or quotations of deceased persons.

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Introduction

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EWR assessment method

The EWR_tool contains the standalone Python package called py-ewr. 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. The EWR tool is version controled via open source GitHub repository . Figure 1 shows schenatic of EWR tool work flow.

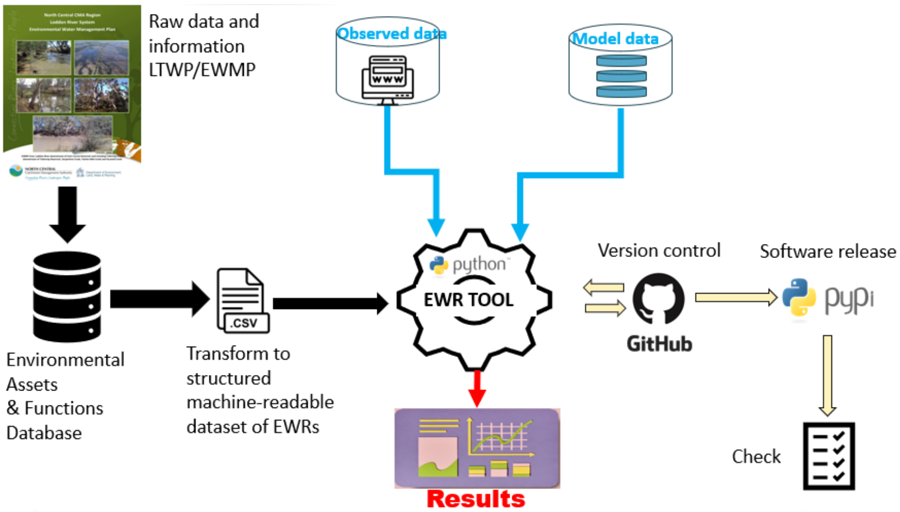

Figure 1 Schematic of EWR tool work flow

Access to EWR tool

EWR tool codes are available as open source for public access via [GitHub] repository. On the GitHub repository, users can find instruction on how to install the Python package via command line using pip: 'pip install py-ewr'. If you find any issues with the package, please submit an issue on the Github issues repository.

Input hydrological data to EWR tool

This Python package has embedded a parameter sheet and takes daily flow data for two types of analysis. In the form of observed flows or modelled scenario flow data.

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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 states long term plans. The parameter sheet can be downloaded from GitHub repository. Users who wish to explore different sets of rules as defined in the parameter sheet, advised to download the parameter sheet into their local pc or individual repositories and apply changes. Applied changes can be pushed into main branch on GitHub where MDBA team will assess case by case requests.

Observed data

If using this option, the tool will fetch the observed data from relevant water data portals for the selected locations using a python package called MDBA_Gauge-Getter which is part of EWR tool package. MDBA Gauge Getter provides a unified and simple interface to collect surface water data from the following state water portals as shown in Table 1. The tool is configured to abstract away the details specific to each state water portal and return a consistent structure. By default it will return a daily mean of a flow in ML/day for a given gauge number, but storage level, storage volume, other intervals and aggregations are available

Table 1 State water portals

State	Site	Source
NSW	realtimedata.waternsw.com.au	CP
QLD	water-monitoring.information.qld.gov.au	PUBLISH
VIC	data.water.vic.gov.au	AT
SA	bom.gov.au/waterdata/	BOM Water Data Online

Modelled scenario

If using this option, the user will need to specify the locations of the modelled scenario data files. 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 errors. The py_ewr package is currently compatible with 3 model formats:

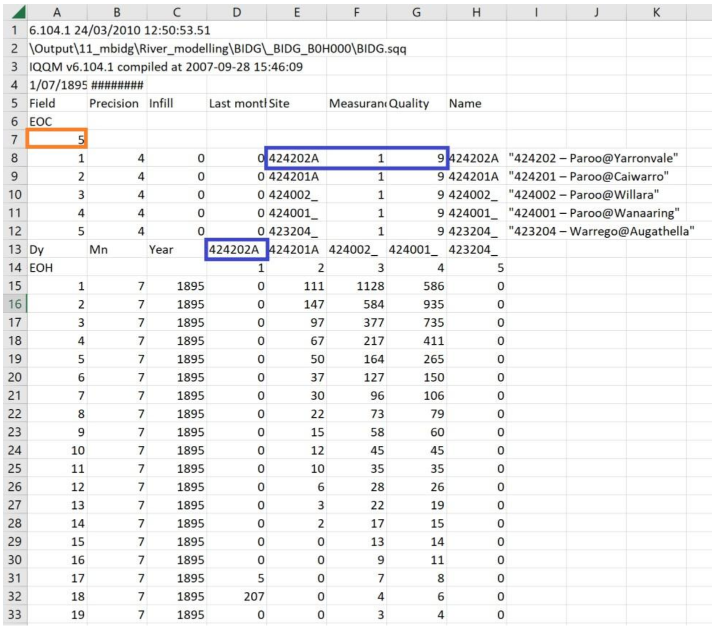
- BigMod – MDBA
- Source – NSW (res.csv)
- IQQM – NSW 10,000 years.

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 2. 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.

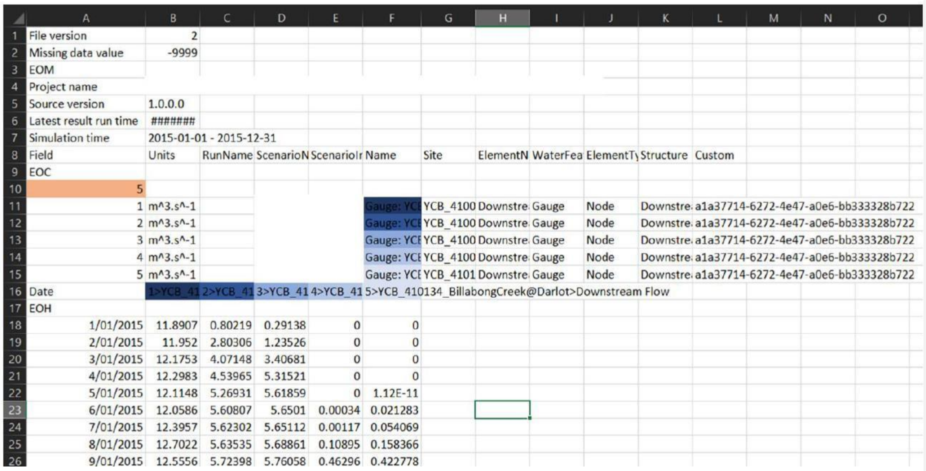


	A	B	C	D	E	F	G	H	I	J	K
1	6.104.1 24/03/2010 12:50:53.51										
2	\Output\11_mbidg\River_modelling\BIDG_BIDG_B0H000\BIDG.sqq										
3	IQQM v6.104.1 compiled at 2007-09-28 15:46:09										
4	1/07/1895	########									
5	Field	Precision	Infill	Last montl	Site	Measuran	Quality	Name			
6	EOC										
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 2 Example of BigMod format data

Source-NSW (res.csv) format

Figure 3 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
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 3 Example of Source format data

IQQM-NSW 10,000 years format

The tool has been written to handle these 10,000-year climate series as requested by New South Wales. Figure 4 gives an example of the file format. This option takes a ‘.csv’ file, and is required to have a ‘Date’ column and a column titled with a text string that contains a gauge (highlighted blue here for display purposes). As long as the gauge is written in the heading, the program will be able to find this, and use it to link to the EWR database.

	A	B	C	D	E
1	Date	Example_timeseries			
2	0105-07-01	586			
3	0105-07-02	935			
4	0105-07-03	735			
5	0105-07-04	411			
6	0105-07-05	265			
7	0105-07-06	150			
8	0105-07-07	106			
9	0105-07-08	79			
10	0105-07-09	60			
11	0105-07-10	45			
12	0105-07-11	35			
13	0105-07-12	26			
14	0105-07-13	19			

Figure 4 Example of IQQM model data

Within the EWR 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 from the EWR tool

The tool outputs 6 Pandas dataframes as shown in Figure 5:

1. ewr_results
2. yearly_ewr
3. all_events
4. all_successful_events

5. all_inter_events
6. 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.

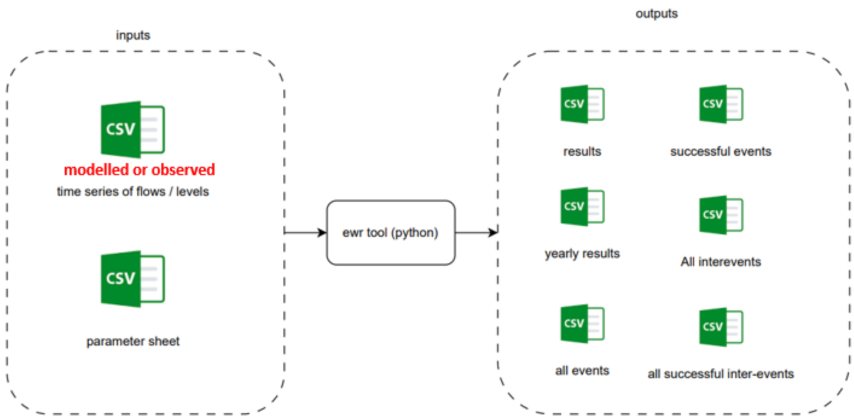


Figure 5 EWR tool output results

Output results description

Description of 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 provides a description of ewr_results dataframe outputs.

Table 2 Descriptions of ewr_results dataframe

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 and timing)	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
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

Description of 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.

Table 3 Description of yearly_ewr dataframe

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 2023	2023
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 days and 110 days occurs numEvents would be 2)	2
numEventsAll	Count of events in the year. Count 1 for each irrespective if the minimum event requirement and duration are achieved	3

Description of 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, i.e. 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 Descriptions of all_events dataframe

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 2023	2023
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)	

Description of 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 as specified in each plan. Table 5 provides a description of all_successful_events dataframe outputs.

Table 5 Description of all_successful_events dataframe

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)	

Description of all_inter_events

The all_inter_events dataframe is the inverse of the all_events dataframe and provides the max 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 Description of all_inter_events dataframe

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

Description of 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 Description of all_successful_interevents dataframe

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

NSW EWRs

Introduction to NSW EWR development

In 2019-20, 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 deliver 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).

NSW flow categories

The sequence of flows over time can be considered as a series of discrete events. These events can be placed into different flow categories as shown in Figure 6 (e.g. baseflows, freshes, bankfull, overbank and wetland flows) according to the magnitude of flow discharge or height within a watercourse, and the types of outcomes associated with the events for example,. inundation of specific features such as channel benches, riparian zones or the floodplain (Barwon-Darling Long Term Water Plan Part A, 2020).

