VMFRP Ecological Objectives and Relaxed Constraints Flows

Final Report

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Report prepared for the Department of Energy, Environment and Climate Action

Acknowledgement of Country

In the spirit of reconciliation, the authors acknowledge the Traditional Custodians of country throughout Australia and their connections to land, sea and community. We pay our respects to their elders past and present and extend that respect to all Aboriginal and Torres Strait Islander peoples today.

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- Rory Nathan
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Executive Summary

This report was prepared for the Department of Energy, Environment and Climate Action with an independent peer review conducted by Professor Rory Nathan from the University of Melbourne. The report compares the extent to which ecological objectives at Victorian Murray Floodplain Restoration Project (VMFRP) sites can be met by inundation patterns enabled through relaxing constraints as indicated by the Victorian Constraints Measures Program (CMP) Feasibility Study.

The report concludes that very few of the VMFRP ecological objectives and environmental water requirements (EWRs) at the eight VMFRP sites can be met by implementing the CMP under historic or climate change conditions. They can be met by the VMFRP. VMFRP is required at all the sites to provide confidence that the ecological health of the waterway, wetland, forest and woodland systems will be protected and restored. A peer review of this study by Professor Rory Nathan from the University of Melbourne supports these findings.

The VMFRP and Victorian CMP watering regimes were defined by the frequency and duration of flows which correspond to Ecological Water Regime Classes (EWRCs). EWRCs consist of one or more Ecological Vegetation Classes (EVCs) with similar inundation requirements. There are 14 EWRCs across the eight VMFRP sites including: Permanent Wetland, Semi-permanent wetland, Redgum Forest, Black Box Forest and Temporary Wetland.

The VMFRP environmental watering regime used in the comparison is the recommended EWRs determined by the VMFRP. The recommended EWRs are used because:

- VMFRP works have been designed to meet these requirements over a wide range of expected future Murray River flows
- they will achieve the environmental objectives for the sites and help to restore the ecological health of these important floodplains and wetlands.

The Victorian CMP environmental water regime was determined using hydrological data from modelling done by the Murray-Darling Basin Authority (MDBA) for the Victorian CMP Feasibility Study. This is the most recent and robust modelling done with constraints relaxed and the only modelling available that uses the Source modelling platform – the standard modelling platform now used by the MDBA.

Stage 1 of this project compared flow regimes at the four Central VMFRP sites and Stage 2 at the four West and East VMFRP Sites. Results for all sites are included in this Stage 2 report:

- East sites –
  - Gunbower National Park
  - Guttrum and Benwell Forests
- Central sites –
  - Vinifera
  - Nyah
  - Hattah Lakes North
  - Belsar-Yungera

- West sites –
    - Wallpolla Island
    - Lindsay Island.

The Stage 1 draft report was peer reviewed by Professor Rory Nathan from the University of Melbourne. His review is provided as **Attachment 1** to this report. Professor Nathan's comments have been incorporated into the methods used in this report, most notably with respect to assessing the ecological significance of differences between flows and corresponding inundation events provided by the VMFRP and CMP.

The analysis was designed to answer the following three questions:

1. Can VMFRP ecological objectives be met by CMP?
2. How might relaxing constraints affect the operation of VMFRP works?
3. How resilient are VMFRP and relaxing constraints under a changing climate?

The average frequency and median duration of flows and the variability of frequency and duration of flows were used to compare outcomes from the VMFRP and CMP flow regimes. The ecological significance of differences between the flow regimes was determined by characterising the 'hydrologic stress' resulting from the proposed CMP flows relative to flows that occurred prior to development of water resources and river regulation, i.e. the degree to which the proposed CMP flow regime shifts the frequency and/or duration of flows outside the range experienced prior to river regulation. The approach is described in Nathan et al. (2019). This was done for each of the 34 flow thresholds that describe the recommended EWRs across the eight VMFRP sites.

The differences in ecological outcomes are described in terms of the 'ecological disbenefit' at the eight sites resulting from only implementing the CMP compared to only implementing VMFRP. The three categories of disbenefit are Not Significant, Significant and Highly Significant (**section 3.2 and Attachment 1**).

Can VMFRP ecological objectives be met by CMP (Historic climate conditions)?

Figure 1 shows the highest ecological disbenefit for flow frequency or duration associated with implementing the CMP compared to VMFRP for the 34 flow thresholds being targeted by VMFRP. Of the 34 targeted flow thresholds 29 have a Significant or Highly Significant ecological disbenefit associated with the inundation events corresponding to the recommended flow frequency or duration. This means that very few of the VMFRP ecological objectives and EWRs at the eight VMFRP sites can be met by implementing the CMP under historic climate conditions. They can be met by the VMFRP. VMFRP is required at all the sites to provide confidence that the ecological health of the waterway, wetland, forest and woodland systems will be protected and restored. The degree of ecological disbenefit for frequency and duration for all EWR flow thresholds is presented in **Attachment 10**.

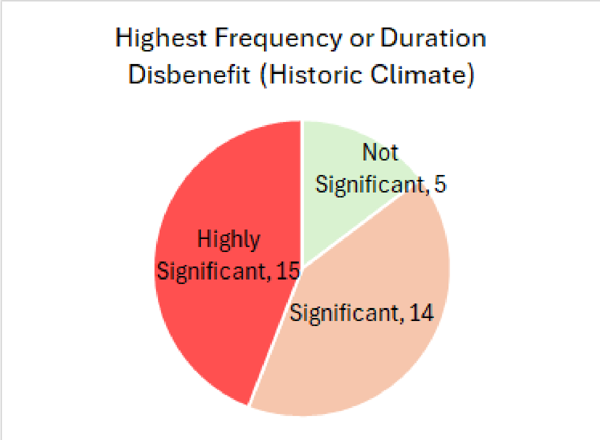

Figure 1 – Highest degree of potential ecological disbenefit for frequency or duration associated with implementing the CMP compared to VMFRP – Historic climate conditions

These findings are consistent with the objectives of the two projects and with results from the Victorian CMP Feasibility Study.

The CMP environmental flow recommendations on the Murray River targeted short duration (mostly 7 to 14 days, occasionally up to 30 days) overbank flows below minor flood level along the river. They were designed to prevent a decline in vegetation condition in lower lying areas of the floodplain (DEECA, 2024, p. 118). The flow recommendations aimed to maximise outcomes from the use of environmental water whilst recognising and effectively managing the risks and minimising and addressing the impacts on landowners (DEECA, 2024, p. 25).

These flow objectives align with the Victorian CMP Feasibility Study findings that, typically, relaxing constraints provides short duration events extending to the minor flood level with most benefits arising from more frequent watering of low-lying riparian vegetation and billabongs and flood runner ecosystems.

VMFRP environmental flow recommendations targeted optimal inundation frequencies and durations up to major flood level. They sort to restore ecological condition at the eight sites.

The results of the analysis in this report are consistent with the different project objectives, i.e. it confirms that VMFRP sites generally require more frequent and/or longer duration inundation at higher flowrates than those provided by the CMP.

The different objectives of environmental flow recommendations for the two projects also mean that additional environmental water recovery through the Basin Plan will not result in the CMP meeting VMFRP ecological objectives. More environmental water would allow the CMP to deliver additional shorter duration lower flow events, but these would not meet the generally longer duration higher flow events being targeted by VMFRP.

How might relaxing constraints affect the operation of VMFRP works?

At Vinifera and Nyah, because the CMP may slightly increase the frequency of events under historic climate conditions at the three lower EWR threshold flows compared to current river flows, its implementation may reduce the work required by VMFRP to meet the EWRs. A higher frequency of events will reduce the number of times that pumping is required to fill the areas within environmental works. While the CMP may help with supplying water to the sites it cannot provide flows to meet the required duration of inundation. Regulators will be able to detain flood water and prolong floods efficiently, mitigating the effects of shorter flood durations under the CMP.

The CMP will not influence the operation of VMFRP works at Gunbower National Park, Guttrum and Benwell Forests, Belsar-Yungera, Hattah Lakes North, Wallpolla Island and Lindsay Island.

How resilient are VMFRP and relaxing constraints under a changing climate?

Treadwell (2022) found that under historic and climate change conditions there is high confidence that there will be sufficient water to meet the water demands at VMFRP sites and sufficient capacity in the Murray River and its tributaries to deliver the water to the sites when needed.

Based on this analysis it is concluded that VMFRP's ability to meet ecological objectives at the eight floodplain sites is highly resilient to climate change because there is high confidence that the operation of VMFRP environmental works will enable recommended EWRs to be delivered under historic and climate change conditions.

Figure 2 shows the highest ecological disbenefit for frequency or duration associated with implementing the CMP compared to VMFRP for the 34 flow thresholds being targeted by VMFRP under Medium and High 2070 climate change.

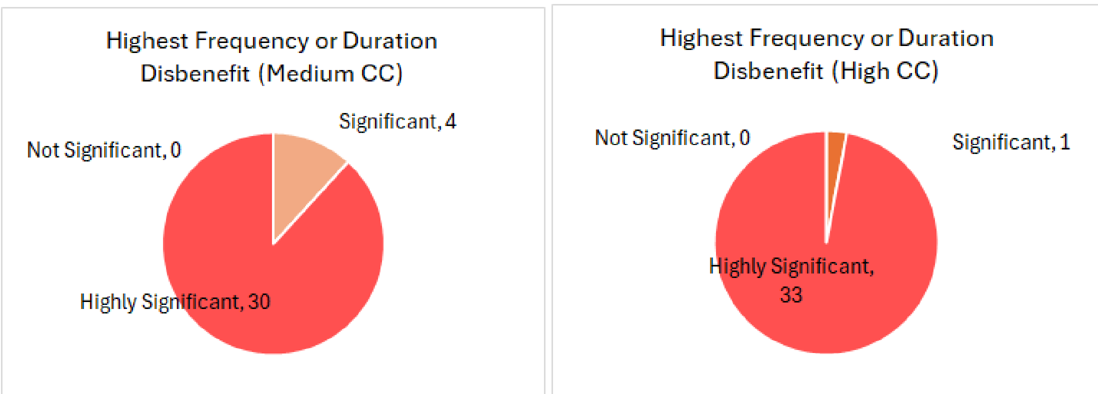

Figure 2 – Highest degree of potential disbenefit for frequency or duration associated with implementing CMP compared to VMFRP – Medium and High 2070 climate change

Under Medium climate change 30 of the 34 targeted flow thresholds have a Highly Significant ecological disbenefit associated with the targeted flow frequency or duration. Under High climate change 33 of the 34 targeted flow thresholds have a Highly Significant ecological disbenefit. The increased disbenefit occurs because the frequency and/or duration of CMP flows decrease substantially under Medium and High 2070 climate change scenarios.

This means that no VMFRP ecological objectives and EWRs at the eight VMFRP sites can be met by implementing the CMP under modelled Medium and High 2070 climate change conditions. VMFRP is required at all the sites to provide confidence that the ecological health of the waterway, wetland, forest and woodland systems will be restored. The CMP is much less resilient to climate change than VMFRP.

Conclusions of the Peer Reviewer

Professor Rory Nathan from the University of Melbourne peer reviewed the Draft Stage 1 Report of this project which looked at the Vinifera, Nyah, Belsar-Yungera and Hattah Lakes North VMFRP sites. The conclusions from the peer review report (**Attachment 1**) are consistent with the conclusions in this report. Professor Nathan stated that:

On the basis of the available information and the above considerations, it is concluded that:

- *The frequency and duration of environmental watering provided by relaxed constraints is of significantly less ecological benefit than VMFRP at the VMFRP sites – this is especially true for high magnitude watering events, but it is also generally the case for smaller flow thresholds.*
- *The efficacy of using relaxed constraints for delivery of environmental water to the VMFRP sites is expected to decrease under climate change, though our ability to estimate the behaviour of the underlying natural streamflow sequences is subject to increasing uncertainty with longer planning horizons.*
- *The delivery of environmental water by relaxed constraints is operationally more uncertain than that by the VMFRP works due to the inherent difficulties in forecasting rainfalls (and hence streamflows) at long lead times.*
- *VMFRP works represent a compelling solution to managing the uncertainty surrounding future water availability.*

Overall, it is considered that relaxed constraints have the potential to provide a valuable complement to VMFRP works for small watering events (and for in-stream and riparian reaches upstream and downstream of VMFRP sites), but they do not represent a credible alternative under either current or future climate conditions.

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Acronyms

BOC	Basin Officials Committee
CC	Climate Change
CEWO	Commonwealth Environmental Water Office
CMA	Catchment Management Authority
CMP	Constraints Measures Program
DEECA	Department of Energy, Environment and Climate Action
EWR	Environmental Water Requirement
EWRC	Ecological Water Regime Class
EVC	Ecological Vegetation Class (are a standard unit for classifying vegetation types in Victoria)
GBCCL	Goulburn, Broken, Campaspe, Coliban, Loddon Source Model
HS	Highly Significant
MDBA	Murray-Darling Basin Authority
MNES	Matters of National Environmental Significance
NS	Not Significant
S	Significant
SIAC	Standing Inquiry and Advisory Committee
SMM	Source Murray Model
CMP	Victorian Constraints Measures Program
VEWH	Victorian Environmental Water Holder
VMFRP	Victorian Murray Floodplain Restoration Project
WMA	Water Management Area

1 Introduction

1.1 Purpose

The purpose of this report is to compare the extent to which ecological objectives at Victorian Murray Floodplain Restoration Project (VMFRP) sites can be met by inundation patterns enabled through relaxing constraints as indicated by the Victorian Constraints Measures Program (CMP) Feasibility Study.