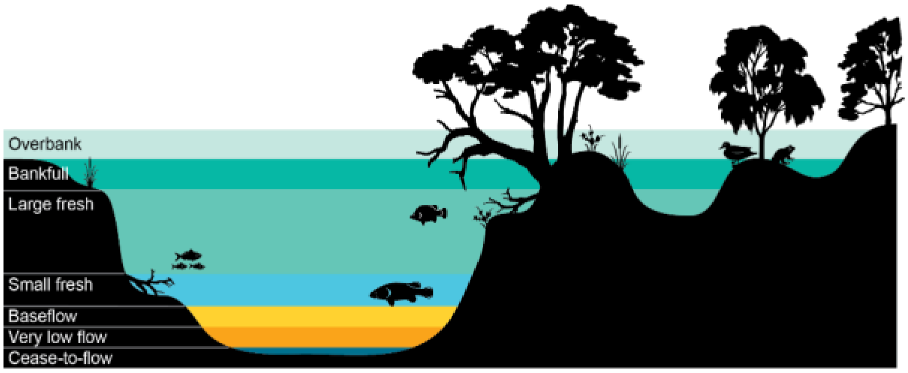


Figure 6 Basic flow categories for NSW

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-flow

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 **Error! Reference source not found.**. 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 Cease-to-flow EWR codes for NSW

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

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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
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 for cease-to-flow NSW

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 methods are 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 two 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.

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Table 9 Visulusation of Cease-to-flow duration 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					

~~Codes~~

~~Relevant functions in the tool are in the evaluate_EWRs.py file: 'ctf_handle' passes to either 'ctf_calc' or 'ctf_calc_anytime' for calculation.~~

Low flows and baseflow

Low flows comprise several EWR flow categories, primarily very low flows and baseflows, that fall across all LTWP areas. Very low flows VF/VL are a flow category that join river pools, thus providing partial or complete connectivity in a reach. Baseflows BF 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. Please note: 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. Low flow EWR codes are described in Table 10 and the assessment methods for testing their achievement are outlined below in the Assessment rules for low flow and baseflow NSW section.

Table 10 Low flow and baseflow EWR codes for NSW

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 '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	Most LTWP areas
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

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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 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	Most LTWP areas
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

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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. 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	Most LTWP areas
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
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 for low flow and baseflow NSW

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

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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 10 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).

~~Code~~

~~Within the evaluate_EWRs.py module, the function 'lowflow_handle' passes to 'lowflow_calc' for calculation.~~

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 for NSW

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 for NSW

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
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 for NSW

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
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 Standaard flow, overbank and wetland connnection EWR codes for NSW

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
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 for standard flow

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 15 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. 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.

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- **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.

~~Code~~

~~Within the evaluate_EWRs.py module, the function 'flow_handle' passes to either 'flow_calc' or 'flow_calc_anytime' for calculation.~~

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 for NSW

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 for volumetric

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.

~~Code~~

~~Within the evaluate_EWRs.py module, the function 'cumulative_handle' passes to 'cumulative_calc'.~~

Table 17 Volumetric EWR example of 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 priod between 2010 to 2013

<table>
<tr><th>Water year</th><th colspan="10">2010</th><th colspan="10">2011</th><th colspan="10">2012</th><th colspan="10">2013</th></tr>
<tr><td>Days</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>Flow rate</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>0</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>0</td><td>0</td><td>0</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>0</td><td>0</td><td>5</td><td>0</td><td>0</td><td>5</td><td>5</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>5</td><td>0</td><td>0</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td>Event count</td><td colspan="5">Event 1
Volume 25 ML</td><td></td><td colspan="4">Event 2
Volume
20 ML</td><td colspan="3">Event 3
Volume
15 ML</td><td colspan="3"></td><td colspan="4">Event 4
Volume
20 ML</td><td colspan="17"></td><td colspan="3">Event 5
Volume
15 ML</td></tr>
<tr><td>Event duration</td><td colspan="5">Duration:
3 days</td><td></td><td colspan="4">Duration:
2 days</td><td colspan="3">Duration:
1 day</td><td colspan="3"></td><td colspan="4">Duration:
2 days</td><td colspan="17"></td><td colspan="3">Duration:
1 day</td></tr>
</table>

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 discription for NSW

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 multigauge for NSW

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.

~~Code~~

~~Within the evaluate_EWRs.py module, the functions 'flow_handle_multi', 'lowflow_handle_multi', 'ctf_handle_multi', 'cumulative_handle_multi' pass to their relevant calculation functions.~~

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Wier 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 discription for NSW

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
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 weir pool for NSW

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. 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). In Table 21, Weir pool level has to be at or below the maximum level threshold for a successful lowering event (WP1, WP3 and WP4) and in Table 22, weir pool level for has to be at or above minimum threshold for a successful raising event (WP2).

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 paramter 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)

Table 22 Raising weir pool level threshold 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 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.

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- **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 weir pool for NSW

- **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 for NSW

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

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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

~~Code~~

~~Within the evaluate_EWRs.py module, the functions involved in the evaluation of weirpool EWRs are 'weirpool_handle', 'weirpool_calc', 'weirpool_check', 'check_wp_level', and 'check_drawdown'.~~

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 for NSW

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 for lake level NSW

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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 27and Table 28, with example lake level EWR parameters in Table 25.

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

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

~~Code~~

~~Within the evaluate_EWRs.py module, the functions involved in the evaluation of lake level EWRs are ‘level_handle’, ‘lake_calc_ltwp’ and ‘level_check_ltwp’.~~

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

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 NSW

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 for NSW

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																																								2
	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																				2

Commented [MJ(1]: Missing the last two events

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 I, Cheshire K, Townsend A, 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 NSW

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 for nesting flows NSW

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 7 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.

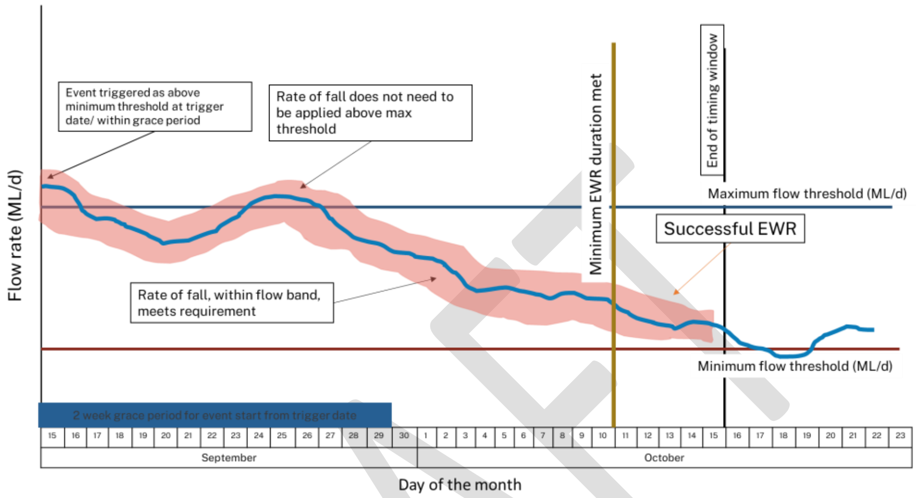

Figure 7 Example of successful nesting flow EWR at a flow gauge NSW

Table 30 EWR paramters for example nesting flow- flow gauge NSW

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

Alternately, a nesting flow – flow gauge EWR event fails if any of the following occur (Figure 8 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.

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.

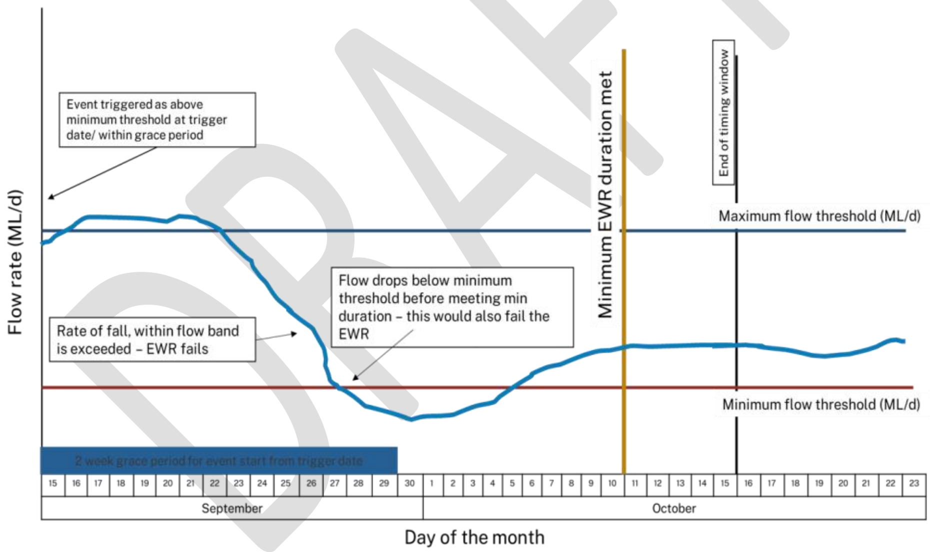

Figure 8 Example of failing nesting flow EWR at a flow gauge NSW

~~Code~~

~~Within the evaluate_EWRs.py module, the functions involved in the evaluation of nesting EWRs are 'nest_handle', 'nest_calc_percent_trigger', 'nest_calc_weirpool', and 'nest_flow_check'.~~

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SA EWRs

Introduction to SA EWR development

The Long Term Environmental Watering Plan for the South Australian River Murray Water Resource Plan (hereafter referred to as the SA LTWP) was published in November 2015 (DEWNR 2015). It identifies three Priority Environmental Assets (PEAs):

1. South Australian River Murray Channel (In-channel, IC) - consists of the area between Wellington, South Australia, and the Victorian border – a total distance of approximately 560 River km. The lateral extent comprises the area inundated at flows up to 40,000 ML/day (QSA; discharge (Q) at the South Australian border) under normal River Murray operations (i.e. without weir pool manipulations or operation of environmental regulators)

2. South Australian River Murray Floodplain (Floodplain, FP) – an equivalent longitudinal extent to the In-channel PEA, extending from Wellington to the South Australian border, and consists of the area that is inundated when flows are between 40,000 ML/day QSA and 80,000 ML/day QSA, under normal River Murray operations (i.e. without weir pool manipulations or operation of environmental regulators)

3. Coorong, Lower Lakes and Murray Mouth (CLLMM) – the Lower Lakes, Coorong and Murray Mouth incorporates 'The Living Murray' Icon Site and the Ramsar Wetland of International Importance 'The Coorong, Lakes Alexandrina and Albert Wetland'

The three PEAs reflect the ecological importance of the mosaic of habitats that comprise the South Australian River Murray ecosystem, rather than focussing on discrete management units that represent only a relatively small portion of the Water Resource Planning Area. It also ensures that a holistic approach is taken to environmental water planning, delivery and evaluation, enabling the contribution of outcomes at smaller scales, towards the achievement of outcomes at the larger scale, to be considered.

For each PEA, the Environmental Watering Requirements (EWRs) are descriptions of the hydrological regimes required to achieve the ecological objectives and targets prescribed within the SA LTWP (DEWNR 2015). The ecological objectives provide a clear statement of what the EWR delivery is expected to achieve and there are a number of objectives for each PEA (Table 1 to Table 3), which focus on key biotic groups or ecosystem processes. Key biota within the three PEAs include water-dependent vegetation types, native fish, frogs, waterbirds, macroinvertebrates, as well as woodland-dependent birds, reptiles and mammals. Improvements in longitudinal and lateral connectivity facilitate key ecosystem processes such as in-stream hydraulic conditions, productivity, carbon and nutrients loads, and the transport of vegetation propagules, invertebrates, tadpoles and fish larvae (DEWNR, 2015). Ecological targets are nested within an ecological objective, where there may be more than one target per objective (Table 1 to Table 3). Ecological targets provide a means of assessing the change in condition and progress towards achieving the anticipated ecological outcomes (DEWNR, 2015).

The SA LTWP is being updated by the Environmental Watering Team within the SA Department for Environment and Water (DEW) in line with the requirements of Chapter 8 of the Basin Plan. The EWRs are a key input into annual planning and evaluation of water delivery and, through their practical application, opportunities to make improvements have been identified. This report is therefore focused on revising the EWRs for each of the PEAs (IC, FP and CLLMM) but also ensuring there is consistency between the EWRs for the three PEAs so that they can inform the coordinated management of environmental water throughout the system.

Any revision to the EWRs must ensure they remain consistent with the requirements described in s8.51 (Chapter 8 of the Basin Plan). Whilst these requirements set some statutory boundaries, they still allow scope to develop EWRs that are fit-for-purpose for the region. Additional considerations and definitions applied to EWRs in the SA LTWP are described below and remain valid for any improvements through this project. The SA EWRs in the SA LTWP:

- Describe the water regimes needed to sustain the ecological values of the PEAs at low levels of risk, which is consistent with the definition agreed by the (then) SA Department of Environment, Water and Natural Resources in 2014,
- Represent a long-term (>30 years), variable hydrological regime needed to support healthy, functioning ecosystems,
- Use appropriate metrics to describe the given asset requirements,
- Are based on the pre-development hydrological regime to inform timing and shape of the hydrograph and biotic requirements, but are not seeking to recreate natural/pre- development conditions,
- Are not constrained to what can be delivered under the Basin Plan (based on water recovery modelling) but have a degree of pragmatism applied.

SA flow categories

A flow component descriptor was considered to provide context around the scale of the IC and FP EWRs and provide an indication of the physical character of the river-floodplain system (e.g. in-channel pulse, bankfull, connection to floodplain etc.). The hydrological descriptors are based on descriptions provided in Table 31. We note that as a result of the intensive regulation of the southern MDB, the low end of the scale is ‘very low flow’ to ‘baseflow’ (i.e. cease-to-flow does not occur in the main channel of the River Murray).

Table 31 Description of SA flow categories

Flow categories	Descriptions
Cease-to-flow	Partial or total drying of the channel. System contracts to a series of disconnected pools. No surface flows.

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Very low flow	Minimum flow in a channel that prevents cease-to-flow conditions. Provides connectivity between some pools.
Baseflow	Long term seasonal flows that provide drought refuge between dry periods and contribute to nutrient dilution during wet periods or after a flood. Provides enough depth for fish movement along reaches.
Small fresh (pulse)	Improves longitudinal connectivity. Inundates lower banks, snags and woody debris, but flows are within the river channel. Maintains instream-habitat and cycles nutrients between parts of the river channel. May trigger aquatic animal movement and breeding. Flushes pools. May stimulate productivity/food webs.
Medium - Large fresh (pulse)	Inundates benches, snags, woody debris and inundation-tolerant vegetation higher in the channel. May connect wetlands and anabranches with low commence-to-flow thresholds. Supports productivity and transfer of nutrients, carbon and sediment. Provides fast-flowing habitat.
Bankfull flow	Inundates all in-channel habitats and connects many low-lying wetlands. Partial or full longitudinal connectivity. Drowns out most in-channel barriers and structures, such as weirs
Overbank flow	Overbank flows provide broad scale lateral connectivity with floodplains and wetlands. Supports nutrient, carbon & sediment cycling between the floodplain and channel. Promotes large-scale productivity. Overbank flows are used to describe flows above bankfull.

In the existing IC and FP EWRs there was a specified 'median' discharge and an associated range (i.e. minimum and maximum discharge values). In practice, there is some confusion as to whether i) the discharges must remain above the lower end of the specified range (i.e. the minimum values provided in 'Discharge Variability' metric), ii) remain at or above the specified 'median discharge' for the given number of days or iii) could exceed the maximum discharge value at any time during the event timeframe. It was proposed that the discharge variability metrics be removed from the EWRs to avoid this confusion and that only the specified target discharge values for each EWR be presented.

As a guideline, the discharge variability or 'flow bands' for all IC and FP EWRs were considered (see Table 32). The flow bands identified for each EWR are largely within incremental steps of 10,000 ML/day and correspond to the flow descriptors outlined in (Table 31).

Table 32 SA discharge variability/flow bands in 10,000 ML/day incremental steps and corresponding flow component descriptors for IC and FP EWRs (modified from Kilsby et al. 2014).

Discharge variability/Flow band (ML/day QSA*)	Target discharge (ML/day QSA)	Flow component descriptor	EWR #
3,000-6,999	≥3,000	Very low baseflow (Entitlement Flow*)	EF
7,000-14,999	≥10,000	Baseflow	IC1
15,000-24,999	≥20,000	Small fresh	IC2
25,000-34,999	≥30,000	Large fresh	IC3
35,000-44,999	≥40,000	Bankfull flow	IC4
45,000-54,999	≥50,000	Low overbank flow	FP1
55,000-64,999	≥60,000	Low to moderate overbank flow	FP2
65,000-74,999	≥70,000	Moderate overbank flow	FP3
75,000-84,999	≥80,000	Moderate to large overbank flow	FP 4 and FP5
* QSA may be <3,000 ML/day during periods of extended dry			

In-channel flow and entitlement flow

The In-channel (IC) EWRs incorporate metrics associated with discharge calculated flow to South Australia (QSA ML/day), duration (days), timing (seasonality), average return frequency (years) and maximum interval between flow pulses (years) as described in the SA LTWP (DEWNR 2015) and associated technical documents (Wallace et al. 2014a,b).

The Entitlement Flow, Under the terms of the Murray–Darling Basin Agreement 2008, South Australia is entitled to a maximum of 1850 GL/yr. The fixed monthly Dilution and Loss Entitlement (58 GL per month), combined with the variable monthly 'consumptive' Entitlement, provides lower flow volumes (3,000 ML/day) in the cooler months and peak flow volumes of 7,000 ML/day in the warmer months when consumptive demand is greater. Entitlement Flow is effectively a very low baseflow and is primarily provided to meet 'consumptive' requirements rather than achieve ecological outcomes. However, Entitlement Flow can support ecological objectives such as avoiding the critical loss of foraging generalist fish species and maintaining key refuges during severe, unnaturally prolonged dry periods (Wallace et al. 2014a).

Commented [LP(2]: This is not an EWR we assessed, we should acknowledge it and acknowledge it is not assessed

Commented [KD(3R2]: Sounds good. Was there a reason we chose not to assess it here? I'm assuming because although it has 'flow-on' benefits, it is not targeting ecological objectives or something of that nature?

Commented [L(4R2]: Comment from SA was "Remove EF – it's not an EWR, just a reference point", so my first comment was a little inaccurate in even referring to it as an EWR at all

Commented [KD(5R2]: I suppose it is not an Environmental Water Requirement if it isn't created to target environmental outcomes. Or at least not specifically.

Although Entitlement Flows (EFs) are described in the SA LTWP, they are not considered to be Environmental Water Requirements and have therefore not been included in the EWR Tool assessment. Table 33 shows list of EWR codes for in-channel flow.

Table 33 List of EWR codes for in-channel flow SA

EWR #	Target discharge (ML/day [min-max]	Duration (days) [Within event gap tolerance [days]	Period	Frequency % of years	Maximum Interval (years)	Rate of water level rise (m/day or [ML/day])	Rate of water level fall (m/day or [ML/day])
IC1_S	10000-100000	40 [3]	Sep-March	95	2	N/A	N/A

EWR #	Target discharge (ML/day [min-max]	Duration (days) [Within event gap tolerance [days]	Period	Frequency % of years	Maximum Interval (years)	Rate of water level rise (m/day or [ML/day])	Rate of water level fall (m/day or [ML/day])
IC1_P	10000-100000	60	Sep-March	95	2	465	232
IC1_PS	10000-100000	60	Sep-March	95	2	N/A	N/A
IC2_S	20000-100000	40 [3]	Oct-March	75	2	N/A	N/A
IC2_P	20000-100000	60	Oct-Dec	75	2	465	232
IC2_PS	20000-100000	60	Oct-Dec	75	2	N/A	N/A
IC3_S	30000-100000	40 [3]	Oct-March	55	2	N/A	N/A
IC3_P	30000-100000	60	Oct-Dec	65	2	465	232
IC3_PS	30000-100000	60	Oct-Dec	65	2	N/A	N/A
IC4_S	40000-100000	40 [3]	Oct-March	59	2	N/A	N/A
IC4_P	40000-100000	60	Oct-Dec	45	2	465	232
IC4_PS	40000-100000	60	Oct-Dec	45	2	N/A	N/A

Assessment Rules for In-Channel EWRs

In-Channel flow EWRs are assessed using the following parameters:

- **Target Discharge:** 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:** The number of days a flow event remains at (or above) a specified discharge target. Duration influences the extent of longitudinal and lateral connectivity. Events are considered successful if the continuous flow duration was equal (or above) the specified durations value.
- **Timing :** Seasonality influences temperature and day length which in turn will influence ecological outcomes. Timing is 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.
- **Frequency:** refers to the number of events of a given magnitude within a specified period. The frequency of IC and FP EWRs has been expressed in three formats: 1. Numbers of flows per Average Return Interval (ARI), 2. Percentage (%) of years and 3. The number of flow years within a 10-year period.
- **Critical Maximum Interval:** this metric identifies the period between successful events, which, if exceeded, may result in irreversible damage and/or significant decline in condition.
- **Rate of Water Level Rise:** describes the maximum rate in which flow can rise (described either in a rise in height or rise in volume per day). Calculated as a 3-day rolling average. Assessed on the rising limb for one month immediately prior to the target minimum discharge metric being met.
- **Rate of Water Level Fall:** describes the maximum rate in which flow can fall (described either as a drop in height or drop in volume per day). Calculated as a 3-day rolling average. Assessed on the falling limb for one month immediately after discharge has fallen below the target minimum discharge metric.

<u>Adjustment to reflect both Optimal and Sufficient conditions</u>

To reflect that some ecological outcomes are achievable with sub-optimal metrics there has been further work done to create metric parameters for the In-Channel and Floodplain EWRs that reflect Optimal/Preferred, Middle ground and Sufficient conditions.

Conditions adjusted to reflect “Sufficient” conditions for In-Channel EWRs include:

- Allowing discharge to fall below minimum value for 3-days.
- Allowing minimum durations to be 2 thirds (66%) of the specified value.
- Allowing timing to be October to March (inclusive).
- Allowing the rate of rise and fall to be disregarded.

Example hydrograph for IC4 for both the Optimal conditions being met and the Sufficient conditions being met are shown in Figure 9 and Figure 10.