1.2 Scope

The project developed and applied a consistent method to determine if the watering regime expected to be delivered by the CMP can meet the recommended EWRs for the eight floodplain sites being restored by the VMFRP. It initially focused on the VMFRP sites that have environmental regulatory approval, i.e. the Central package of projects comprising Nyah, Vinifera, Hattah Lakes North and Belsar-Yungera. Following a Peer Review of the Stage 1 Report the analysis was extended to the East (Guttrum and Benwell Forests and Gunbower National Park projects) and West (Lindsay Island and Wallpolla Island projects) packages.

1.3 Background

To secure the long-term health of rivers and floodplains the Murray-Darling Basin Plan requires communities to use less water for irrigation, drinking and industry. These water savings are being returned to our rivers as environmental flows. To date 2,100 GL of water has been recovered for the environment.

The VMFRP is a response to the severe decline in the health of high-value floodplains caused by a century of river regulation and the increasing effects of climate change, which has severely threatened ecological communities and threatened species. It aims to restore health to 14,000 hectares of ecologically important floodplain at eight sites along the Murray River. The program will reconnect the river to its floodplain, efficiently and effectively delivering water where it's most needed, to ensure lasting, positive outcomes.

The VMFRP is an engineering solution for the long-term restoration and protection of eight culturally and environmentally significant sites on Victoria's Murray River floodplains. All along the Murray River there are operating rules in place for the fair and efficient delivery of water to optimise water use, as well as reducing any flood risk to towns, private properties and community infrastructure like bridges and roads.

The VMFRP will use infrastructure such as flow regulators, channels, containment banks, tracks and pumps to flood forests and wetlands and detain water on the floodplain. The works are used to fill gaps in the flow regime at VMFRP sites where more frequent or longer duration flooding is required to meet EWRs. The infrastructure at the eight sites will be operated flexibly to suit river conditions and environmental water requirements. For example:

- when the Murray River is high and flowing onto the floodplain, and the water will stay on the floodplain for long enough, regulators will be opened to leave the water to flow naturally

- when the Murray River is high and flowing onto the floodplain, but the flood won't last as long as needed, regulators will be closed to hold the water on the floodplain, before returning the water to the river
- if the floodplain is too dry, temporary pumps can be used to get environmental water onto the floodplain and regulators closed to hold the water there for as long as needed, before returning the water to the river.

An advantage of the VMFRP is that it can direct water to places that need it, without causing undesirable risks to infrastructure like roads, or putting floods across private land that has been cleared and is of low ecological value.

The environmental watering plans at each site will be flexible; each watering event will be planned according to the condition of the floodplain, water availability, river flows and timing since the last flood or watering. If funding is approved VMFRP will be able to begin managing watering of floodplains and wetlands in a few years.

The VMFRP builds on the knowledge gained through The Living Murray program which was a joint initiative between the Australian, NSW, Victorian and South Australian governments. The program implemented environmental works to restore the health of floodplains along the Murray River. The overall condition of the sites that have received water for the environment has followed a clear trajectory of improvement with most sites now in good or excellent condition (MDBA, 2024b).

The CMP is a separate initiative to promote river health by exploring how enhanced river flows could be delivered (i.e. 'piggybacking' regulated releases on unregulated flows), while managing risks and impacts to public and private land, infrastructure, stock, crops and people. The CMP aims to restore the small flow peaks in the heavily regulated rivers that used to occur naturally in winter and spring. The CMP aims to introduce water to low lying floodplain creeks and wetlands and to restore the seasonal flooding, breeding cues and migration pathways for aquatic fauna. In combination with unregulated flow peaks, the CMP can contribute to wider floodplain inundation along some areas of the Murray River. Currently river operators can regularly support in-channel outcomes across tributaries and rivers of the Murray. The CMP would enable operators to provide overbank flows and align tributary and Murray River flows while managing the risk of unintended flooding and impacts of managed inundation on landowners.

The MDBA released its Constraints Relaxation Implementation Roadmap in December 2024 (MDBA, 2024). It provides a guide for governments and communities in navigating the complex reforms required to relax constraints. The Roadmap identifies a 10-year program to achieve constraint relaxation. At present, there is no Commonwealth Government commitment to fund and implement the Roadmap.

2 Environmental watering regimes

2.1 VMFRP

The VMFRP environmental watering regime used in this analysis is the recommended environmental water requirements (EWRs) that will meet the ecological objectives at each site.

The recommended EWRs are used because VMFRP works have been designed to meet these requirements over a wide range of expected future Murray River flows. The EWRs were taken from VMFRP project descriptions for environmental approvals (VMFRP (2022a), (2022b), (2024), (Draft)).

Ecological objectives for VMFRP sites were developed over the past decade using a range of evidence including hydrological modelling, desktop and field-based flora and fauna surveys, workshops and other consultation with ecological and hydrological experts and project stakeholders.

Basin Plan hydrological modelling results presented in Gippel ((2014a) and (2014b)) supported the development of recommended EWRs and the design of VMFRP works and their operational strategies. This modelling used the MSM_Bigmod model with climate data from 1 July 1895 to 30 June 2009, river operating rules and practices in place in 2009 and assumed 2,750 GL of Basin Plan water recovery for the environment.

The operation of environmental works was designed to fill gaps between the recommended EWRs and flows expected with 2,750 GL of Basin Plan water recovery. If less water is recovered the works may have to be operate differently (e.g. more frequently) but the recommended EWRs remain unchanged.

The recommended EWRs at each VMFRP site were defined by the frequency and duration of flows which correspond to Ecological Water Regime Classes (EWRCs). EWRCs consist of one or more Ecological Vegetation Classes (EVCs) with similar inundation requirements. There are 14 EWRCs across the eight VMFRP sites:

1. Water Courses
2. Seasonal Anabranch and Billabong
3. Permanent Wetland
4. Semi-permanent Wetland
5. Temporary Wetland
6. Seasonal Wetland
7. Red Gum Swamp Forest
8. Red Gum Forest
9. Red Gum Forest and Woodland
10. Lignum Shrubland and Woodland
11. Black Box Woodland
12. Floodplain Lake
13. Episodic Wetlands
14. Alluvial Plain.

The frequency and duration of flows at reference gauges and locations along the Murray River represent expected flows at the eight VMFRP sites. The VMFRP sites and nearby reference gauges and locations in the Murray River are shown in **Table 1**. VMFRP works are used to fill gaps in the flow regime at VMFRP sites where more frequent or longer duration flooding is required to meet EWRs.

Table 1 – Reference gauges/locations used to represent flows at each VMFRP site

No.	VMFRP Site	Reference Gauge/Location
1	Gunbower Forest	Downstream of Torrumbarry Weir
2	Guttrum and Benwell Forests	Barham
3	Vinifera	Swan Hill
4	Nyah	Swan Hill
5	Belsar-Yungera	Downstream of Euston Weir
6	Hattah Lakes North	Downstream of Euston Weir
7	Wallpolla Island	Upstream of Lock 9 (VMFRP) and Lock 10 (CMP)
8	Lindsay Island	South Australian Border

2.2 CMP

The environmental watering regimes and scenarios for the CMP used in this analysis used the hydrological data from modelling done by the MDBA for the Victorian CMP Feasibility Study ((DEECA (2024) and MDBA (2022)). This is the most recent and robust modelling done with constraints relaxed and the only modelling available that uses the Source modelling platform – the standard modelling platform now used by the MDBA.

The analysis uses relaxed constraints flow rates that were officially notified to the Basin Officials Committee. The MDBA's Constraints Roadmap recognises that the cost and complexity of relaxing constraints was underestimated in the initial 2013 Constraints Management Strategy (MDBA, 2013) and that flow rates were conceptual and not supported by communities. Thus, if the CMP is implemented relaxed constraints flows may be lower than those notified and used in this study.

Key technical improvements in modelling for the Victorian CMP Feasibility study included:

- hydrological models were upgraded from a monthly time step to a daily time step which is required to model environmental water deliveries which vary significantly over a week
- for the first time in the modelling history of the Murray-Darling Basin, daily flow information from the Goulburn River hydrological model was used to provide flow data to the daily Murray River hydrological model. This is the first step to integrate Goulburn, Murrumbidgee and Murray models to improve analysis of integrated system response to relaxed constraints
- the hydrological models were used to investigate how climate change would influence the benefits of relaxing constraints.

The modelling upgrades improved the hydrological connection between the Murray and Goulburn Rivers and allowed the Murray system to order environmental releases from Eildon considering operational aspects of the Goulburn-Broken system including losses and travel time.

Details of modelling used to generate flow hydrographs used in this study are documented in a series of technical reports available at https://www.water.vic.gov.au/our-programs/murray-darling-basin/victorian-constraints-measures-program.

To determine the frequency and duration of flows a watering event must be defined. The definition of a spell/event for this study was:

- a spell could occur on any day of the year
- independent events were separated from other events by a period of 28 days when flow was less than threshold
- the duration of events with multiple, but non-independent peaks, was calculated as the sum of days above threshold
- valid events had a minimum duration of 14 days.

The CMP modelling used the Source Murray Model (SMM) and Goulburn, Broken, Campaspe, Coliban, Loddon (GBCCL) Source model using an historical climate sequence from 1 July 1895 to 30 June 2019. The modelling assumed approximately 2,100 GL of environmental water recovery under the Basin Plan. The relaxed constraints scenarios used in this analysis correspond to flow constraints relaxed to levels notified in business cases submitted to the Basin Officials Committee (BOC), i.e. Mid-Goulburn 10,000 ML/day and Lower Goulburn 17,000 ML/day; Hume to Yarrawonga (Doctors Point) 40,000 ML/day and Yarrawonga to Wakool 40,000 ML/day.

Table 2 summarises key features of the CMP scenarios used in this analysis.

Table 2 – Key features of the CMP modelling scenarios used in this analysis

Scenario	Model[1]	Water Recovery[2]	Climate	Operational Constraints[4]
Scenario 1 – Without Development	SMM and GBCCL	Not applicable	Historic – 1 July 1895 to 30 June 2019[3]	Not applicable
Scenario 2 - Current condition (reference)	SMM and GBCCL	CEWO recovery at June 2019 (~2100 GL)	Historic – 1 July 1895 to 30 June 2019[3]	Current, i.e. M10L9.5 – Y15D25
Scenario 3 - CMP Implemented (Constraints relaxed)	As above	As above	As above	M10L17 – Y40D40
Scenario 4 – Medium 2070 CC (Constraints relaxed)	As above	As above	Medium 2070 Climate Change[5]	M10L17 – Y40D40
Scenario 5 – High 2070 Climate Change (Constraints relaxed)	As above	As above	High 2070 Climate Change[5]	M10L17 – Y40D40

[1] Source Murray Model (SMM) and Source Goulburn, Broken, Campaspe, Coliban and Loddon Model (GBCCL)

[2] Environmental water recovery includes environmental water recovery by the Commonwealth Environmental Water Office (CEWO) as of June 2019. This level of water recovery is approximately 2,100 GL of water recovered under the Basin Plan. See page 3 of MDBA (2022) for details.

[3] See page 20 of DPE (2022) https://www.dpie.nsw.gov.au/water/our-work/water-infrastructure-nsw/sdlam/reconnecting-river-country-program/information-hub/technical-documents

[4] Current constraints are represented by M10L9.5 – Y15D25, i.e. Mid-Goulburn 10,000 ML/day and Lower Goulburn 9,500 ML/day; Hume to Yarrawonga (Doctors Point) 25,000 ML/day and Yarrawonga to Wakool 15,000 ML/day.

The relaxed constraints flows chosen represent the closest modelled relaxed constraints flows that were officially notified to the Basin Officials Committee in project business cases (M10L17 – Y40D40), i.e. Mid-Goulburn 10,000 ML/day and Lower Goulburn 17,000 ML/day; Hume to Yarrawonga (Doctors Point) 40,000 ML/day and Yarrawonga to Wakool 40,000 ML/day.

[5] Climate change scenarios used historical data scaling as described in DELWP (2020) https://www.water.vic.gov.au/our-programs/climate-change-and-victorias-water-sector/climate-change-water-resources/water-availability-climate-change-guidelines

3 Method

The method was designed to answer the following three questions:

1. Can VMFRP ecological objectives be met by CMP?
2. How might relaxing constraints affect the operation of VMFRP works?
3. How resilient are VMFRP and relaxing constraints under a changing climate?

3.1 Flow scenarios

The flow scenarios used in the analyses for this report are summarised in **Table 3**.

Table 3 – Flow scenarios used in the analyses undertaken in this report

No.	Name	Description
1	Recommended Environmental Water Requirements (EWRs)	Recommended environmental water requirements (EWRs) for VMFRP sites determined as part of the development of the VMFRP project. The EWRs represent the flow/inundation regime that will be delivered by VMFRP projects at each of the eight floodplain sites
2	Scenario 1 – Without Development (Scen 1 – W/O Dev)	CMP modelled flows with major storages and water extractions removed. In this analysis it is used to provide insights into the natural variability of river flows prior to regulation of the system. Knowledge of flow variability is important to understand if differences in flow/inundation frequency and duration between VMFRP and CMP will result in different ecological outcomes

3	Scenario 2 – Current (Scen 2 – Current)	CMP modelled flows assuming existing constraints (including river operating rules) are in place and 2,100 GL of Basin Plan water recovery. In this analysis it represents Murray River flows under existing operating arrangements and is compared to Scenario 3 – CMP to determine how CMP implementation may affect the operation of VMFRP works
4	Scenario 3 – CMP (Scen 3 – CMP)	CMP modelled flows assuming constraints are relaxed to levels notified to the Basin Officials Committee (BOC) and 2,100 GL of Basin Plan water recovery
5	Scenario 4 – Medium 2070 Climate Change (Scen 4 – Med CC)	CMP modelled flows assuming constraints are relaxed to levels notified to BOC, 2,100 GL of Basin Plan water recovery and Medium 2070 climate change
6	Scenario 5 – High 2070 Climate Change (Scen 5 – High CC)	CMP modelled flows assuming constraints are relaxed to levels notified to BOC, 2,100 GL of Basin Plan water recovery and High 2070 climate change

3.2 Frequency and duration statistics

The frequency and duration of flows are used to compare VMFRP and CMP flow regimes. VMFRP frequency and duration statistics are assumed to be the same as those for the EWRs determined by hydrological and ecological experts.