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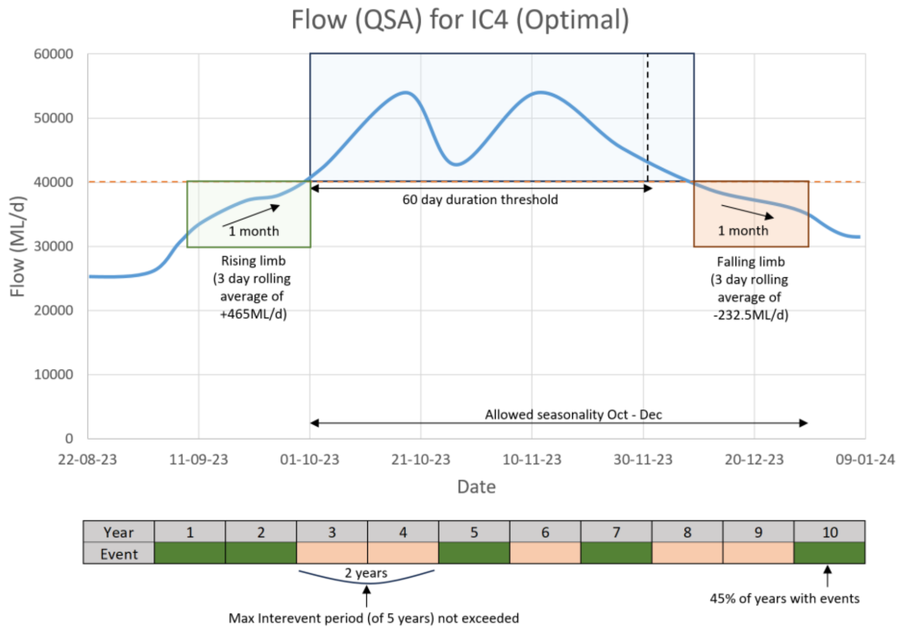

Figure 9 Presentation of IC4_P

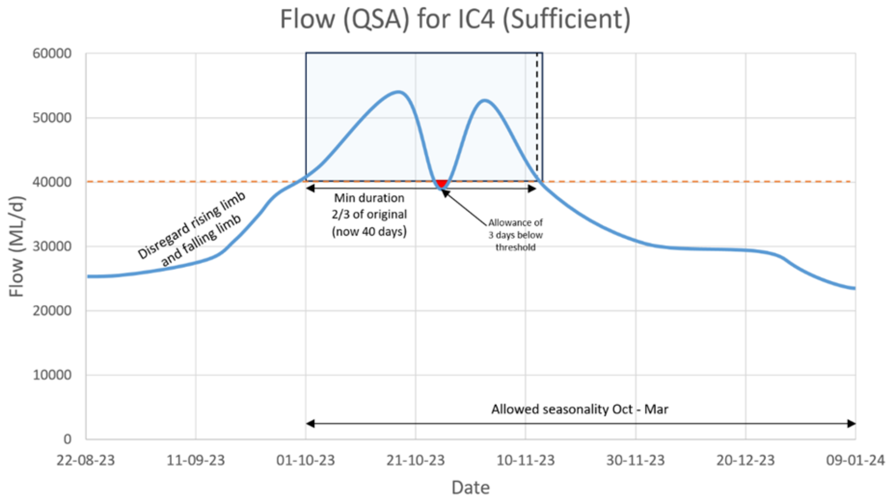

Figure 10 Presentation od IC4_S

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Floodplain flow

the Floodplain (FP) EWRs incorporate metrics associated with discharge calculated flow to South Australia (QSA ML/day), duration (days), timing (months), average return frequency (years), maximum interval (years) and maximum rates of rise and fall (m/day) as described in the SA LTWP (DEWNR 2015) and associated technical documents (Kilsby and Steggles 2015). Table 34 shows the list of floodplain EWR codes for SA. To reflect that some ecological outcomes are achievable with sub-optimal metrics there has been further work done to create metric parameters for the Floodplain EWRs that reflect Optimal/Preferred, Middle ground and Sufficient conditions. Figure 11 and Figure 12 show presentation of floodplain EWR FP1_P (preferred) and FP1_S (sufficient) respectively. Conditions adjusted to reflect "Sufficient" conditions for Floodplain EWRs include:

- Allowing discharge to fall below minimum value for 6-days.
- Allowing minimum durations to be 2 thirds (66%) of the specified value.
- Allowing timing to be any time of the year.
- Allowing the rate of rise and fall to be disregarded.

Table 34 Floodplain EWR code description for SA

EWR #	Target discharge (ML/day [min-max]	Duration (days) [Within event gap tolerance [days]	Period	Frequency % of years	Maximum Interval (years)	Rate of water level rise (m/day or [ML/day])	Rate of water level fall (m/day or [ML/day])
FP1_S	50000-100000	25 [6]	July-June	63	4	N/A	N/A
FP1_P	50000-100000	40	Sep-Dec	60	4	465	232
FP1_PS	50000-100000	40	Sep-Dec	60	4	N/A	N/A
FP2_S	60000-100000	12 [6]	July-June	50	5	N/A	N/A
FP2_P	60000-100000	20	Sep-Dec	45	5	465	232
FP2_PS	60000-100000	20	Sep-Dec	45	5	N/A	N/A
FP3_S	70000-100000	20 [6]	July-June	38	5	N/A	N/A

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EWR #	Target discharge (ML/day [min-max]	Duration (days) [Within event gap tolerance [days]	Period	Frequency % of years	Maximum Interval (years)	Rate of water level rise (m/day or [ML/day])	Rate of water level fall (m/day or [ML/day])
FP3_P	70000-100000	30	Sep-Dec	35	5	465	232
FP3_PS	70000-100000	30	Sep-Dec	35	5	N/A	N/A
FP4_S	80000-100000	20 [6]	July-June	28	5	N/A	N/A
FP4_P	80000-100000	30	Sep-Dec	25	5	465	232
FP4_PS	80000-100000	30	Sep-Dec	25	5	N/A	N/A
FP5_S	80000-100000	20 [6]	July-June	13	8.5	N/A	N/A
FP5_P	80000-100000	30	Sep-Dec	13	8.5	465	232
FP5_PS	80000-100000	30	Sep-Dec	13	8.5	N/A	N/A

~~CODE~~

~~Example Hydrograph for FP1 for both the Optimal conditions being met and the Sufficient conditions being met:~~

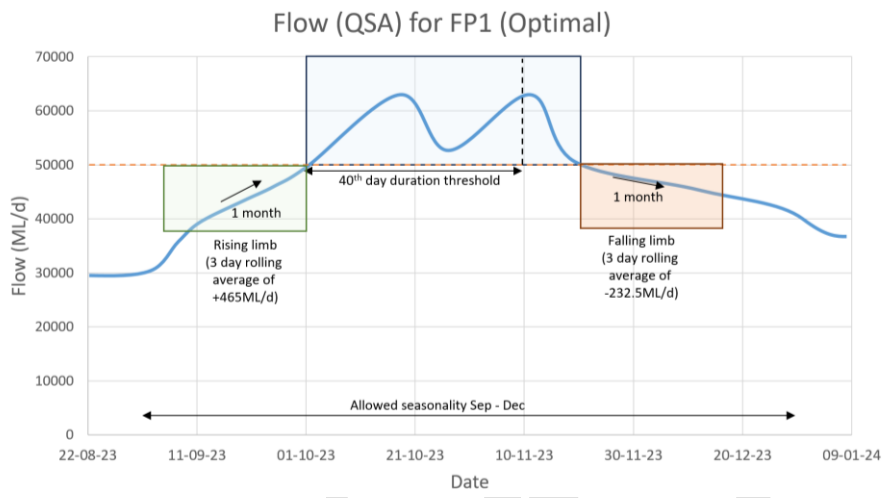

Figure 11 Presentation of a floodplain EWR FP1_P

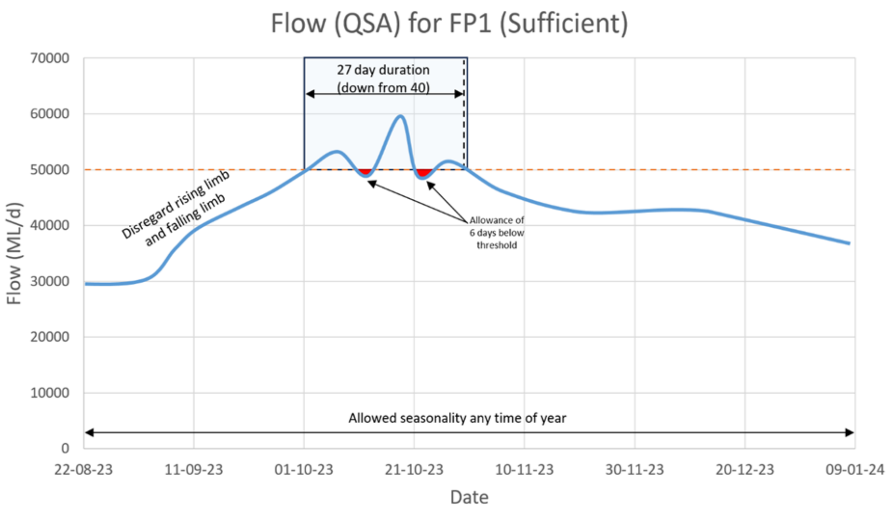

Figure 12 Presentation of a floodplain EWR FP1_S

Coorong, Lower Lakes and Murray Mouth flow

The CLLMM EWRs incorporate metrics associated with annual barrage flow volumes (GL/year) and barrage flow timing (months), Lower Lakes (i.e. Lake Alexandrina and Lake Albert) water levels (m AHD), Coorong South Lagoon levels (m AHD), the timing of peak and minimum water levels in both the Lower Lakes and Coorong South Lagoon (months) and the duration of Coorong South Lagoon peak water levels (days) as outlined in the SA LTWP (DEWNR 2015) and associated technical documents (O'Connor et al. 2015). Table 35 shows CLLMM EWR code description for SA. In summary:

CLLMM 1: annual barrage flows of >2000 GL.y-1 (average over a 3-year period with no less than 650 GL in any one year) and Coorong South Lagoon water levels of 0.0 to 0.2 m AHD for ≥90 days in spring. This EWR is further divided into CLLMM1a_p, CLLMM1a_S, CLLMM1b, CLLMM1c_P, CLLMM1c_S, CLLMM1d_p and CLLMM1d_S. Detailed information about these EWRs are shown in Table 35. Figure 13, Figure 14,Figure 15and Figure 16show presentation of CLLMM1a_P, CLLMM1b, CLLMM1c and CLLMM1d respectively.

CLLMM 2: annual barrage flow of >4000 GL.y-1 (average over a 3-year period with no less than 3150 GL every two years) and Coorong South Lagoon water levels of 0.35-0.45 m AHD for ≥120 days over spring and summer. This EWR is further divided into CLLMM2a_p, CLLMM2a_S, CLLMM2b, CLLMM2c, CLLMM2d_p and CLLMM2d_S. Detailed information about these EWRs is shown in Table 35. Figure 17 and Figure 18 show the presentation of CLLMM2a_P and CLLMM2b respectively.

CLLMM 3: barrage flows of >6000 GL.y-1 every three to five years, and Coorong South Lagoon water levels of 0.35- 0.45 m AHD for ≥150 days over spring and summer. This EWR is further divided into

CLLMM3a_p, CLLMM3a_S, CLLMM3c, CLLMM3d_p and CLLMM3d_S. Detailed information about these EWRs is shown in Table 35.

CLLMM 4: barrage flows of >10,000 GL.y-1 every seven to 17 years and Coorong South Lagoon water levels of 0.35- 0.45 m AHD for ≥180 days over spring and summer. This EWR is further divided into CLLMM4a_p, CLLMM4a_S and CLLMM4c. Detailed information about these EWRs is shown in Table 35.

Table 35 CLLMM EWR codes discription for SA

EWR #	Average Annual Barrage flow (GL/yr)	Total barrage flow over rolling 3-yr period (GL)	Barrage outflow annual pattern	Frequency [% of years]	Critical Max Interval (years)	Lakes water level (m AHD)	Coorong South Lagoon peak water level (m AHD)	Coorong South Lagoon peak water level timing (months)	Coorong South Lagoon peak water level duration (days)	
CLLMM1a_P	≥2,000	N/A	Sum of flow between Sep-Dec needs to be greater than sum of flow between Jan-Aug	1-in-1 [%100]	0	N/A	N/A	N/A	N/A	
CLLMM1a_S	≥2,000	N/A	Anytime of year	1-in-1 [%100]	0	N/A		N/A	N/A	N/A
CLLMM1b	≥ 650	≥6,000	Sum of flow between Sep-Dec needs to be greater than sum of flow between Jan-Aug	1-in-1 [%100]	0	N/A	N/A	N/A	N/A	
CLLMM1c_P	N/A	N/A	5 day rolling average of levels across 5 sites within Lake Alexandrina: 1. A4260527 2. A4261133 3. A4260524 4. A4260574 5. A4260575	N/A	0	0.5-0.75 mAHD from September to December (inclusive)	N/A	N/A	N/A	
CLLMM1c_S	N/A	N/A	5 day rolling average of levels across 5 sites within Lake Alexandrina:	N/A	0	0.4 to 0.5 AmHD from September to December (inclusive)		N/A	N/A	N/A

EWR #	Average Annual Barrage flow (GL/yr)	Total barrage flow over rolling 3-yr period (GL)	Barrage outflow annual pattern	Frequency [% of years]	Critical Max Interval (years)	Lakes water level (m AHD)	Coorong South Lagoon peak water level (m AHD)	Coorong South Lagoon peak water level timing (months)	Coorong South Lagoon peak water level duration (days)	
			1. A4260527 2. A4261133 3. A4260524 4. A4260574 5. A4260575							
CLLMM1d_P	N/A	N/A	5 day rolling average based on 3 sites within the South Lagoon: Parnka Woods Well Snipe Island	N/A	0	N/A		between 0.0 and 0.1 mAHD	Sep-Dec	90
CLLMM1d_S	N/A	N/A	5 day rolling average based on 3 sites within the South Lagoon: Parnka Woods Well Snipe Island	N/A	0	N/A		Above 0.0 mAHD	Sep-Dec	90
CLLMM2a_P	≥4,000	≥12,000	Total sum of flow in Sep-Dec needs to be greater than Jan-Aug	1-in-2 [50%]	3	N/A		N/A	N/A	N/A

EWR #	Average Annual Barrage flow (GL/yr)	Total barrage flow over rolling 3-yr period (GL)	Barrage outflow annual pattern	Frequency [% of years]	Critical Max Interval (years)	Lakes water level (m AHD)	Coorong South Lagoon peak water level (m AHD)	Coorong South Lagoon peak water level timing (months)	Coorong South Lagoon peak water level duration (days)	
CLLMM2a_S	≥4,000	≥12,000	N/A	1-in-2 [50%]	3	N/A		N/A	N/A	N/A
CLLMM2b	≥3150	≥12000	N/A	1-in-2 [50%]	3	N/A		N/A	N/A	N/A
CLLMM2c	N/A	N/A	5 day rolling average	1-in-2 [50%]	3	0.5 to 0.83 Peak Dec-Feb Low Peak Mar-May		N/A	N/A	N/A
CLLMM2d_P	N/A	N/A	5 day rolling average	1-in-2 [50%]	3	0.2 to 0.45 Sep-Jan		N/A	N/A	150
CLLMM2d_S1	N/A	N/A	5 day rolling average	1-in-2 [50%]	3	≥ 0.2 Sep-Jan		N/A	N/A	150
CLLMM3a_P	6000		Sum of barrage flows between September and January needs to be greater than the sum of water between February and August	[33%]	5	N/A		N/A	N/A	N/A
CLLMM3a_S	6000		Any	[33%]	5	N/A		N/A	N/A	N/A
CLLMM3c	N/A	N/A	5 days rolling average in Lake Alexandrina	[33%]	5	0.6- 0.83 Min level between March-May and Max level between Sep-		N/A	N/A	N/A

EWR #	Average Annual Barrage flow (GL/yr)	Total barrage flow over rolling 3-yr period (GL)	Barrage outflow annual pattern	Frequency [% of years]	Critical Max Interval (years)	Lakes water level (m AHD)	Coorong South Lagoon peak water level (m AHD)	Coorong South Lagoon peak water level timing (months)	Coorong South Lagoon peak water level duration (days)
						Dec			
CLLMM3d_P	N/A	N/A	5 days rolling average in South Lagoon	[33%]	5	N/A	0.2-0.45	Sep-Feb	180
CLLMM3d_S	N/A	N/A	5 days rolling average in South Lagoon	[33%]	5	N/A	≥ 0.2	Sep-Feb	180
CLLMM4a_P	10,000		Sum of barrage flows between September and January needs to be greater than the sum of water between February and August	[14%]	17	N/A	N/A	N/A	N/A
CLLMM4a_S	10,000		Any time between Sep-Feb	[14%]	17	N/A	N/A	N/A	N/A
CLLMM4c	N/A	N/A	5 days rolling average level in Lake Alexandrina	[14%]	17	0.6-0.9 ≥0.6 between March-May ≥0.9 between Sep-Dec	N/A	N/A	N/A

Assessment Rules for CLLMM EWRs

- **Annual barrage flow**: the minimum volume (gigalitres per year) released from the barrages (all gates) over the course of a water-year. For some EWRs this should be calculated as a rolling average (i.e. average volume over multiple years).
- **Average return interval:** the desired average frequency that the minimum annual volume is released e.g. 1-in-3 ARI means once every three years (or 33% of years) on average and does not seek to describe a regular pattern.(ARI: average return interval - the long-term average number of years between the occurrence of a flow event equal to or great than the selected event.)
- **Maximum interval:** the maximum number of years between events that meet the EWR metrics
- **Timing:** barrage releases should occur over the entire water-year but the EWRs seek to vary the monthly outflow volume with peaks outflows in late spring/early summer in order to support seasonal ecological processes
- **Lake water level range:** the range that Lake water levels should remain within throughout the year (in mAHD); water level values should be calculated as the average across the Lower Lakes rather than a minimum or maximum at any given location.
- **Lake water level timing:** describes the months when maximum and minimum water levels should occur. 7. Coorong South Lagoon water level - the range that water levels (in mAHD) should remain within at the indicated time. This should be based on the minimum water level at any given point rather than an average across multiple locations.
- **Coorong South Lagoon water level timing**: the months when South Lagoon water levels need to remain within the specified range.
- **Coorong South Lagoon duration:** the number of days that South Lagoon water levels need to remain within the specified range.

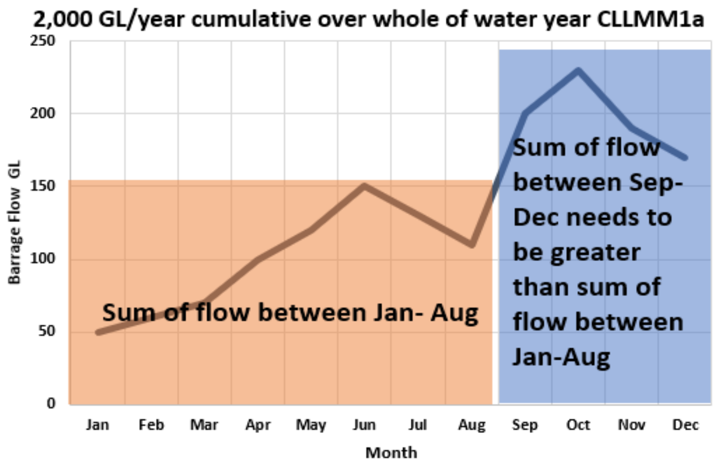

Figure 13 CLLMM1a_P presentation of barrage flow.

CLLM1b

Year	1	2	3	4	5	6	7	8	9
Event									
Total averaged flow	2000 GL/year not less than 6000GL			2000 GL/year not less than 6000GL			2000 GL/year not less than 6000GL		
averaged flow anaually	>650 GL	>650 GL	>650 GL	>650 GL	>650 GL	>650 GL	>650 GL	>650 GL	>650 GL