The average frequency and median duration of flows for the CMP are used in charts in the main body of this report to compare flow regimes. These statistics were derived from outputs of a spells analysis performed on data from modelling done as part of the Victorian CMP Feasibility Study. The frequency and duration statistics were determined by:

- Average frequency – for a given flow threshold, dividing the total number of events equal to or greater than 14 days duration in the 124-year modelling period by 124 and multiplying by 10 to get the average number of events per 10 years
- Median duration – for a given flow threshold, taking the duration of the middle event in all events that occurred over the 124-year modelling period. If there was an even number of events the median was determined by averaging the middle two events.

The variability of frequency and duration for the CMP is also used as a check on whether the differences between VMFRP and CMP flows and corresponding inundation events are expected to be ecologically significant given the underlying variability in Without Development/natural flows. The ecological significance of differences between the flow regimes was determined by characterising the ‘hydrologic stress’ resulting from the proposed CMP flows relative to flows that occurred prior to development of water resources and river regulation, i.e. the degree to which the proposed CMP flow regime shifts the frequency and/or duration of flows outside the range experienced prior to river regulation (Nathan, McMahon, Peel, & Horne, 2019).

The variability was represented by the 25th, 50th and 75th percentile of frequency and duration. The percentiles were determined by:

- Frequency – for a given flow threshold, counting the number of events in each of 12 non-overlapping 10-year sequences[1] over the 124-year modelling period and determining the percentiles of the resultant 12 frequency values
- Duration – for a given flow threshold, determining the percentiles of event durations over the full 124-year modelling period.

The above approach means that there may be some minor differences between the average CMP frequencies presented in the charts in the main body of the report and the 50th percentile frequencies presented in **Attachments 2 to 9**.

There should not be any differences between the CMP median durations presented in the main body of the report and those in **Attachments 2 to 9**.

Based on advice from the Peer Review report (**Attachment 1**) the differences in ecological outcomes are described in terms of the 'ecological disbenefit' at the eight sites resulting from only implementing the CMP compared to only implementing VMFRP. The three categories of disbenefit are (**Figure 3**):

1. **Not significant** disbenefits denote results where the CMP yields median ecological outcomes that lie within the 50% range of natural variability found under "baseline" conditions. The baseline adopted in this report relates to the outcomes over the 124 years of historical climate corresponding to the Without Development scenario (Scen 1 – W/O Dev).
2. **Significant** disbenefits denote results where the median ecological outcome of using CMP lies below the 50% range of natural variability found under "baseline" conditions. Attention is given here only to results where the outcomes are worse, as it is assumed that opportunities to provide watering events more frequently or longer than found under the Without Development scenario will not be prioritised.
3. **Highly Significant** disbenefits denote results where the full 50% range of outcomes under the CMP lies below the 50% range of natural variability found under "baseline" conditions; that is, where the distribution of CMP outcomes is largely worse than the range of conditions that the ecology is assumed to have adapted to.

The disbenefit is not assessed if the recommended EWR (and VMFRP) median or average frequency and duration of flows are less than the central 50% range of without development flows, i.e. VMFRP is not targeting frequency or duration of flows that are close to natural.

[1] Events in the final four years of the 124-year modelling period were not included in the analysis.

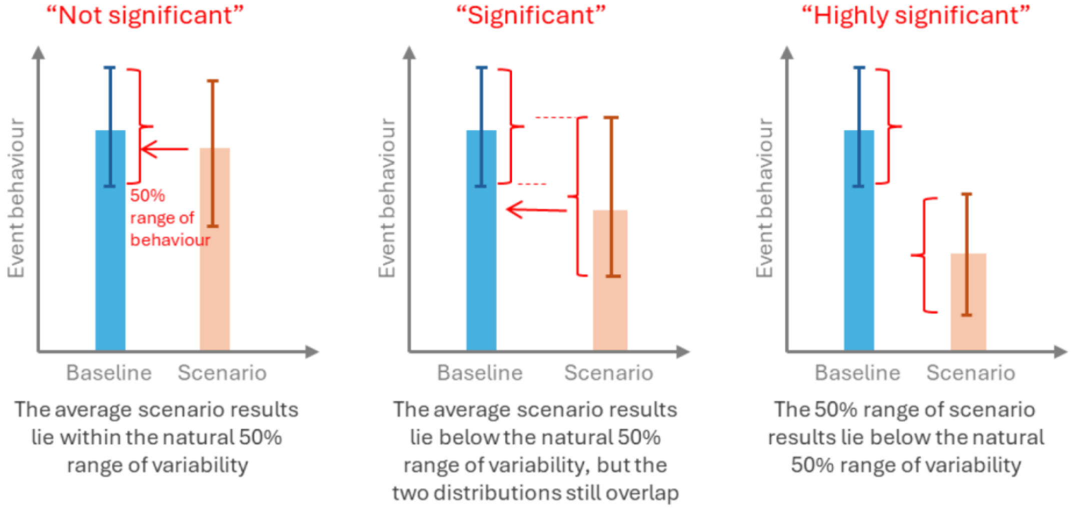

Figure 3 – Definition of degree of ecological significance for the potential disbenefit in using CMP compared to VMFRP environmental works. Note that in this analysis: i) Event behaviour is the frequency or duration of flow; ii) Baseline is the Without Development scenario (Scen 1 – W/O Dev); Scenario is either Scenario 3 – CMP (Scen 3 – CMP), Scenario 4 – Medium 2070 Climate Change (Scen – 4 Med CC) or Scenario 5 – High 2070 Climate Change (Scen 5 – High CC)

3.3 Questions investigated by the analysis

The three questions investigated in this analysis and the methods used to answer them are discussed in the following sections.

3.3.1 Can VMFRP ecological objectives be met by CMP?

Firstly, the recommended environmental water requirements (EWRs) that will be achieved by operation of VMFRP works at each site were compared to modelled flowrates expected to be achieved by the CMP (Scen 3 – CMP). The ecological consequences of the differences between the recommended EWRs and the CMP scenario flowrates for each EWRC were then described. This determination was based on expert opinion considering the magnitude of the differences in frequency and duration.

Secondly, the ecological significance of the differences between the recommended EWRs and CMP flowrates for each EWRC were checked. The check was based on the magnitude of the differences in CMP and VMFRP frequency and duration compared to the underlying variability of Without Development flows as per **Figure 3**.

Thirdly, the significance of the ecological disbenefits of using the CMP compared to VMFRP to water the eight floodplain sites was determined for the recommended EWR flows for each of the 34 EWRCs. The determination was based on the magnitude of the differences between CMP and VMFRP flow frequency and duration compared to the underlying variability of Without Development flows as per **Figure 3**.

Information used:

- recommended EWRs for the VMFRP sites are from environmental approval Project Descriptions. These data were used for charts in the main body of the report and the charts in **Attachments 2 to 9**.

- CMP (Scen 3 – CMP) average frequency and median duration statistics calculated using MDBA modelling results from the Victorian CMP Feasibility Study for each EWRC and corresponding flow threshold. These data were used for charts in the main body of the report.
- CMP (Scen 3 – CMP) and Without Development (Scen 1 – W/O Dev) 25^{th}, 50^{th} and 75^{th} percentile frequency and duration statistics from MDBA modelling results from the Victorian CMP Feasibility Study for each EWRC and corresponding flow threshold. These data were used for charts in **Attachments 2 to 9**.

3.3.2 How might relaxing constraints affect the operation of VMFRP works?

This question is posed to understand if changes to flows provided by the CMP (Scen 3 – CMP) compared to current flows (Scen 2 – Current) would alter how VMFRP structures (detaining water, pumping) would be operated, e.g. if the CMP increased the frequency of flows at a given threshold compared to current flows then there may be less need to pump water into a site.

Information used:

- Current (Scen 2 – Current) and CMP (Scen 3 – CMP) average frequency and median duration statistics calculated using MDBA modelling results from the Victorian CMP Feasibility Study for each EWRC and corresponding flow threshold. These data were used for charts in the main body of the report.

3.3.3 How resilient are the projects under a changing climate?

The analysis first determined whether the operation of VMFRP works is likely to be able to maintain the recommended EWRs under climate change conditions, e.g. would sufficient water be available to operate VMFRP works. The results informed a discussion about VMFRP resilience to climate change.

For the CMP, frequency and duration results for Medium (Scen 4 – Med CC) and High (Scen 5 – High CC) climate change scenarios modelled for the Victorian CMP Feasibility study were compared to recommended EWRs for each site. Comment was then made about the ecological consequences of the differences between the recommended EWRs and the CMP climate change scenario flowrates for each EWRC and corresponding flow threshold. This determination was based on expert opinion considering the magnitude of the differences in frequency and duration.

The significance of the ecological disbenefit in using CMP compared to VMFRP environmental works was determined for frequency and duration for each EWR flow threshold as per **Figure 3**.

Information used:

- recommended EWRs for the VMFRP sites from environmental approval Project Descriptions. These data were used for charts in the main body of the report and the charts in **Attachments 2 to 9**
- average frequency and median duration statistics calculated using MDBA modelling results from the Victorian CMP Feasibility Study for each EWRC and corresponding flow threshold for the following scenarios – CMP (Scen 3 – CMP), Medium 2070 Climate Change (Scen 4 – Med CC) and High 2070 Climate Change (Scen 5 – High CC). These data were used for charts in the main body of the report
- 25^{th}, 50^{th} and 75^{th} percentile frequency and duration statistics calculated using MDBA modelling results from the Victorian CMP Feasibility Study for each EWRC and corresponding flow threshold for the following scenarios – Without Development (Scen 1 – W/O Dev), CMP (Scen 3 – CMP), Medium 2070 Climate Change (Scen 4 – Med CC)

and High 2070 Climate Change (Scen 5 – High CC). These data were used for charts in **Attachments 2 to 9**.

- Treadwell (2022) Technical Memo on VMFRP Environmental Water Availability and Deliverability.

4 Results

4.1 VMFRP resilience to climate change

Treadwell (2022) investigated whether:

- under historical and climate change conditions there is adequate water available from environmental allocations to environmental entitlements, unregulated flows and other sources (e.g. carryover, return flows and trade) to meet the environmental water demands of VMFRP sites
- there is sufficient delivery capacity in the Murray River and its tributaries to deliver the available water to VMFRP sites when it is required.

The investigation found that under historical and climate change conditions there is high confidence that there will be sufficient water to meet the water demands at VMFRP sites and sufficient capacity in the Murray River and its tributaries to deliver the water to the sites when needed.

The conclusion that there will be sufficient water was based on:

- relatively minor water demands at VMFRP sites compared to the availability of environmental water – MDBA modelling indicates that on average approximately 70 GL/year will be required to meet the watering requirements for VMFRP sites (MDBA, 2017)
- large volumes of allocations to environmental entitlements under long-term average and climate change conditions are available for environmental watering. Annual allocations to Victorian and Commonwealth environmental entitlements is expected to be in the order of 2,000 GL in most years under long-term average conditions. Under a 2070 dry climate scenario the Commonwealth environmental allocation would still in the order of 600 GL in 70% of years.
- additional water for the environment is also available from unregulated flow, smart use of allocated water through carryover and the reuse of return flows, and if necessary, temporary trade
- high priority will be given to watering high conservation value sites, which includes Ramsar sites and sites that support Matters of National Environmental Significance (MNES) and threatened ecological flora and fauna and communities. VMFRP sites fall within this category because of the important environmental values they contain, including MNES (some sites are also Ramsar sites or associated with Ramsar sites), threatened flora and fauna and high value EVCs – this has been confirmed by the Victorian Environmental Water Holder (VEWH).

The conclusion that this water will be able to be delivered to VMFRP sites is based on:

- MDBA modelling in 2017 for the determination of supply measure offsets which showed water could be delivered to most VMFRP sites at the specified frequencies (MDBA, 2017)
- results from more recent analysis of flow and river capacity data provided by the MDBA, which shows that over the last decade there was sufficient capacity to deliver VMFRP demands in most years when taking into consideration the frequency and timing of managed inundation.

Based on Treadwell's analysis it is concluded that VMFRP's ability to meet ecological objectives at the eight floodplain sites is highly resilient to climate change because there is high confidence that the operation of VMFRP environmental works will enable recommended EWRs to be delivered under long-term average and climate change conditions.

4.2 Gunbower National Park

4.2.1 Site characteristics

The Gunbower Forest floodplain system extends over approximately 20,000 ha between Torrumbarry in the south-east and Koondrook in the north-west. Gunbower Forest is one of the Living Murray Icon Sites. The Gunbower National Park VMFRP complements and builds on the ecological outcomes of the Living Murray environmental works by extending watering to the southern parts of the forest. Together with Living Murray works it will enable a total of approximately 5,500 hectares of the forest to be watered.

The Gunbower National Park VMFRP project proposes to deliver and manage environmental water in Gunbower National Park in the upstream part of Gunbower Island. Water will be managed in two areas over a total area of 706 ha (**Figure 4**):

- Upper Gunbower Water Management Area (WMA) (243 ha) which includes Camerons Creek, Black Charlie Lagoon and Baggots Creek area
- Middle Gunbower WMA (463 ha) which includes the Emu Hole Lagoon, Pig Swamp and the floodplain between Old Straight Cut Channel and Upper Spur Creek.

Flows at this location reference the Torrumbarry downstream gauge.