Figure 14 Presentation of CLLMM1b barrages flow

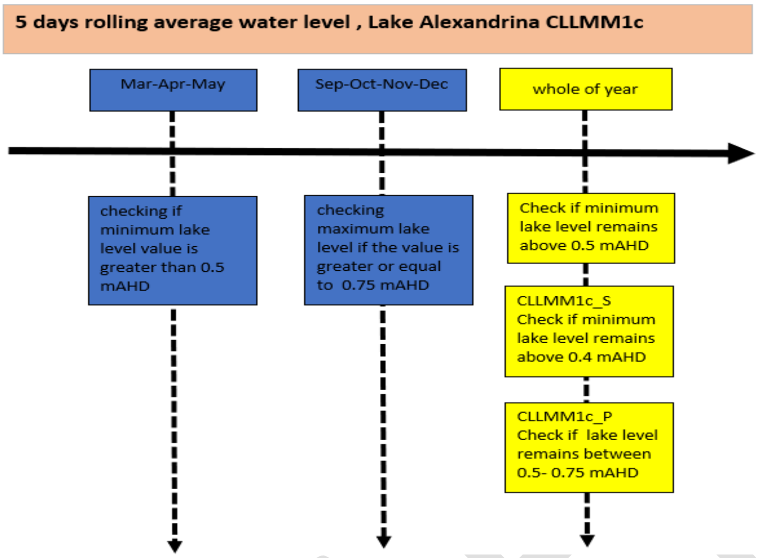

Figure 15 Presentation of CLLMM1c_P and CLLMM1c_S

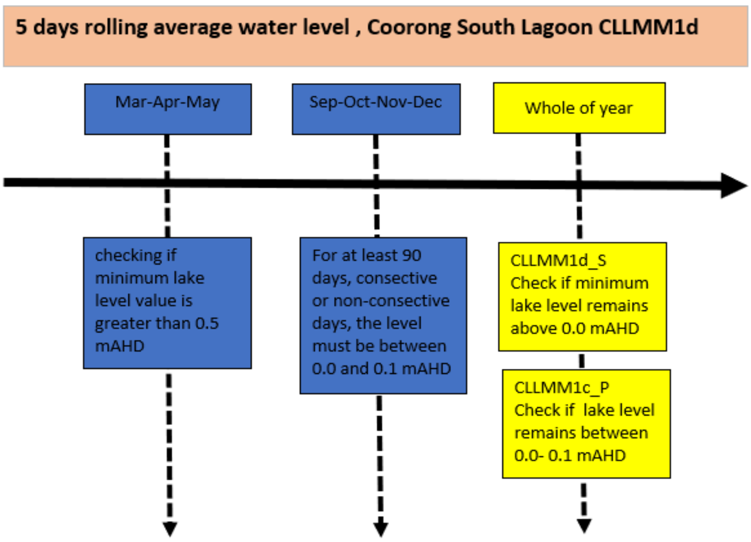

Figure 16 Presnetation of CLLMM1d_P and CLLMM1d_S

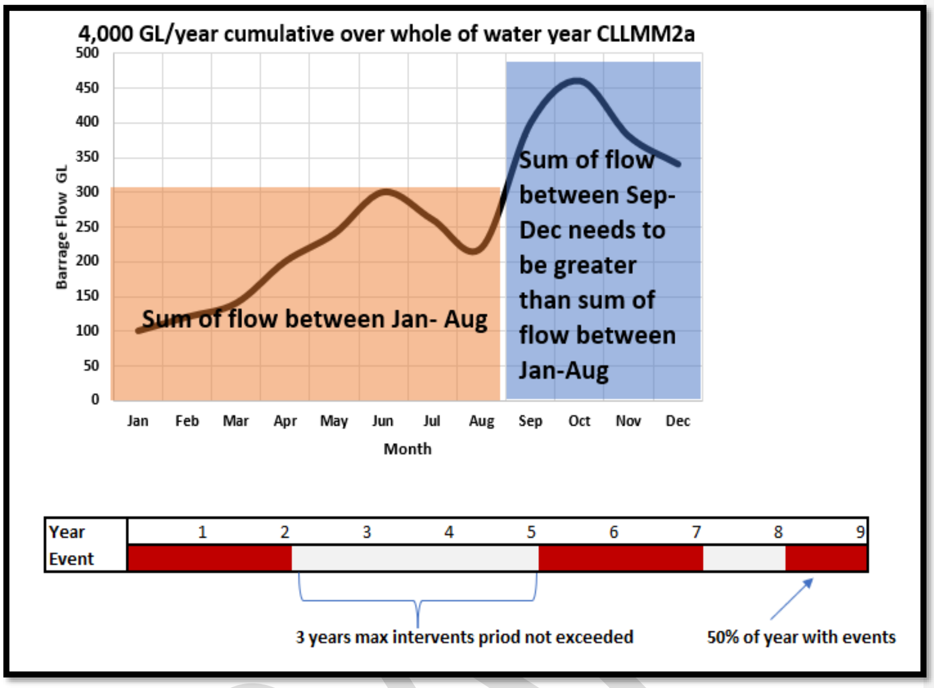

Figure 17 Presentation of CLLMM2a_P

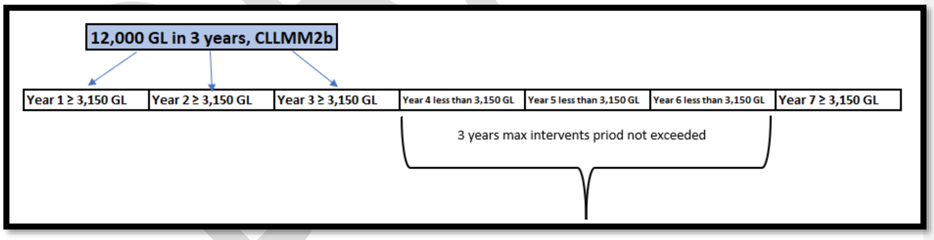

Figure 18 Peresnetaion of CLLMM2b

QLD EWRs

Introduction to QLD EWR development

Chapter 8 of the Murray-Darling Basin Plan 2012 requires Basin States to prepare a Long-term watering plan.The Department of Regional Development, Manufacturing and Water has published the long-term watering plans for ‘Border Rivers and Moonie’, ‘Condamine and Balonne’ and ‘Warrego, Paroo, Nebine’. These plans identify priority environmental assets, functions, objectives and targets for each of the Queensland Murray-Darling Basin water plan areas.

An environmental water requirement (EWR) for the purpose of QLD LTWPs, describes a set of recommended flow characteristics (magnitude, duration, timing, frequency, rate of change) at a certain location (river gauge) to meet a particular set of environmental objectives.

The EWRs were informed by ecohydrological science projects implemented under Queensland’s Environmental Flows Assessment Program (EFAP), along with other relevant research projects, such as those undertaken during the Northern Basin Review.

QLD flow categories

QLD EWRs are categorized by their ecological objectives (e.g. drought refuge) and then by hydrological requirements. There are many different types of EWRs throughout the LTWPs. 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 EWRs have been categorized under the following key types:

- Standard Flow (QLD)
- Standard Flow with Cease to Flow (QLD)
- Volumetric – Bird Breeding (QLD)
- Multiple Locations Flow and Volumetric – Bird Breeding (QLD)
- Water Stability
- Water Stability (level)
- Event years connecting events

The assessment method and rules for each EWR assessment category are described below.

Standard Flow (QLD)

Standard flows in QLD target the following categories: anabranch connection – fish dispersal, drought refuge, fish recruitment, nutrients and energy, primary productivity, lateral dispersal of fish, waterbirds, fish and turtles. The differing EWR codes that represent these are outlined in Table 36.

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Table 36 Standard flow types for QLD

EWR code	Description	LTWP area
dANA	Dispersal to and from anabranches (dANA) applies in the Border Rivers and Moonie LTWP area. Aims to Increase the frequency or duration of flows that create connectivity with anabranches.	Border Rivers and Moonie
DR_S	Drought Refuge. Aims to increase the frequency of scouring flows that maintain waterhole depth	Border Rivers and Moonie
DR_VLF	Drought Refuge – Very Low Flow. Aims to decrease the length of no-flow spells that threaten waterhole persistence and/or habitat quality	Border Rivers and Moonie
DR1	Drought Refuge 1. Aims to decrease the length of no-flow spells that threaten waterhole persistence and/or habitat quality.	Warrego, Paroo, Bulloo and Nebine
DR2	Drought Refuge 2. Aims to increase the frequency of scouring flows that maintain waterhole depth	Warrego, Paroo, Bulloo and Nebine
FR1	Fish Recruitment 1. Aims to Increased provision of reproduction and recruitment opportunities for flow spawning fish.	Condamine and Balonne
FR2	Fish Recruitment 2. Aims to Increased provision of reproduction and recruitment opportunities for flow spawning fish.	Border Rivers and Moonie, and Condamine and Balonne
NE	Nutrients and Energy. The ecosystem function supports the transportation and dilution of nutrients, organic matter and sediment. The EWR aims to increase the frequency of flow events that connect anabranches and channels.	Border Rivers and Moonie
PP	Primary Productivity. The ecosystem function provides connections across floodplains, adjacent wetlands and billabongs (lateral connections). The EWR aims to increase frequency of flow events that fill anabranches to allow primary production.	Border Rivers and Moonie
LDF	Lateral Dispersal of Fish. Aims to maintain or increase the frequency or duration of flows that create connectivity with floodplains	Warrego, Paroo, Bulloo and Nebine
WFT	Breeding of Waterbirds, Fish and Turtles. Aims to increase frequency/duration of flows that trigger bird breeding opportunities and sustain adults and fledglings. Increase frequency of flow events that provide breeding opportunities for floodplain specialist fish and turtles in floodplain wetland	Warrego, Paroo, Bulloo and Nebine
BBR	Bird breeding and Recruitment	Condamine and Balonne
FrW	Fish recruitment water stability	

Commented [KD6]: Combine all to one table.

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EWR code	Description	LTWP area
FrL	Fish recruitment water stabilities level	
rANA	Fish recruitment in Anabranches	

Commented [KD6]: Combine all to one table.

Assessment rules for standard flow

Commented [KD7]: Review and make relevant to QLD

Standard flow (QLD)

Standard flow QLD EWRs shown in Table 37 include preferred (either donated by a '_P' or with no additional underscore) and sufficient (Denoted by an '_S'). Preferred standard flow are assessed using the following parameters:

- **Timing window:** Start month and end month (both inclusive). Where an event crosses over the water year, the event continues to be tracked and then is assigned to the most recent water year.
- **Flow threshold min:** minimum flow threshold (greater than or equal to)
- **Flow threshold max:** max flow threshold (less than or equal to). This is an optional requirement, if not defined it is assumed there is no maximum threshold.
- **Duration:** total days required in the year for the EWR to be achieved.
- **Minimum spell (minSpell):** minimum individual spell length that can contribute towards the duration. It is usually either a 1 or equal to the duration. When it is a 1 this implies that the duration is a non-consecutive requirement. If the minimum spell and duration are the same it means the duration is a consecutive requirement.
- **Target frequency:** We have used where possible but there are some missing frequencies.
- **Events per year:** Can be more than 1 but all instances of these in Qld only require 1 per year for this category
- **Maximum inter-event period:** Defined in years – the maximum recommended time between events.

Commented [LP(8]: Not all standard flow EWRs have this, but some do (i.e. have used where possible but there are some missing Max inter-event periods)

For sufficient standard flow all parameters will be the same as the preferred option with the exception of the timing window. The timing window will be relaxed to whole of the year.

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Table 37 Standard flow QLD EWRs

EWR category	EWR codes
Standard Flow (QLD)	• dANA (Anabranch Connection – fish dispersal) • DR_VLF (drought refuge – very low flow) • FR1 (Fish Recruitment 1) • FR2 (Fish Recruitment 2) • NE (Nutrients and Energy) • PP (Primary Productivity) • DR1 (Drought Refuge 1) • DR2 (Drought Refuge 2) • LDF (Lateral dispersal of fish) • WFT (Waterbirds, fish and turtles) • FrC (Fish Recruitment)*

*Please be aware that the 2022 Warrego Paroo Bulloo and Nebine Long-term watering plan represents FrC (Table 5. Environmental watering requirements for fish recruitment) as a Standard flow with Cease to flow, but this will be corrected in subsequent publications. The EWR tool treats this EWR as a Standard Flow with a max inter-event period of 4 years as advised by QLD (in line with other fish recruitment EWR types).

Standard flow with Cease to flow (QLD)

Standard flow with cease to flow is shown in Table 38. There is a two phase EWR for standard flow with cease to flow:

Phase 1: The first phase is defined by a check for a cease to flow period. This period is defined by a duration of x days (in the parameter sheet under the heading *NonFlowSpell*), under a flow user defined flow rate (1 ML currently but can be modified).

Phase 2: The second phase is essentially the exact implementation of the standard flow handling and will include all of the same parameters and have the same calculation method.

Currently the time between phase 1 and phase 2 is restrained to 90 days. For example, phase 2 needs to occur within 90 days of phase 1 finishing to be counted as an event. If phase 2 occurs without a phase 1 the event will not be counted as a successful event.

Table 38 Standad flow with cease to flow (QLD)

EWR category	EWR codes
Standard Flow with cease to flow (QLD)	• FD1 (Fish Dispersal 1) • FD2 (Fish Dispersal 2)

FD1 and FD2 also include two proxy EWRs for each Fish Dispersal EWR. This splits into the BF_FD and SF_FD

These are the sub components of the FD EWRs that look at __ and __.

Volumetric (QLD)

Volumetric EWRs in QLD consist of bird breeding and recruitment. Table 36 provides a description of the code used and what it represents. This information can be found in Table 6 of the Condamine and Balonne LTWP.