4.2.2 Environmental Water Requirements

The EWR aims to maintain Permanent and Semi-permanent Wetlands in the Upper Gunbower area with flows of 25,000 ML/day. Black Charlie Lagoon and Camerons Creek are deep localised depressions that provide important habitat and a drought refuge for vegetation-dependent fish species and support source populations of native fish that disperse to the wide forest during floods. They also provide breeding habitat for waterbirds and food sources for birds and bats.

Temporary Wetlands are shallow depressions and flood runners within the forest and woodland of the National Park with diverse sizes and aquatic plant assemblages. Temporary Wetlands are inundated at a range of flows between 30,000 and 45,000 ML/day and include Baggots Creek Swamp, Deep Creek Swamp, McGillvray Swamp and Red Rise Swamp. These areas are highly productive habitat for fish including channel-specialist fish that access the forest during floods. Temporary wetlands provide shelter and productive foraging areas for waterbirds as well as bats and mammals.

Red Gum with flood dependent understorey has a target flow of 45,000 ML/day in the Upper Gunbower area and 30,000 ML/day in the Middle Gunbower area. When flooded, these areas provide important seasonal habitat for aquatic fauna such as frogs and fish which disperse from refuge habitat and breed in large numbers. Waterbirds, including waders, will make use of the abundant prey in the understorey. Flooding initiates the emergence of a range of aquatic plants, increasing the diversity of the forest.

The ecological objectives for the EWRCs at Gunbower National Park are shown in **Table 4**. The EWRs for the EWRCs at Gunbower Forest are shown in **Table 5**.

Table 4 – Ecological objectives for EWRCs at Gunbower National Park (NCCMA (2014a))

Specific Objective	**Water Regime Class**
Maintain and where possible improve the current diversity of the small-bodied native fish community in Black Charlie Lagoon	• Permanent Wetlands
Support waterfowl breeding events in most years	• Permanent Wetlands • Temporary Wetlands
Contribute to the success of breeding events of colonial nesting waterbirds in the lower Gunbower Forest by providing foraging areas in Gunbower National Park	• River Red Gum with Flood Dependent Understorey • Temporary Wetlands
Maintain and where possible increase the current diversity of threatened wetland bird species	• Permanent Wetlands • Temporary Wetlands
Achieve an appropriate cover and diversity of species characteristic of the plant functional groups	• River Red Gum with Flood Dependent Understorey
Maximise the proportion of trees with healthy canopy condition	• River Red Gum with Flood Dependent Understorey
Maintain and where possible increase the current diversity of threatened flora species	• River Red Gum with Flood Dependent Understorey • Temporary Wetlands

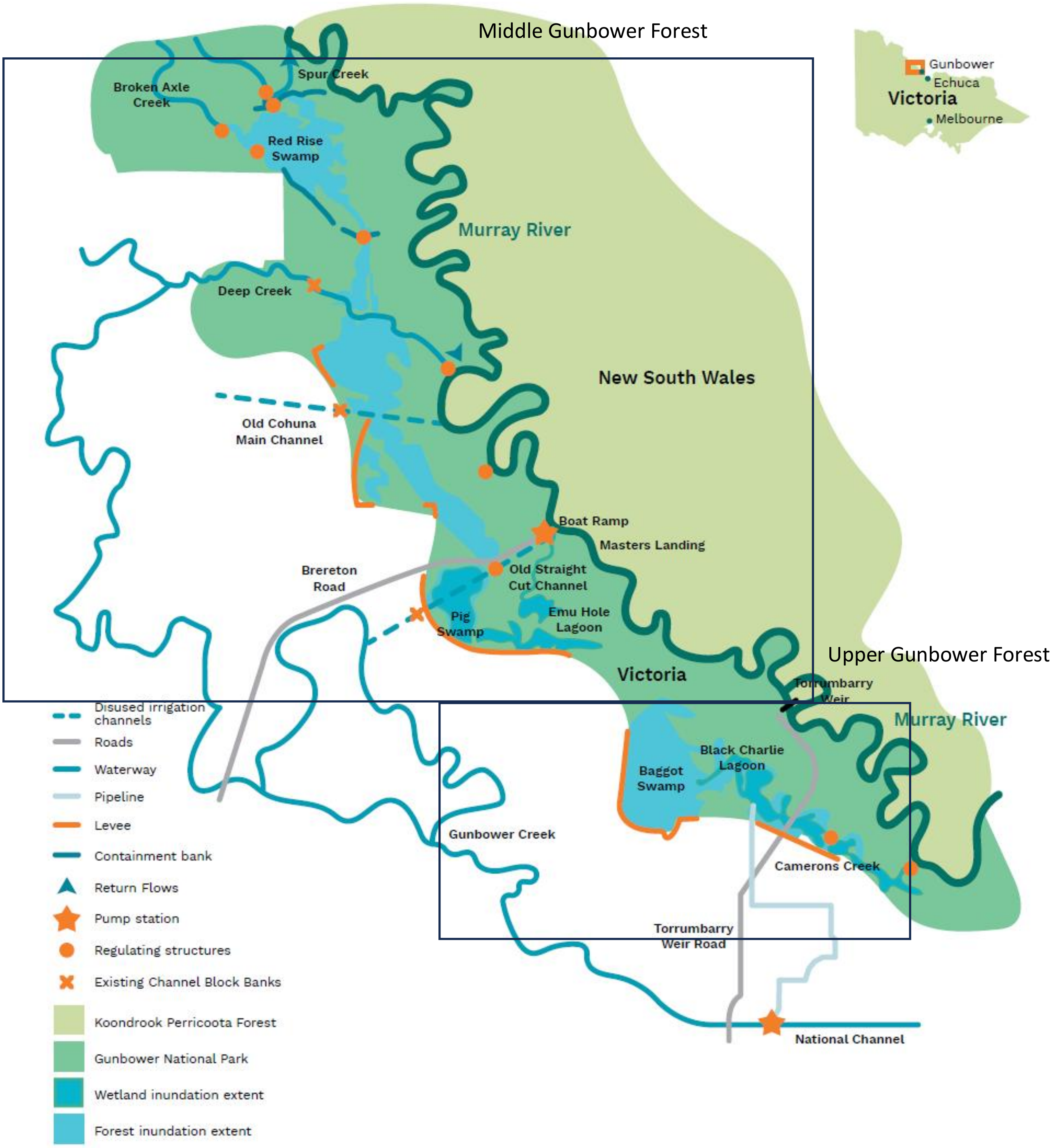

Figure 4 – Schematic of Middle and Upper Gunbower Forest (Source: Gunbower National Park Fact Sheet, https://www.vmfrp.com.au/wp-content/uploads/2020/11/VMFRP_FactSheet_A4_Gunbower_1120_04.pdf)

Table 5 – EWRCs and EWRs at Gunbower National Park (VMFRP (2024))

Ecological Water Regime Class (EWRC)	Flow Threshold	Environmental Water Requirement (EWR)
Permanent Wetland	25,000 ML/day	• Frequency – 10 events in 10 years average • Duration – 2.7 months median peak duration
Semi-permanent Wetlands	30,000 ML/day	• Frequency – 8 events in 10 years average • Duration – 3.0 months median peak duration
Red Gum Forest and Temporary Wetlands	30,000 to 45,000 ML/day	• Frequency – 8 events in 10 years average • Duration – 2.0 months median peak duration (Red Rise Swamp and Upstream of Deep Creek) • Duration - 3.0 months median peak duration (Downstream of Deep Creek)
Red Gum Forest and Woodland	50,000 ML/day	• Frequency – 4 events in 10 years average • Duration – 1.2 months median peak duration

4.2.3 Can VMFRP ecological objectives be met by CMP?

Figure 5 shows median duration and average frequency of flows for four flow thresholds at Gunbower National Park corresponding to the recommended EWRs (and VMFRP), CMP flows with constraints relaxed (Scen 3 – CMP) and Current flows with existing constraints in place (Scen 2 – Current).

The CMP does not increase the frequency or duration of the current flow regime. The CMP median event durations are generally similar to the EWRs at all flow thresholds. However, when combined with the very low event frequencies, the water regime is insufficient to meet ecological objectives. The CMP does not meet EWRs at any flow threshold.

Under the CMP:

- wetlands will retain the current low capacity to support waterbird breeding
- woodland and forest understorey will have low canopy health, low productivity, low understorey plant cover and diversity and will have low capacity to provide waterbird foraging habitat.

Data on the variability in median flow frequency and duration reinforces these results. The charts in **Attachment 2** show that:

- the median frequency of events at all flow thresholds under the CMP lies below the central 50% range of natural variability (Scen 1 – W/O Dev)
- the median frequency and duration of EWR flows, which will be achieved by VMFRP, lie within the central 50% of Without Development flow durations at all flow thresholds.

This indicates that the differences in EWRs (and VMFRP inundation) and the CMP flows are likely to be ecologically significant when the natural underlying variability of flows is considered. This is further illustrated in **Table 6** which shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant or Significant for the flow frequency at all flow thresholds under historic climate.

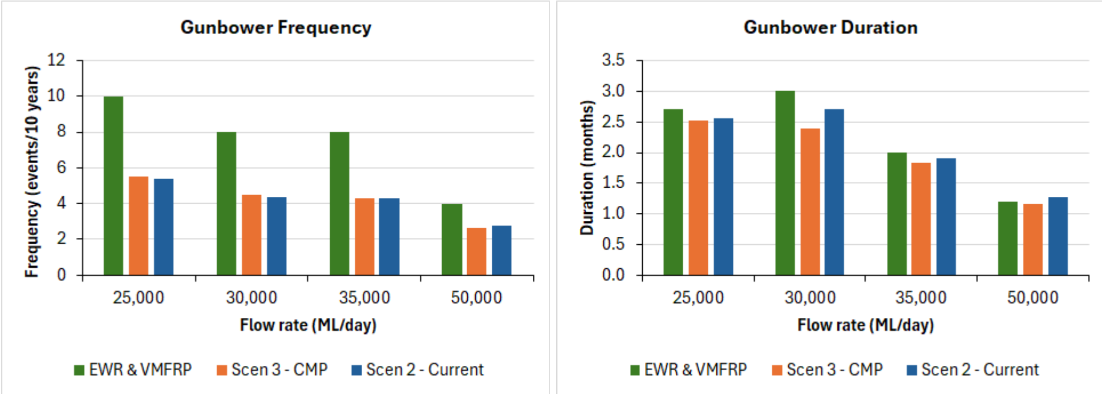

Figure 5 – Frequency and duration of events at Gunbower National Park for 25,000, 30,000, 35,000 and 50,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 2 – Current

Table 6 – Significance of the potential ecological disbenefit in using CMP compared to VMFRP environmental works at Gunbower National Park

	EWR			Frequency			Duration		
EWRC	Flow Threshold (ML/day)	Average Frequency	Median Duration	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
Permanent Wetland	25,000	10	2.7	HS	HS	HS	NS	S	HS
Semi-Permanent Wetland	30,000	8	3	HS	HS	HS	NS	S	S
Red Gum Forest and Temporary Wetlands	35,000	8	2	HS	HS	HS	NS	S	HS
Red Gum Forest and Woodland	50,000	4	1.2	S	HS	HS	NS	NS	HS

4.2.4 How might relaxing constraints affect the operation of VMFRP works?

Figure 5 shows that the CMP (Scen 3 - CMP) has little effect on any of the EWR thresholds. Implementation of the CMP will therefore not affect the operation of VMFRP works at Gunbower National Park.

4.2.5 How resilient are the projects under a changing climate?

Section 4.1 demonstrated that VMFRP can meet ecological objectives and EWRs at the eight floodplain sites under climate change and that it is highly resilient to climate change.

Figure 6 shows that event frequency for all EWR thresholds decreases with increasing climate change for the CMP Medium and High climate change scenarios. Medium CC event frequencies are less than Scenario 3 – CMP at all flow thresholds. For Scenario 5 – High CC, flow thresholds are exceeded rarely or not at all.

There is an overall decline in event duration under the Medium and High CMP climate change scenarios compared to Scenario 3 – CMP which is based on historic climate. Event durations under the Medium and High CC scenarios are less than half of Scenario 3 - CMP at the 25,000 and 30,000 ML/day. The median durations for the High CC scenario are based on very few events.

Table 6 shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant for flow frequency at all flow thresholds under Medium and High CC. It is also Highly Significant or Significant for duration at all but one flow threshold under Medium and High CC.

At Gunbower National Park the CMP is much less resilient to climate change than VMFRP as it would not meet VMFRP ecological objectives under a hotter drier climate and the health of the floodplain would decline.

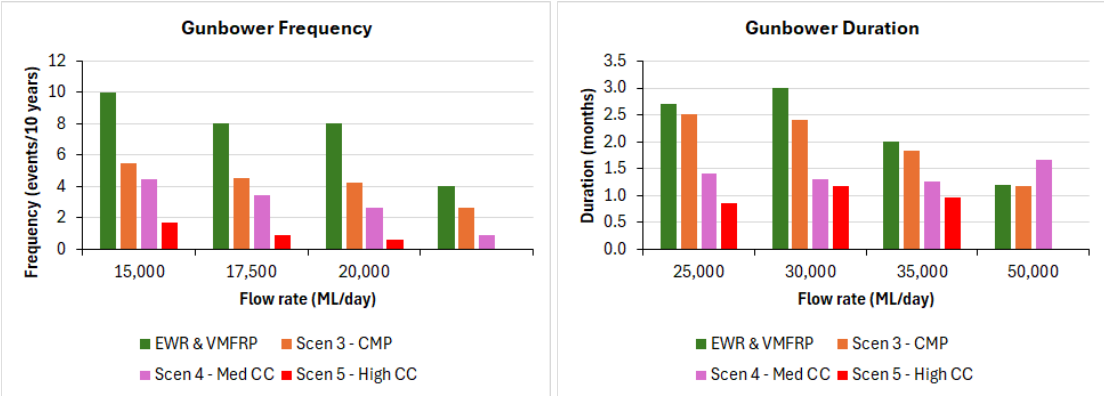

Figure 6 – Frequency and duration of events at Gunbower National Park for 25,000, 30,000, 35,000 and 50,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 4 - Medium 2070 climate change; iv) Scenario 5 - High 2070 climate change

4.3 Guttrum and Benwell Forests

4.3.1 Site characteristics

Guttrum and Benwell Forests are adjacent floodplain systems located downstream of Koondrook. The sites extend over 1,270 ha and 660 ha, respectively.

The Guttrum and Benwell Forests VMFRP project proposes to deliver and manage environmental water over an area of 1,152 ha in the two forests (**Figure 7**):

- the Guttrum Forest WMA
- the Benwell Forest WMA.

Flows at this location reference the Barham gauge.

4.3.2 Environmental Water Requirements

The EWRs aim to maintain Semi-permanent Wetlands which are inundated by flows of 21,000 ML/day. The wetlands comprise shallow marsh, open water, reed beds and herbland. Red Gum was excluded from the wetlands under the natural flooding regime. Areas subject to shallow flooding in spring support macrophytes-ribbons, while deeper areas that remain flooded in summer and autumn are dominated by rushes and reeds. Wetland fringes support herblands and low-growing emergent species.

Semi-permanent Wetlands support numerous waterbird species by providing shelter, nesting habitat and food sources. Flooded reedy vegetation provides habitat for frogs and birds such as bitterns and crakes. The seasonal inundation and recession of flood water stimulates microbial and planktonic productivity which in turn maintains invertebrate, frog and fish productivity. The fringing Red Gums provide nesting habitat for waterbirds.

Red Gum with water-dependent understorey is inundated by flows exceeding 26,000 ML/day at Guttrum and 24,000 ML/day at Benwell. The understorey is dominated by grassy perennial species that require seasonal flooding, combined with rushes and reeds in local depressions. Floating-leaved aquatic macrophytes appear during winter and spring flooding but die off as the forest dries out.

When flooded, the forest provides important seasonal habitat for aquatic fauna such as frogs and fish which disperse from wetlands and breed in large numbers. Waterbirds, including waders, find prey in the flooded understorey. Damp soil left by retreating flood water promotes the growth of grasses and other understorey plants. The understorey provides a range of food sources for woodland birds including seeds and nectar.

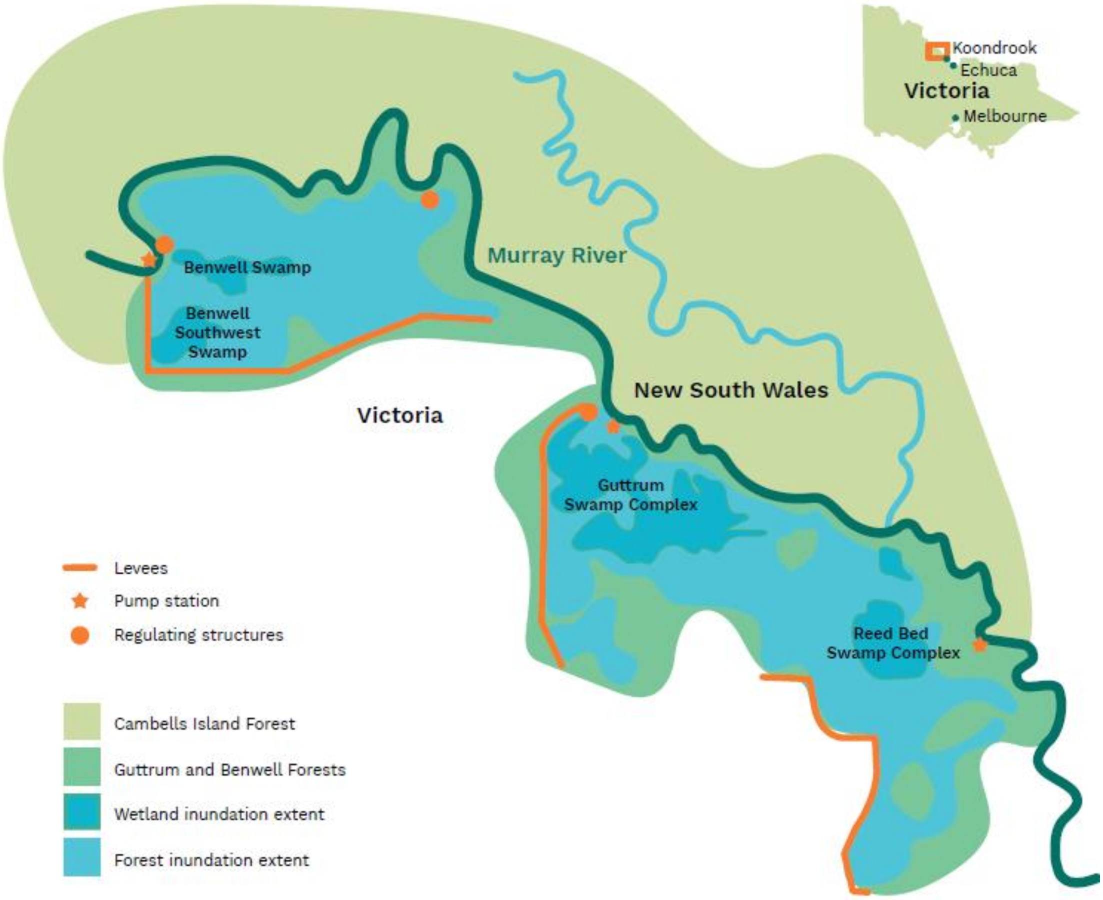

Figure 7 – Schematic of Guttrum and Benwell Forests (Source: Guttrum and Benwell Forests Fact Sheet, https://www.vmfrp.com.au/wp-content/uploads/2020/11/VMFRP_FactSheet_A4_Guttrum_Benwell_1120_04.pdf)

Red Gum with flood-tolerant understorey is inundated by flows exceeding 27,000 ML/day. The vegetation tolerates longer intervals between floods but is dependent on floods to maintain productivity, promote regeneration and exclude terrestrial species. Woodland vegetation is an abundant source of insects and other invertebrates and provides nesting, sheltering and foraging habitat for woodland birds, reptiles and mammals.

The ecological objectives for the EWRCs at Guttrum and Benwell Forests are shown in **Table 7**. The EWRs for the EWRCs at Guttrum and Benwell Forests are shown in **Table 8**.

Table 7 – Ecological objectives for EWRCs at Guttrum and Benwell Forests (Source: NCCMA (2014b))

Specific Objective	**Water Regime Class**
Improve Semi-permanent wetlands by: • providing appropriate cover and diversity of plant species • reducing River Red Gum encroachment • providing suitable habitat for threatened flora • maintaining and where possible increasing the diversity of threatened flora species • reducing the area of high threat weed species	• Semi-permanent Wetlands
Support a suite of waterbirds including waterfowl, colonial waterbirds and other wetland-dependent species	• Semi-permanent Wetlands
Providing foraging areas for colonial waterbirds	• Semi-permanent Wetlands • River Red Gum with Flood-dependent Understorey
Providing suitable habitat for threatened bird species	• Semi-permanent Wetlands • River Red Gum with Flood-dependent Understorey
Maintaining and where possible increasing the diversity of threatened bird species	• Semi-permanent Wetlands • River Red Gum with Flood-dependent Understorey
Improve River Red Gum Forest values by: • achieving appropriate cover and diversity of understorey species • improving canopy condition in River Red Gums • maintaining and where possible increasing diversity of threatened species • reducing the area of high threat weed species	• River Red Gum with Flood-dependent Understorey

Table 8 – EWRCs and EWRs at Guttrum and Benwell Forests (VMFRP (2024))

Ecological Water Regime Class (EWRC)	Flow Threshold	Environmental Water Requirement (EWR)
Semi-permanent Wetlands	21,000 ML/day	• Frequency – 9 events in 10 years average • Duration – 5 months median peak duration
Red Gum Forest	Guttrum 26,000 ML/day Benwell 24,000 ML/day	• Frequency – 8 events in 10 years average • Duration – 4.1 months median peak duration
Red Gum Forest and Woodland	>27,000 ML/day	• 4 events in 10 years average • 3 months median duration

4.3.3 Can VMFRP ecological objectives be met by CMP?

Figure 8 shows median duration and average frequency of flows for four flow thresholds at Guttrum and Benwell Forests corresponding to the recommended EWRs (and VMFRP), CMP flows with constraints relaxed (Scen 3 – CMP) and Current flows with existing constraints in place (Scen 2 – Current).

The CMP does not substantially increase event frequency above the current flow regime and does not meet EWRs at flow thresholds of 26,000 ML/day or lower. Event frequency is one half to two thirds of the environmental water requirement at flow thresholds of 26,000 ML/day and lower. Median event duration under the CMP is slightly shorter than the current flow regime at all thresholds, but substantially shorter than the EWR.

The water requirement of Red Gum Forest and Woodland, which is inundated by flows of 27,000 ML/day and higher, is met in the Current and CMP scenarios.

Under the CMP:

- Semi-permanent wetlands will be infrequently and briefly flooded, will continue to be invaded by Red Gum, have limited aquatic plant cover and diversity, and will provide poor and infrequent habitat and breeding opportunities for waterbirds
- Red Gum Forest will have degraded canopy condition with a sparse understorey lacking in species diversity that provides poor quality habitat for threatened fauna
- the productivity and condition of Red Gum Forest and Woodland will be maintained.

Data on the variability in median flow frequency reinforces these results which are based on average frequency and median duration. The duration plot in **Attachment 3** shows that:

- the central 50% range of frequency of events at the three lower flow thresholds under the CMP lies below the central 50% range of natural variability (Scen 1 – W/O Dev)

- the median frequency and duration of EWR flows, which will be achieved by VMFRP, lie within the central 50% of Without Development flow at the three lower flow thresholds.

This indicates that the differences in EWRs and the CMP flows are likely to be ecologically significant when the natural underlying variability of flows is considered. This is further illustrated in **Table 9** which shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant for flow frequency at the three lower flow thresholds under historic climate[2].

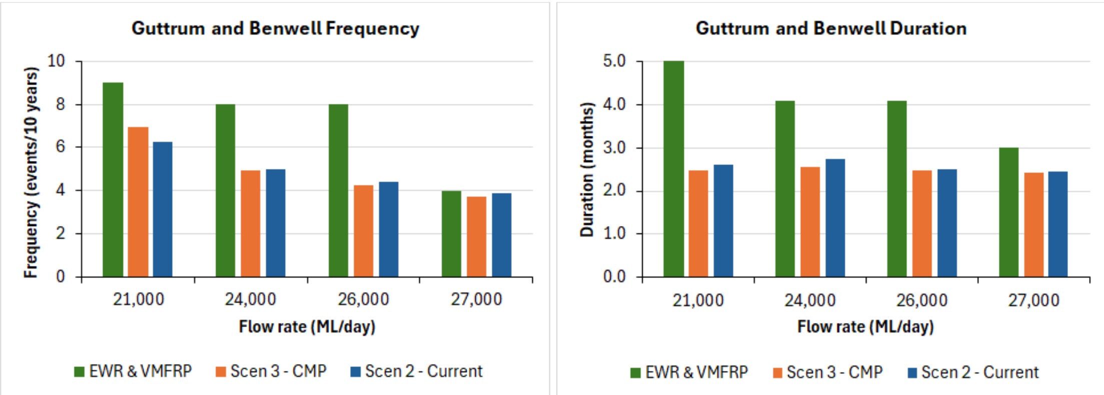

Figure 8 – Frequency and duration of events at Guttrum and Benwell Forests for 21,000, 24,000, 26,000 and 27,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 2 – Current

Table 9 – Significance of the potential ecological disbenefit in using CMP compared to VMFRP works at Guttrum and Benwell Forests

	EWR			Frequency			Duration		
EWRC	Flow Threshold (ML/day)	Average Frequency	Median Duration	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
Semi-Permanent Wetland	21,000	9	5	HS	HS	HS	S	S	HS
Red Gum Forest (Benwell)	24,000	8	4.1	HS	HS	HS	NS	S	S
Red Gum Forest (Guttrum)	26,000	8	4.1	HS	HS	HS	NS	S	S
Red Gum Forest and Woodland	27,000	4	3	NA	NA	NA	NS	S	S

4.3.4 How might relaxing constraints affect the operation of VMFRP works?

Figure 8 shows that the CMP (Scen 3 - CMP) has little effect on any of the EWR thresholds. Implementation of the CMP will therefore not affect the operation of VMFRP works at Guttrum and Benwell Forests.

4.3.5 How resilient are the projects under a changing climate?

Section 4.1 demonstrated that VMFRP can meet ecological objectives and EWRs at the eight floodplain sites under climate change and that it is highly resilient to climate change.

Figure 9 shows that the frequency and duration of flow events declines under the Medium and High CC CMP scenarios. Medium CC event frequencies are less than for Scenario 3 – CMP at all

[2] Note: the difference in flow frequency was not assessed for 27,000 ML/day because VMFRP was not targeting flows close to without development (marked as NA in **Table 9**).

flow thresholds. In the High CC scenario events only occur approximately one to two times in 10 years at all thresholds.

Median event duration is reduced from Scenario 3 – CMP in the Medium and High CC scenarios. Duration is maintained somewhat in the Medium CC scenario at the 21,000 ML/day threshold while at higher thresholds, duration is less than half the EWR duration. Duration is less than 50% of EWRs for all thresholds in the High CC scenario.

Table 9 shows that the ecological significance of the potential disbenefit of using CMP compared to VMFRP is Highly Significant for flow frequency at all flow thresholds except 27,000 ML/day under Medium and High CC. It is Highly Significant or Significant for duration at all flow thresholds.