Table 39 Volumetric flow codes for QLD

Category	EWR code	Description	LTWP area
Bird breeding and Recruitment 2	BBR2	Aims to increase the frequency/duration of flows that maintain the condition and extent of vegetation to support bird breeding opportunities. • Occurring within the months of July to June. • Target Frequency is 76%. • Requires 1 event per year. • Duration of events is 1 day. • Minimum spell is 1 day.	Condamine and Balonne

Assessment rules for volumetric

For a volumetric EWR event to occur, a minimum volume threshold must be met each day for a number of consecutive days. 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, and in some cases daily flow. These details can be found in EWR tables in the QLD LTWPs. 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 window:** Start month and end month (both inclusive). Where an event crosses over the water year, the event continues to be tracked and then is assigned to the most recent water year. 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 min:** Expressed as a minimum threshold that needs to be exceeded. For volumetric EWRs the cumulative volume will not start to accrue unless the minimum flow threshold is met. In the case of this EWR, the minimum flow threshold is 0 ML/day (thereby all flows can contribute to the required volume target).

- **Flow threshold max:** 1000000 ML/day (i.e. so large that it will never be hit)

- **Volume threshold:** The minimum cumulative volume to be reached over the required accumulation period below (greater than or equal to)

- **Accumulation period (days):** the number of days that the flows are aggregated over. Often presented as duration in the EWR tables in the QLD LTWPs. This is the period in days that the flow volume must accrue in to be achieved. For example, to achieve targeted bird breeding opportunities at Wilby Wilby, 25GL is required for over 60 days.

- **Target frequency:** ranges from 0–100% and can be found in the EWR tables of the QLD LTWP. For example, a target frequency of every 1.3 years (76%) is required to ensure lignum shrubland in Northern Narran Lakes is in the most suitable condition to support bird breeding.

- **Events per year:** One event is required per year.

Table X Example of volumetric EWR event calculation for QLD. 1 event per year requirement, minimum flow threshold of 0ML, volume threshold of 100ML, accumulation period of 10 days. Events 1 and 2 had duration periods of 8 and 10 days respectively.

Month	July																			
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Flow (ML)	1	1	2	1	2	2	10	15	18	18	20	23	24	16	3	4	1	2	2	1
Events												Event 1 (8 days)								

Month	July											August							
Day	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8
Flow (ML)	1	2	2	3	5	50	60	50	4	1	2	1	1	2	3	1	1	1	1
Events							Event 2 (10 days)												

The first assessable day is the first day that the program can look back at the last 10 days (n-10) to day (n). On this day the program looks back 10 days, sums all the flows over the minimum flow threshold (0ML/day) and checks to see if the sum is over the volume threshold (in this case 100ML). In this example, the 10th of July is the first assessable day. On this day the sum of the flows for the last 10 days is only 70ML and therefore an event does not occur on this day. On day 11, the program does the same check, with the sum of the flows for the last 10 days being only 89ML and still not starting an event. On day 12, the sum of the flows for the last 10 days is 111ML and an event (Event 1) begins. Each day following day 12 is assessed and found to have a sum of flows above 100ML up until day 20. On day 20 the sum of flows for the last 10 days is 96ML and therefore the event has ended on this day, making Event 1 a total of 8 days long. This assessment continues for the remainder of the days, with a second event found to run been the 27th of July and the 5th of August.

Water Stability Level (QLD)

Water Stability Level EWRs in QLD consist of fish recruitment water stability. Table 38 provides a description of the code used and what it represents. This information can be found in Table 5 of the Condamine and Balonne LTWP.

Table 38 Water stability level codes for QLD

Category	EWR code	Description	LTWP area
Fish Recruitment water stability level 1	FrL1	Specifies the required duration of flow events that provide egg and larval development conditions for stable low-flow spawning fish. • Occurring within the months of December to February. • Requires 2 events per year. • Duration of events is 10 days. • Minimum spell is 10 days. • Flow threshold min of 2 ML. • EggsDaysSpell is 9 days. • LarvaeDaysSpell is 1 day.	Condamine and Balonne
Fish Recruitment water stability level 2	FrL2	Specifies the required duration of flow events that provide egg and larval development conditions for stable low-flow spawning fish. • Occurring within the months of August to December. • Requires 1 event per year. • Duration of events is 9 days. • Minimum spell is 9 days. • Flow threshold minimum of 3 ML. • EggsDaysSpell is 3 days. • LarvaeDaysSpell is 6 days.	Condamine and Balonne

Assessment rules for water stability level

These EWRs have two phases, an egg phase, and a larvae phase. The larvae phase needs to immediately follow the egg phase with no gap in between them. The tool will iterate over the days in the timeseries one at a time. The tool will check to see if the levels are below the required value (1.63 or 1.8 m depending on the EWR) between day *n* and day *n + duration egg phase + duration larvae phase.* If the levels of this period are not below the required level it will go to the next day and check again, however, if the levels are below this value the tool will look forward to *n + duration of egg phase* and check to see if the difference between the highest and lowest level in this range is greater than the maximum recommended change (i.e. 5 cm over the entire egg duration). The tool will then look at the day immediately following the end of the egg phase (the start of the larvae phase) and look forward to the end of the larvae phase (defined by the larvae duration in the

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parameter sheet). Within the larvae phase it will check to see if the daily flow is within the tolerance defined (usually 5 cm/day for each day). If the levels meet the conditions an event is recorded and then the tools looks at days *n + 1* (i.e., it does not skip forward until after the end of the larvae phase – events can be stacked one after the other). The requirements for individual species is located in Appendix B of the Condamine Balonne LTWP.

Water stability level EWRs utilise the following parameters:

- **Timing window:** Start month and end month (both inclusive).
- **Duration:** 9 or 10 days (duration of egg phase + duration of larvae phase)
- **Target frequency:** not defined.
- **Events per year:** either 1 or 2 events per year required.
- **Level threshold max:** 1.63 or 1.8. The value that the median levels need to be below within the event window
- **Max inter-event period:** Not defined.
- **Drawdown rate:** Egg phase drawdown rate (net difference between the highest and lowest level in the egg phase)
- **MaxLevelRise:** Daily larvae phase drawdown rate
- **EggDaysSpell:** Length of days in the eggs phase
- **LarvaeDaysSpell:** Length of days in the larvae phase

Figure Y. Examples of QLD Water Stability Level EWR calculations for successful and failed events. *Hyseleotris spp* requirements for spawning: Time of year = August to December; Water stability of (1) eggs = 5cm / 3 days, (2) Larvae = 5cm / 6 days; ≤ median river height of 1.8 m.

(a) Pass: Successful events - stacked

Month		August														
Day		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Water level (m)		1.81	1.8	1.74	1.76	1.76	1.75	1.74	1.74	1.75	1.76	0.75	0.74	0.74	0.76	0.81
Level change (cm)		0	1	6	2	0	1	1	0	1	1	1	1	0	2	5
Egg Phase		N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Larvae Phase		N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Successful event tracking	Event 1			Egg phase			Larvae phase									
	Event 2				Egg phase			Larvae phase								
	Event 3					Egg phase			Larvae phase							

(b) Failed phase: Level change too great.

Month	August			
Day	1	2	3	4
Water level (m)	1.81	1.8	1.74	1.76
Level change (cm)	0	1	6	2
Event tracking		Failed egg phase		

(c) Failed event: 1 day gap between the egg and larvae phase.

Month	August														
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Water level (m)	1.81	1.8	1.74	1.76	1.76	1.81	1.74	1.74	1.75	1.76	0.75	0.74	0.74	0.76	0.81
Level change (cm)	0	1	6	2	0	1	1	0	1	1	1	1	0	2	5
Egg Phase	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N
Larvae Phase	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N
Event tracking			Egg phase				Larvae phase								

Check 1: Water level is below required value (egg phase)

The first assessable day is day 1. The first check the program undertakes is to see if the water level is below the required value. For the example in Figure Y, the required value is ≤ 1.8 m. On day 1, the water level is above this value (water level: 1.81 m), so an event cannot start, and the program moves to day 2. On day 2, the program undertakes the same check, meeting the requirements (water level: 1.8 m) and passes the first check.

As day 2 (n) passed the first check, the program then undertakes this check for n + duration egg phase, which in this example is 3 days. Days 3 and 4 also pass the first check (water levels: 1.74 m and 1.76 m respectively). This means the water level meets this requirement for 3 consecutive days and the program proceeds to check 2.

Check 2: Specifications are met for water stability (egg phase)

The second check the program undertakes is to see if the water stability meets the requirements for the egg phase duration specified for the species. For the example in Figure Y, the egg phase requires 3 consecutive days with no more than a 5 cm change in depth between the highest and lowest water level. Looking at days 2-4, the difference between the highest water level (1.8 m on day 2) and the lowest water level (1.74 m on day 3) is a difference of 6 cm. This means day 2 fails check 2 (refer to figure Y(b)) and the program moves back to check 1 for the next three consecutive days: days 3-5.

Days 3-5 pass check 1 and the program proceeds to check 2. The difference between the highest water level (1.76 m on days 4 & 5) and the lowest water level (1.74 m on day 3) is a difference of 2 cm. As the difference is no more than 5 cm in depth, these days pass check 2 and the egg phase is considered successful.

Commented [AG(9]: Would it be days 3, 4 and 5 passing check 2 or just day 3 passing check 2?

Check 3: Daily flow tolerance is met (Larvae Phase)

The third check the program undertakes is to see if the daily flow tolerances are being met for a successful larvae phase. For the example in Figure Y, this requires that the water level does not change more than 5cm/day for 6 consecutive days. Another requirement for a successful larvae phase is that it begins the day after the completion of the egg phase. So in this example, because an egg phase occurs from days 3-5, the larvae phase must begin on day 6. This means the program looks at day 6 and checks that it is within 5 cm of the water depth from the previous day (day 5).

For the example in Figure Y(a), the difference between the water depth of day 5 and 6 is only 1 cm and thus passes the check. This means that the program proceeds to the next day (days n+1) and undertakes the same check until the required duration has been met. Days 6-11 all pass the check and so the program marks the larvae phase as successful, which translates to a successful event.

For the example in Figure Y(c), there is a one day gap between the egg and larvae phase due to a water level exceedance on day 6. This gap means that the larvae phase fails, and the event is considered unsuccessful.

Once an event has failed or succeeded, the program returns to the day after the beginning of the last round of checks. In this example, because the last round of checks started with day 3, the program will begin the next round of checks on day 4. It is important to note that events can be stacked one after the other, as shown in Figure Y(a).

Water Stability (QLD)

Water Stability EWRs in QLD consist of fish recruitment water stability. Table 38 provides a description of the code used and what it represents. This information can be found in Table 5 of the Border Rivers and Moonie LTWP. We have split these out into the requirements for individual species using Appendix B in the Border Rivers plan.