At Guttrum and Benwell Forests the CMP has much less resilience to climate change than VMFRP as it would not meet VMFRP ecological objectives under a hotter drier climate and the health of the floodplain would decline.

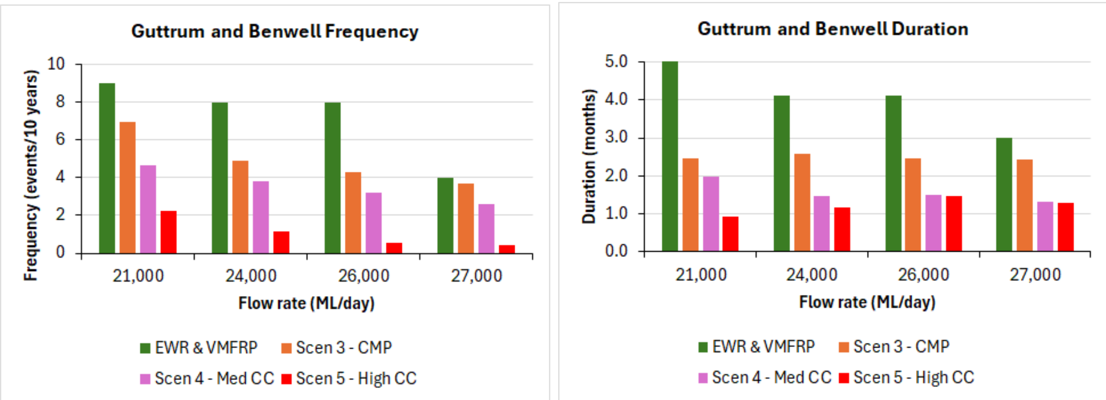

Figure 9 – Frequency and duration of events at Guttrum and Benwell Forests for 21,000, 24,000, 26,000 and 27,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 4 - Medium 2070 climate change; iv) Scenario 5 - High 2070 climate change

4.4 Vinifera

4.4.1 Site characteristics

Vinifera is a floodplain system located 25 km north-west of Swan Hill. The floodplain covers an area of 638 ha. The Vinifera VMFRP project proposes to deliver and manage environmental water in a single area of 335 ha (**Figure 10**).

Vinifera is an elongate basin aligned parallel to the Murray River. The basin is formed between the terrestrial landscape to the south and the natural levee of the riverbank to the north.

Flows at this location reference the Swan Hill gauge. Flows in this reach rarely exceed 30,000 ML/day because high flows are diverted from the Murray northwards to the Wakool River by creeks and floodways.

4.4.2 Environmental Water Requirements

Vinifera Creek passes through the centre of the floodplain and retains water after flood water recedes, forming a Seasonal Wetland. The creek flows when river discharge exceeds 12,500 ML/day. The adjacent floodplain is subject to sustained inundation by flows exceeding 17,500

ML/day and supports a Red Gum Swamp Forest. The outer floodplain is inundated by flows exceeding 20,000 ML/day and supports Red Gum Forest.

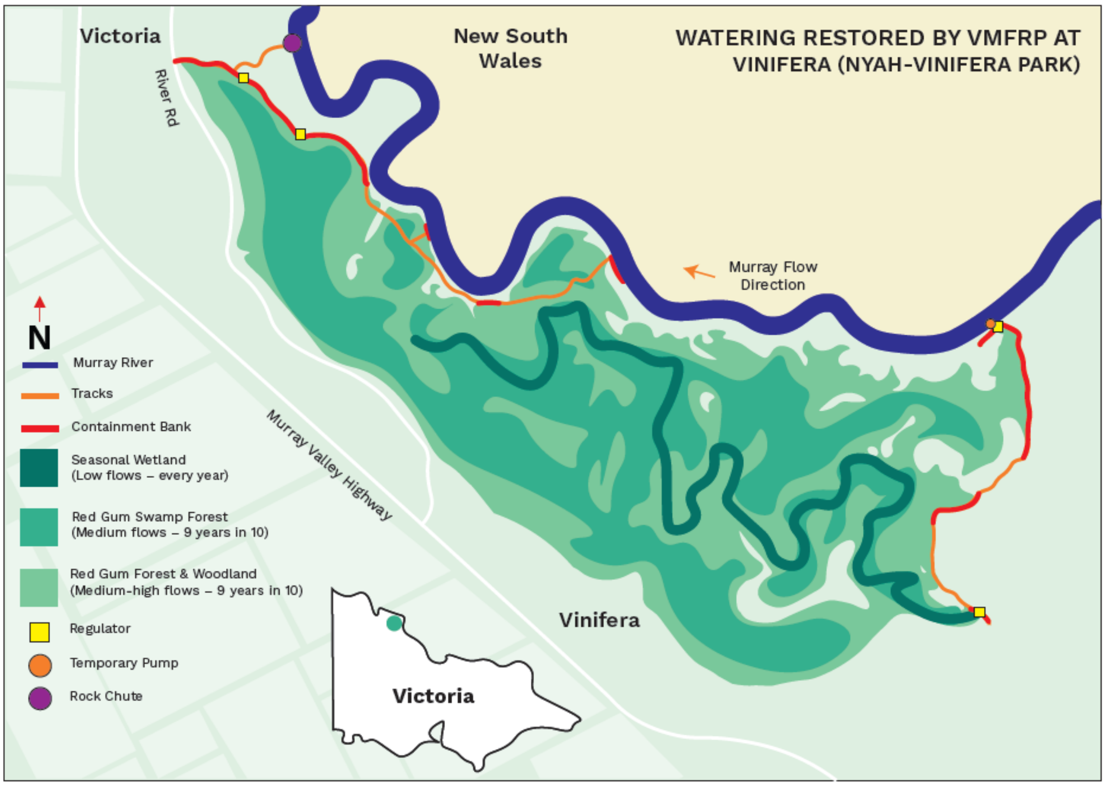

Figure 10 – Schematic of Vinifera (Source: Vinifera Forest Fact Sheet, https://media.caapp.com.au/pdf/iijug6/0b581650-68c3-4312-877e-f4cfabae83b6/Site%20map.pdf)

The EWR aims to maintain semi-permanent flooding in the wetland with sustained seasonal flooding in the surrounding swamp forest. This water regime will provide reliable feeding and breeding habitat for waterbirds and maintain resident populations of frogs and fish. Aquatic vegetation will extend from the wetland into the surrounding swamp forest. Frequent flooding in the outer floodplain will maintain flood-dependent understorey grasses, rushes and sedges beneath the red gum canopy. Flooding will maintain high levels of floodplain productivity which will maintain floodplain bird (bush bird) diversity and abundance.

The ecological objectives for the EWRCs at Vinifera are shown in **Table 10**. The EWRCs and EWRs are shown in **Table 11**.

Table 10 – Ecological objectives for EWRCs at Vinifera (MCMA (2014a))

Specific Objective	**Water Regime Class**
Restore the vegetation structure of wetland plant communities	• Seasonal Wetlands • Red Gum Swamp Forest • Red Gum Forest and Woodland
Re-establish resident populations of frogs and small fish	• Seasonal Wetlands • Red Gum Swamp Forest • Red Gum Forest and Woodland

Provide reliable breeding habitat for waterbirds including colonial nesting species	• Seasonal Wetlands • Red Gum Swamp Forest • Red Gum Forest and Woodland • Black Box Woodland
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler	• Red Gum Forest and Woodland • Black Box Woodland
Contribute to the carbon requirements of the River Murray channel ecosystem	• Red Gum Swamp Forest • Red Gum Forest and Woodland • Black Box Woodland

Table 11 – EWRCs and EWRs at Vinifera (VMFRP (2022a))

Ecological Water Regime Class (EWRC)	**Flow Threshold**	**Environmental Water Requirement (EWR)**
Seasonal Wetland	15,000 ML/day	Frequency – 10 events in 10 years average Duration – 4.9 months median peak duration
Red Gum Swamp Forest	17,500 ML/day	Frequency – 9 events in 10 years average Duration – 3.9 month median peak duration
Red Gum Forest and Woodland	20,000 ML/day	Frequency – 9 events in 10 years average Duration – 3.9 month median peak duration

4.4.3 Can VMFRP ecological objectives be met by CMP?

Figure 11 shows median duration and average frequency of flows for three flow thresholds at Vinifera corresponding to the recommended EWRs (and VMFRP), CMP flows with constraints relaxed (Scen 3 – CMP) and Current flows with existing constraints in place (Scen 2 – Current).

The frequency of spells under the CMP is slightly lower than, but similar to, the EWR at the 15,000 and 17,500 ML/day thresholds but 25% lower than the EWR at 20,000 ML/day.

Median event duration is more than 25% shorter than the EWR at all thresholds under CMP.

Events exceeding 15,000 ML/day contribute to the semi-permanent inundation of Vinifera Wetland. Reliable flooding is important to maintaining resident populations of fish, frogs and waterbirds and to support annual waterbird breeding. The CMP (without complementary action by VMFRP) would maintain the current seasonal water regime and fail to achieve the EWRs and ecological objectives. VMFRP is designed to achieve the EWRs.

Red gum forest is maintained by events exceeding 17,500 and 20,000 ML/day. The frequency and duration of these events under the CMP is lower than the EWR and similar to the current water regime. Under the CMP the objectives to increase the productivity of trees and understorey vegetation and provide longer events that support colonial nesting waterbird breeding are less likely to be met.

Data on the variability in flow duration reinforces these results which are based on average frequency and median duration. The duration plot in **Attachment 4** shows that:

- the median duration of events at all flow thresholds under the CMP lies below the central 50% range of natural variability (Scen 1 – W/O Dev)
- the median duration of EWR flows, which will be achieved by VMFRP, lie within the central 50% of natural (Scen 1 – W/O Dev) flow durations at all flow thresholds.

This indicates that the differences in EWRs and the CMP flows are likely to be ecologically significant when the natural underlying variability of flows is considered. This is further illustrated in **Table 12** which shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Significant for flow duration at all flow thresholds under historic climate.

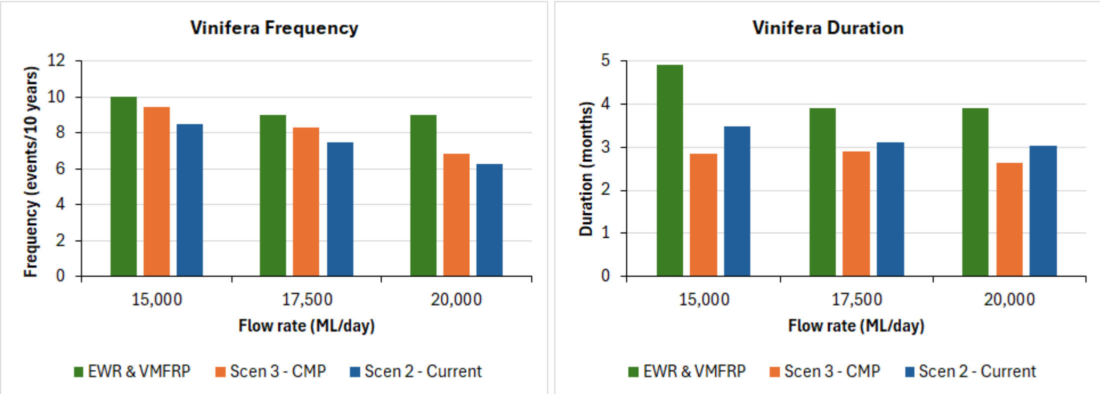

Figure 11 – Frequency and duration of events at Vinifera for 15,000, 17,500 and 20,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 2 – Current

Table 12 – Significance of the potential ecological disbenefit in using CMP compared to VMFRP works at Vinifera Forest

		Frequency			Duration		
EWRC	Flow Threshold (ML/day)	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
Seasonal Wetland	15,000	NS	HS	HS	S	S	HS
Red Gum Swamp Forest	17,500	S	HS	HS	S	S	HS
Red Gum Forest and Woodland	20,000	HS	HS	HS	S	S	HS

4.4.4 How might relaxing constraints affect the operation of VMFRP works?

Figure 11 shows that the CMP (Scen 3 - CMP) has a slightly higher frequency of events at each of the EWR thresholds of 15,000, 17,500 and 20,000 ML/day compared to Current (Scen 2 – Current). However, the duration of these events is slightly shorter under the CMP compared to Current.

Overall, the differences between the CMP and Current are small and would be difficult to define ecologically.

Because the CMP may increase the frequency of events compared to Current its implementation may reduce the work required by VMFRP to meet the EWRs. A higher frequency of events will reduce the times that pumping is required to fill the areas within environmental works. Regulators will be able to detain flood water and prolong floods efficiently, mitigating the effects of shorter flood durations under the CMP.

4.4.5 How resilient are the projects under a changing climate?

Section 4.1 demonstrated that VMFRP can meet ecological objectives and EWRs at the eight floodplain sites under climate change and that it is highly resilient to climate change.

Figure 12 shows that the frequency and duration of events under the CMP declines under the Medium (Scen 4 – Med CC) and High (Scen 5 – High CC) CC scenarios compared to the CMP under historic climate (Scen 3 - CMP).

Under the Medium CC scenario (with the CMP), event frequencies are reduced from the CMP – Scenario 3 by approximately 30% at the 15,000, 17,500 and 20,000 ML/d thresholds. Under the High CC scenario frequencies are less than half the CMP scenario under historic climate.

The duration of events declines from the CMP under historic climate by less than 15% under the Medium CC scenario but by approximately half under the High CC scenario.

Table 12 shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant or Significant for flow frequency and duration at all flow thresholds under Medium and High CC.

The depletion of flooding under the Medium and High CC scenarios would result in further decline in the health of the floodplain, including a reduction of red gum tree density and increasing dominance of terrestrial grasses and shrubs in the understorey. The wetland would become intermittently inundated for shorter periods and would only provide opportunistic habitat for waterbirds and aquatic fauna.

At Vinifera the CMP has much less resilience to climate change than VMFRP as it would not meet VMFRP ecological objectives under a hotter drier climate and the health of the floodplain would decline.

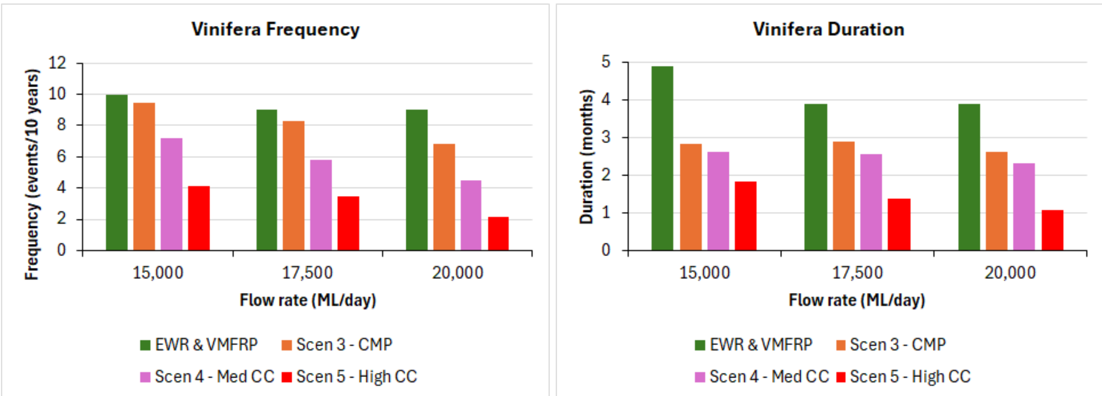

Figure 12 – Frequency and duration of events at Vinifera for 15,000, 17,500 and 20,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 4 - Medium 2070 climate change; iv) Scenario 5 - High 2070 climate change

4.5 Nyah

4.5.1 Site characteristics

Nyah is a floodplain system located 30 km north-west of Swan Hill and directly downstream of the Vinifera VMFRP site. The floodplain extends over 913 ha. The Nyah VMFRP Project proposes to deliver and manage water in a single area of 475 ha (**Figure 13**).

Flows at this location reference the Swan Hill gauge. Flows in this reach rarely exceed 30,000 ML/day because high flows are diverted from the Murray northwards to the Wakool River by creeks and floodways.

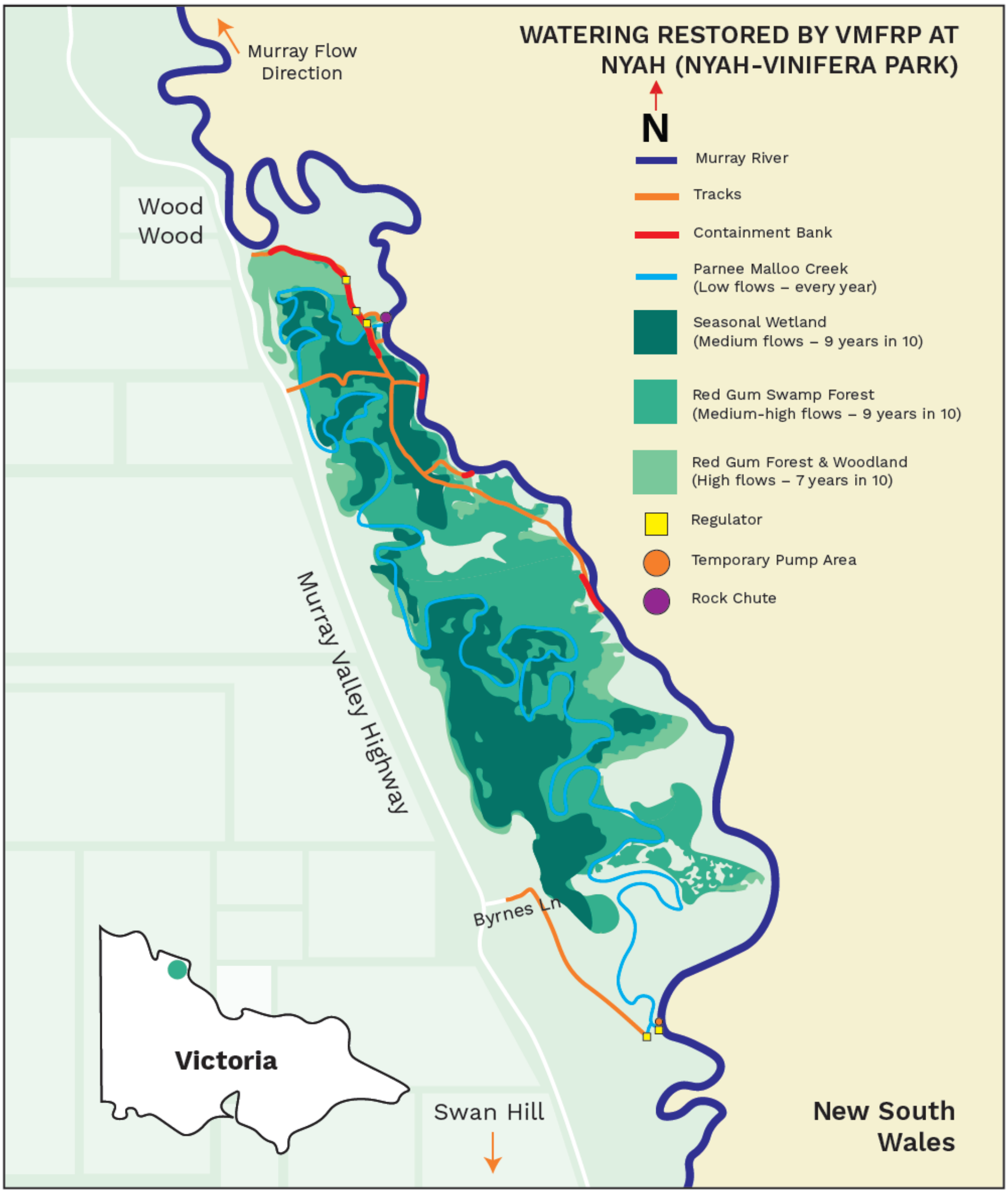

Figure 13 – Schematic of Nyah (Source: Nyah Forest Fact Sheet, https://media.caapp.com.au/pdf/0zfv93/e9a474ee-90ab-449d-845b-46a5f5550e0b/Site%20map.pdf)

4.5.2 Environmental Water Requirements

The Nyah floodplain forms an elongate basin aligned with the Murray River, formed between the terrestrial landscape to the west and the natural levee of the river. The incised Parnee Malloo Creek passes through the centre of the floodplain and starts to flow at river levels exceeding 12,500 ML/day. The creek retains water in pools when river levels recede. The creek connects to low-lying wetlands on the floodplain, the largest of which is Green Swamp. The broader floodplain is largely inundated by flows exceeding 25,000 ML/day and supports Red Gum Forest and Woodland with small areas of Black Box Woodland at the outer fringe.

The EWRs aim to maintain semi-permanent flooding in the wetland with sustained seasonal flooding in the surrounding swamp forest. This water regime will provide reliable feeding and breeding habitat for waterbirds and maintain resident populations of frogs and fish. Aquatic vegetation will extend from the wetland into the surrounding swamp forest. Frequent flooding in the outer floodplain will maintain flood-dependent understorey grasses, rushes and sedges beneath the river red gum canopy. Flooding will maintain high levels of floodplain productivity which will maintain floodplain bird (bush bird) diversity and abundance.

The ecological objectives for the EWRCs at Nyah are shown in **Table 13**. The EWRs for the EWRCs at Nyah are shown in **Table 14**.

Table 13 – Ecological objectives for EWRCs at Nyah (MCMA (2014b))

Specific Objective	Water Regime Class
Restore the vegetation structure of wetland plant communities	• Seasonal anabranch • Seasonal wetlands
Re-establish resident populations of small fish	• Seasonal wetlands
Provide seasonal feeding and reproductive opportunities for riverine fish species	• Seasonal anabranch • Seasonal wetlands
Provide reliable breeding habitat for waterbirds including colonial nesting species	• Seasonal wetlands • Red Gum Swamp Forest • Red Gum Forest and Woodland
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler	• River Red Gum Swamp Forest • Red Gum Forest and Woodland
Contribute to the carbon requirements of the River Murray channel ecosystem	• River Red Gum Swamp Forest • Red Gum Forest and Woodland

Table 14 – EWRCs and EWRs at Nyah (VMFRP (2022a))

Ecological Water Regime Class (EWRC)	Flow Threshold	Environmental Water Requirement (EWR)
Seasonal Anabranch and Billabong	15,000 ML/day	Frequency – 8.6 events in 10 years average Duration – 4.9 months median peak duration
Seasonal Wetland	17,500 ML/day	Frequency – 9 events in 10 years average Duration – 3.9 months median peak duration
Red Gum Swamp Forest	20,000 ML/day	Frequency – 9 events in 10 years average Duration – 3.9 months median peak duration
Red Gum Forest and Woodland	25,000 ML/day	Frequency – 7 events in 10 years average Duration – 2.5 months median peak duration

4.5.3 Can VMFRP ecological objectives be met by CMP?

Figure 14 shows median duration and average frequency of flows for four flow thresholds at Nyah corresponding to the recommended EWRs (and VMFRP), CMP flows with constraints relaxed (Scen 3 – CMP) and Current flows with existing constraints in place (Scen 2 – Current).

The statistics for Nyah are similar to Vinifera as flows are measured at the same gauge and for the same flow thresholds, with the addition of 25,000 ML/day at Nyah. The EWR frequency at 15,000 ML/day is slightly lower at Nyah (8.6 times in 10 years) compared to Vinifera (10 times in 10 years).

The frequency of events under the CMP are similar to the EWR at the 15,000 and 17,500 ML/day thresholds but 22% lower than the EWR at 20,000 ML/day. Median event duration is more than 25% shorter than the EWR at all of these flow thresholds under the CMP.

Events exceeding 17,500 ML/day contribute to the semi-permanent inundation of wetlands. Reliable flooding is important to maintaining resident populations of fish, frogs and waterbirds and to support annual waterbird breeding. The CMP would maintain the current seasonal water regime and fail to achieve the ecological objectives.

For the 25,000 ML/day flow threshold at Nyah, event frequency under the CMP is less than half the EWR. Median event duration is slightly lower than the EWR - 1.9 months under the CMP compared to the 2.5 months EWR.

Red Gum Woodland and Black Box Woodland are maintained by flow events exceeding 25,000 ML/day. The low frequency and duration under the CMP will fail to achieve ecological objectives to increase vegetation productivity and habitat for floodplain birds (bush birds) and to maintain flood-dependent plants in the understorey.

Data on the variability in flow duration reinforces these results which are based on average frequency and median duration. The duration plot in **Attachment 5** shows that the median duration of events at the three lower flow thresholds under the CMP lie below the central 50% range of without development (Scen 1 – W/O Dev) durations. The median frequency of events for flows at 17,500, 20,000 and 25,000 ML/day under CMP lie below the central 50% range of without development frequencies. This indicates that the differences between EWRs and the CMP flows are likely to be ecologically significant when the natural underlying variability of flows is considered.

This is further illustrated in **Table 15** which shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Significant or Highly Significant for flow frequency at three of the four flow thresholds under historic climate. The disbenefit is also Significant for flow duration at three of the four flow thresholds[3].

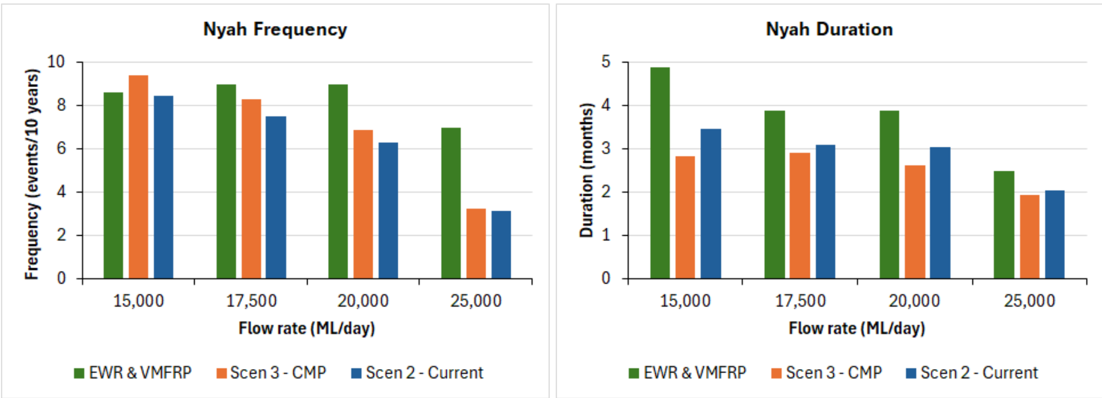

Figure 14 – Frequency and duration of events at Nyah for 15,000, 17,500, 20,000 and 25,000 ML/day flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 2 – Current

Table 15 – Significance of the potential ecological disbenefit in using CMP compared to VMFRP works at Nyah Forest

	EWR			Frequency			Duration		
EWRC	Flow Threshold (ML/day)	Average Frequency	Median Duration	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
Seasonal Anabranch and Billabong	15,000	10	4.9	NA	NA	NA	S	S	HS
Seasonal Wetland	17,500	9	3.9	S	HS	HS	S	S	HS
Red Gum Swamp Forest	20,000	9	3.9	HS	HS	HS	S	S	HS
Red Gum Forest and Woodland	25,000	7	2.5	HS	HS	HS	NS	S	S

4.5.4 How might relaxing constraints affect the operation of VMFRP works?

Figure 14 shows that the CMP (Scen 3 - CMP) has a slightly higher frequency of events at 15,000, 17,500 and 20,000 ML/day EWR thresholds compared to Current (Scen 2 – Current). However, the duration of these events is slightly shorter under the CMP compared to Current. The frequency and duration of events at 25,000 ML/day for CMP and Current are very similar.