Table 38 Water stability codes for QLD

Category	EWR code	Description	LTWP area
Fish recruitment water stability 1	FrW1	• Occurring within the months of October to December. • Requires 1 event per year. • Duration of events is 27 days. • Minimum spell is 27 days. • Maximum inter-event period is 3 years.	Border Rivers and Moonie
Fish recruitment water stability 2	FrW2	• Occurring within the months of August to December. • Requires 1 event per year. • Duration of events is 9 days. • Minimum spell is 9 days. • Maximum inter-event period is 3 years	Border Rivers and Moonie
Fish recruitment water stability 3	FrW3	• Occurring within the months of December to February. • Requires 2 events per year. • Duration of events is 10 days. • Minimum spell is 10 days. • Maximum inter-event period is 2 years	Border Rivers and Moonie
Fish recruitment water stability 4	FrW4	• Occurring within the months of December to February. • Requires 1 event per year. • Duration of events is 7 days. • Minimum spell is 7 days. • Maximum inter-event period is 3 years	Border Rivers and Moonie

Assessment rules for water stability level

These EWRs have two phases, an egg phase and a larvae phase. The larvae phase needs to immediately follow the egg phase with no gap in between them. The tool will iterate over the days in the timeseries one at a time. At day *n,* the tool will check to see if the flow is within the required range (e.g. 70 to 120 ML/day), if the flow is not in this range it will go to the next day and check again, however, if the flow is within the range the tool will look forward to *n + duration of egg phase* and check to see if the difference between the highest and lowest level in this range is greater than the maximum recommended change (i.e. 5 cm over the entire egg duration). The tool will then look at the day immediately following the end of the egg phase (the start of the larvae phase) and look forward to the end of the larvae phase (defined by the larvae duration in the parameter sheet). Within the larvae phase it will check to see if the daily flow is within the tolerance defined (usually 5 cm/day for each day). If the levels meet the conditions an event is recorded and then the tools looks at days *n+1* (i.e. it doesn't skip forward until after the end of the larvae phase – events can be stacked one after the other).

This type of EWR needs the following parameters:

- **Timing window:** Start month and end month (both inclusive).
- **Target frequency:** not defined.
- **Events per year:** either 1 or 2 events per year required.
- **Flow threshold min:** 0 or 70 ML/day.
- **Flow threshold max:** 120 or 360 ML/day.
- **Max inter-event period:** 2 or 3 years.
- **Drawdown rate:** Egg phase drawdown rate (net difference between the highest and lowest level in the egg phase)
- **MaxLevelRise:** Daily larvae phase drawdown rate
- **EggDaysSpell:** Length of days in the eggs phase
- **LarvaeDaysSpell:** Length of days in the larvae phase

Figure Z. Examples of QLD Water Stability EWR calculations for successful and failed events. *Hyseleotris spp* requirements for spawning: Time of year = August to December; Water stability of (1) eggs = 5cm / 3 days, (2) Larvae = 5cm / 6 days; Flow range = 70 to 120 ML/day.

(a) Pass: Three Achievements - stacked

Month		August 2020														
Day		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Flow (ML/day)		70	73	77	77	78	79	80	80	80	77	80	110	115	120	125
Level change (cm)		0	2	3	0	1	1	1	0	0	0	1	6	6	6	6
		5cm/3 days			3cm/6 days											
Successful event tracking	Event 1	Egg phase			Larvae phase											
	Event 2		Egg phase			Larvae phase										
	Event 3			Egg Phase			Larvae phase									

(b) Fail: Even though there is a complete egg and larvae phase, they are broken by a day where the flow and level requirements went outside the required range.

Month	August 2020														
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Flow (ML/day)	70	70	70	60	70	70	70	70	70	70	80	90	95	100	105
Level change (cm)	0	0	0	3	0	0	0	0	0	0	6	6	6	6	6
	0cm/3 days				3cm/6 days										
Event tracking	Egg phase				Larvae phase										

(c) Fail: Even though the flow and level change requirement is met during the larvae phase, the level exceeds the 5cm/3 days requirement during the egg phase.

Month	August 2020														
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Flow (ML/day)	70	75	80	70	70	70	70	70	70	75	80	90	95	100	105
Level change (cm)	0	3	3	0	2	0	1	0	0	6	6	6	6	6	6
	6cm/3 days			3cm/6 days											
Event tracking	Egg phase			Larvae phase											

(d) Fail: Even though the level requirement is met for the first 9 days, the flow drops out of the required range on days 1-4 and 7 causing the fail.

Month	August 2020														
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Flow (ML/day)	60	60	60	60	70	70	68	70	70	75	80	90	95	100	105
Level change (cm)	0	0	0	0	2	0	1	0	0	6	6	6	6	6	6
	0cm/3 days			3cm/6 days											
Event tracking	Egg phase			Larvae phase											

VIC EWRs

Introduction to VIC EWR development

In Victoria, the Environmental Water Requirement (EWR) is the legally defined volume of water allocated to sustain the health of rivers, wetlands, and floodplains. This allocation is crucial for maintaining ecological processes, supporting biodiversity, and ensuring the resilience of aquatic ecosystems. Environmental water is managed by the Victorian Environmental Water Holder (VEWH), an independent statutory body responsible for holding and managing Victoria's environmental water entitlements. The VEWH collaborates with Catchment Management Authorities (CMAs) to plan and deliver environmental water through seasonal watering plans. These plans are informed by Environmental Water Management Plans (EWMPs), which outline the ecological objectives, watering requirements, and management strategies for specific sites.

The delivery of environmental water provides numerous benefits, including improving water quality, providing cues for fish spawning and bird breeding, and enhancing riparian and wetland vegetation. These ecological improvements contribute to the overall health of the environment and support the diverse species that depend on these habitats.

Environmental Water Management Plans (EWMPs) are medium- to long-term planning documents—typically spanning 8 to 10 years—developed for key environmental assets across Victoria, including river systems, wetlands, wetland complexes, and estuaries. Each EWMP outlines critical site-specific details such as location, ecological values, condition, and threats. It also defines the environmental objectives for the site and the watering regime required to support those objectives.

EWMPs incorporate scientific assessments—including Traditional Ecological Knowledge (TEK), FLOWS studies, and expert input—alongside consultation with partners and stakeholders. They also document the hydrology of the system, environmental water delivery infrastructure, and identify any complementary management actions needed to support environmental outcomes. Gaps in current knowledge and recommendations for future improvement are also detailed.

These plans are essential tools for Catchment Management Authorities (CMAs), the Victorian Environmental Water Holder (VEWH), and the Department of Energy, Environment and Climate Action (DEECA, formerly DELWP), informing both annual and multi-year environmental water planning. They provide the foundation for seasonal watering proposals, operational decisions, and reporting. In northern Victoria, EWMPs also serve as key reference documents for Long-Term Watering Plans developed under the Basin Plan, and they align with relevant obligations under state, national, and international frameworks, such as Regional Waterway Strategies, the Directory of Important Wetlands in Australia, and the Ramsar Convention.

VIC flow categories

Environmental Water Management Plans (EWMPs) in Victoria describe a suite of flow components that are critical to supporting the ecological values and objectives of rivers, wetlands, and floodplains. These flow categories reflect different elements of the natural hydrological regime and are informed by scientific studies such as FLOWS assessments and the Basin Plan environmental watering requirements.

The key flow categories commonly used in EWMPs include:

Cease-to-Flow: Periods where there is no measurable surface water flow. These events are part of the natural variability of many river systems and can play an important ecological role, such as promoting vegetation zonation or allowing certain aquatic species to complete parts of their life cycle.

Base Flows: continuous low-level flows that maintain basic habitat conditions and connectivity. Low-flow-season base flows occur typically in summer and autumn. High-flow-season base flows occur during wetter months, such as winter and spring.

Freshes: short-duration, higher-than-base-flow events that help flush the system, cue fish migration or spawning, and maintain water quality. Low-flow-season freshes often occur in autumn or early winter. High-flow-season freshes are usually timed in spring to mimic natural rainfall-driven pulses.

Bank-Full Flows: flows that fill the river channel to capacity and initiate interaction with the floodplain, essential for sediment transport, nutrient cycling, and rejuvenating in-stream habitat.

Overbank Flows: larger flood events that spill beyond the riverbanks into floodplain areas. These flows support wetland inundation, promote vegetation recruitment, recharge groundwater, and deliver ecological benefits across broader floodplain landscapes.

Each flow component is defined not only by its magnitude (flow rate or volume), but also by its timing, frequency, duration, and variability. Together, they form an intended watering regime that mimics natural variability to the extent possible within operational and climatic constraints.

Given the complexity of environmental water planning and the rapidly changing nature of environmental conditions, we have worked directly with Catchment Management Authorities (CMAs) to review and refine the existing Environmental Water Requirements (EWRs). The EWRs presented in this manual reflect on-ground insights provided by CMAs, including consideration of their current operational constraints and local environmental conditions. These EWRs may differ from those documented in existing Environmental Water Management Plans (EWMPs) and should be viewed as the most current interpretation based on available advice. As updated EWMPs are developed or released, EWRs may be subject to further revision.

Flow regimes

To compare flow categories/regimes across the basin, EWRs have been grouped into four generic flow categories – Baseflow, Fresh, Bankfull, Overbank/wetland inundation – which are considered comparable across states. EWRs that fall outside these categories or that aren't comparable across states are excluded.

When adding additional EWRs to the parameter_sheet, this section, and the NSW flow categories can be used as guidance to determine the flow regime of the new EWR.

The following sections outline and justify some of the decisions regarding assumptions and exclusions, particularly around edge or non-standard cases.

NSW

Assumptions

Anabranch Connecting flows:

Anabranch Connecting flows (with EWR codes of AC1* and AC2*) have been classified as Freshes for the purpose of flow regime mapping, based on the representation of their EWRs in the Namoi Long Term Water Plan for gauges 419001, 419012, and 419021. These EWRs show flow rates falling between the Fresh and Bankfull flow rates for those gauges, but significantly closer to the Fresh values.

The flow regime of anabranch connection EWRs should be determined on a case-by-case basis.

Exclusions

The following EWR groups have been excluded:

- Cease to flows (CF* and ALT_CTF)
- Very low flow (VF* and VL*)
- De-stratifying flow (DSF*)
- Lake Level flows (LLLF, MLLF, HLLF, and VHLL)
- Wier pool (WP*, SF_WP, and LF*_WP)
- Nesting flows (Nest*)

QLD

Exclusions

- SF_FD* and BF_FD*
    - Both of these are proxy EWRs for fish dispersal
    - Some interesting characteristics of their EWRs are shown in Table 39Table 40 below
- DF_VLF
    - Note: These could be reconsidered for certain gauges
        - 416011 – Baseflow
        - 416048 – Bankfull
    - Broadly, part of Drought Refuge
    -

Commented [ZF10]: This section needs better justification, Martin might be able to explain?

Commented [ZF11]: Note: in the parameter sheet, these ewrs are SF-FD and BF-FD, not _

Commented [ZF12]: Note this

Table 40 - Patterns identified in the relationships between values for EWRs with codes BF_FD, SF_FD or FD

Parameter	BF_FD*	SF_FD*	FD*
FlowThresholdMin	Low values	Same value as the corresponding values for the FD* EWR for that gauge	Included
MaxInter-event	Included	No values	No values
NonFlowSpell	No values	No values	Included

SA

The conversion of the EWR codes to flow regime categories was based on the descriptions in Table 31 and Table 32.

Exclusions

- CLLMM
  - All of the CLLMMs are excluded from the basin wide flow regime aggregation, as those EWRs are hyper specific to their location

VIC

Exclusions

- FLR - Fresh Level Rise: included as a fresh, but might be reconsidered to exclude. In the Goulburn Broken CMA EWR parameter sheet development notes and assumptions.docx
- Excluding all of the RRF, RFF, RRL, RFL

Commented [ZF13]: I didn't finish this section

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