[3] Note: the difference in flow frequency was not assessed for 15,000 ML/day because VMFRP was not targeting flows close to without development (marked as NA in **Table 15**).

Overall, the differences between the CMP and Current are small and would be difficult to define ecologically.

As for Vinifera, because the CMP may increase the frequency of events at the three lower EWR thresholds compared to Current, its implementation may reduce the work required by VMFRP to meet the EWRs. A higher frequency of events will reduce the times that pumping is required to fill the areas within environmental works. Regulators will be able to detain flood water and prolong floods efficiently, mitigating the effects of shorter flood durations under the CMP.

4.5.5 How resilient are the projects under a changing climate?

Section 4.1 demonstrated that VMFRP can meet ecological objectives and EWRs at the eight floodplain sites under climate change and that it is highly resilient to climate change.

Figure 15 shows that the trends in the depletion of flow in the Medium and High CC scenarios described for Vinifera continue at Nyah (including at the higher 25,000 ML/day flow threshold), i.e. the frequency and duration of events under the CMP declines under the Medium (Scen 4 – Med CC) and High (Scen 5 – High CC) CC scenarios compared to the CMP under historic climate (Scen 3 - CMP).

Table 15 shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant for flow frequency at the three higher flow thresholds under Medium and High CC. The disbenefit is Significant or Highly Significant for flow duration at all flow thresholds under climate change conditions.

Similar to at Vinifera the depletion of flooding under the Medium or High CC scenarios would result in a decline in the health of the floodplain, including a reduction of red gum tree density and increasing dominance of terrestrial grasses and shrubs in the understorey. The wetland would become intermittently inundated for shorter periods and would only provide opportunistic habitat for waterbirds and aquatic fauna.

At Nyah the CMP has much less resilience to climate change than VMFRP as it would not meet VMFRP ecological objectives under a hotter drier climate and the health of the floodplain would decline.

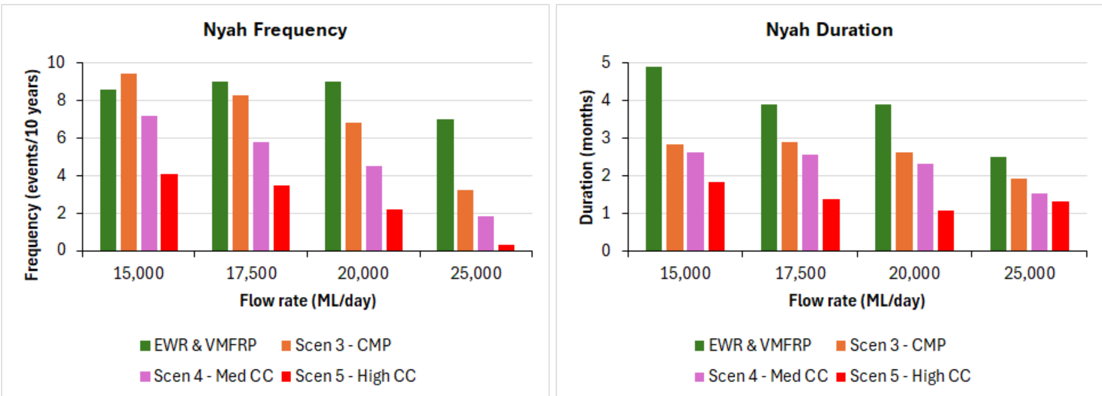

Figure 15 – Frequency and duration of events at Nyah for 15,000, 17,500, 20,000 and 25,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs; ii) Scenario 3 - CMP; iii) Scenario 4 - Medium 2070 climate change; iv) Scenario 5 - High 2070 climate change

4.6 Belsar-Yungera

4.6.1 Site characteristics

The Belsar-Yungera floodplain system is located 30 km upstream of Euston Weir in northern Victoria. The site extends over 8,200 ha and lies between 1,157 river km, near the Murrumbidgee confluence, and 1,201 river km, at the upper limit of the Euston Weir pool.

The Belsar-Yungera VMFRP project proposes to manage environmental water in four areas over a total area of 2,374 ha (**Figure 16**):

- WMA 1 (1,540 ha) inundates watercourses and floodplain areas of Belsar and Yungera Islands
- WMA 2 (526 ha) inundates areas south of middle and upper Narcooyia Creek
- WMA 3 (36 ha) inundates an area around a flood runner south of Narcooyia Creek
- WMA 4 (272 ha) inundates Lake Powell and Lake Carpul and surrounding areas.

Flows at this location reference the Euston downstream gauge.

4.6.2 Environmental Water Requirements

EWRs have been specified for the major hydraulic components of the floodplain.

Narcooyia Creek is a permanent channel which passes through the floodplain. The creek is isolated from the river at very low flows by a levee bank upstream and a weir downstream. The bank is overtopped by small peaks in river flow of more than 10,000 ML/day which are termed 'Spring Fresh' events under VMFRP. The frequency and duration of these events is close to the EWR to maintain fish habitat and riparian vegetation and no additional water management under VMFRP is required.

Floodplain creeks connect to several small Semi-permanent Wetlands including Belsar Wetland and Yungera Wetland. The wetlands and the surrounding red gum trees are inundated by river flows exceeding 30,000 ML/day. The EWR aims to maintain flooding throughout the year in most years with a seasonally inundated fringe. Aquatic vegetation at the edge of the wetlands extends into the surrounding forest vegetation which supports waterbird breeding.

The broader floodplain is inundated by flows between 40,000 and 100,000 ML/day and includes extensive lignum shrubland and woodlands. The lower range of flows inundates mostly red gum and the upper range reaches black box. The EWR aims to maintain the productivity and habitat value of vegetation to support waterbirds, fish, frogs and aquatic invertebrates when flooded and floodplain birds between flood events.

Lakes Powell and Carpul are large lakes located at the limit of the floodplain and are inundated by very high flows. They are mostly treeless and when flooded support large numbers of waterbirds. The lakes can be important waterbird breeding habitat.

Lake Powell starts to receive water at about 70,000 ML/day but is not fully inundated until 100,000 ML/day. Lake Carpul starts to flood at 120,000 ML/day but the lake and surrounding floodplain are not fully inundated until 170,000 ML/day.

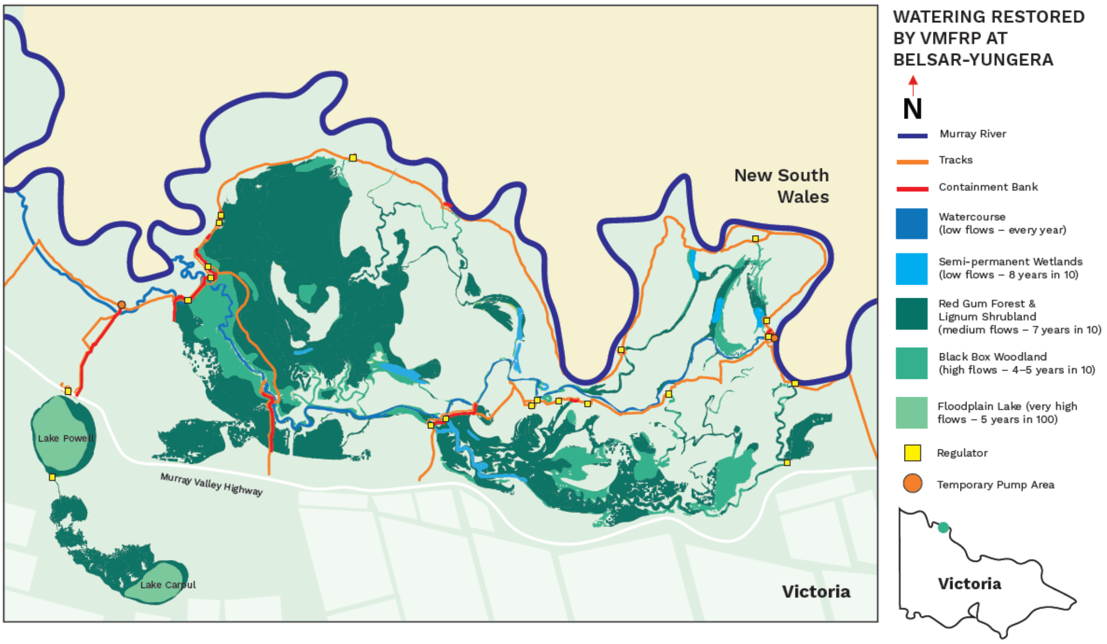

Figure 16 – Schematic of Belsar-Yungera (Source: Belsar-Yungera Fact Sheet, https://media.caapp.com.au/pdf/1x4pff/5078dfac-088d-485e-a8b1-2ec0f5fb346c/Site%20Map.pdf)

The ecological objectives for the EWRCs at Belsar-Yungera are shown in **Table 16**. The EWRs for the EWRCs at Belsar-Yungera are shown in **Table 17**.

Table 16 – Ecological objectives for EWRCs at Belsar-Yungera (MCMA (2014c))

Specific Objective	**Water Regime Class**
Restore and enhance habitat linkages between the river and Narcooyia Creek for Murray cod and other native fish	• Watercourses
Restore and enhance native fish habitat by improving the productivity of riparian zones and wetlands	• Watercourses • Semi-permanent Wetlands
Restore and enhance semi-permanent wetlands capable of supporting growling grass frog	• Semi-permanent Wetlands
Maintain lignum shrubland as a frequently flooded and productive habitat for fish and waterbirds	• Lignum shrubland and Woodland
Restore and enhance floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats.	• Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Black Box Woodland
Intermittently provide productive lake habitat for hundreds of waterbirds	• Floodplain Lakes

Contribute to the carbon requirements of the River Murray channel ecosystem	• Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Black Box Woodland

Table 17 – EWRCs and EWRs at Belsar-Yungera (VMFRP (2022b))

Ecological Water Regime Class (EWRC)	Flow Threshold	Environmental Water Requirement (EWR)
Watercourse	10,000 ML/day	• Permanent with seasonal flow provided by peaks in Murray River flow exceeding 10,000 ML/day • Frequency – 12 events in 10 years average • Duration – 5.4 months median peak duration
Semi-permanent Wetlands	30,000 ML/day	• Frequency – 8 events in 10 years average • Duration – 3.9 months median peak duration
Red Gum Forest and Woodland	40,000 ML/day	• Frequency – 8 events in 10 years average • Duration – 3.9 months median peak duration
Lignum Shrubland and Woodland	50,000 ML/day	• Frequency – 7 events in 10 years average • Duration – 3.3 months median peak duration
Black Box Woodland	100,000 ML/day	• Frequency – 4 events in 10 years average • Duration – 1.4 months median peak duration
Floodplain Lakes	170,000 ML/day	• Frequency – 0.5 events in 10 years average • Duration – 1.6 months median peak duration

4.6.3 Can VMFRP ecological objectives be met by CMP?

Figure 17 shows median duration and average frequency of flows for six EWR flow thresholds at Belsar-Yungera corresponding to the recommended EWRs (and VMFRP), CMP flows with constraints relaxed (Scen 3 – CMP) and Current flows with existing constraints in place (Scen 2 – Current).

The frequency and duration of the CMP and Current events equal or exceed the EWR for the 10,000 ML/day threshold (spring fresh). This EWR is already met under current conditions so there is no water delivery planned for this threshold under VMFRP.

The CMP inundation duration and frequency for all other thresholds is less than the EWR.

The events that relate to Semi-permanent Wetlands (30,000 ML/day) are slightly less than the EWR. These events provide inundation to Belsar Wetland and Yungera Wetland and contribute to the productivity and habitat quality of the riparian zone along Narcooyia Creek. Lower spell occurrence will increase the likelihood that these wetlands will dry out and fail to achieve objectives to provide refuge habitat for aquatic fauna.

Duration under the CMP is substantially lower than the EWR for the 40,000, 50,000 and 170,000 ML/day thresholds. Frequency under the CMP is substantially less than the EWR at the 40,000, 50,000 and 100,000 ML/day thresholds.

Inundation events between 40,000 and 100,000 ML/day provide inundation to Red Gum, Lignum and Black Box communities, which represent the majority of the Belsar-Yungera floodplain area. The low occurrence under the CMP is likely to lead to:

- reduced vegetation productivity
- reduced resilience of perennial vegetation to drought
- less frequent flooding events of shorter duration to support floodplain fish productivity, frog productivity and waterbird breeding
- reduced floodplain bird (bush bird) abundance and diversity.

The frequency of floodplain lake inundation is less than half the EWR for flows that reach Lake Powell (100,000 ML/day) and Lake Carpul (170,000 ML/day). The lakes support Red Gum and Black Box plant communities which will be less productive and provide poorer quality habitat for terrestrial fauna between flood events. Lignum Shrublands near the lakes are likely to decline. The lakes provide important waterbird feeding and breeding habitat when flooded which will be rarely available under the CMP scenario.

VMFRP ecological objectives at Belsar-Yungera will not be met by implementation of the CMP.

Data on the variability in flow frequency reinforces these results which are based on average frequency and median duration. The frequency plot in **Attachment 6** shows that:

- the median frequency of events under the CMP at all EWR thresholds from 40,000 to 100,000 ML/day lie below the central 50% range of Without Development frequencies
- the median frequency of events for EWR (and VMFRP) flows lie within the central 50% range of Without Development flow frequencies at the same flow thresholds.

This indicates that the differences in EWRs and the CMP flows are likely to be ecologically significant when the natural underlying variability of flows is considered. This is further illustrated in **Table 18** which shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Significant or Highly Significant for flow frequencies at all flow thresholds from 40,000 to 100,000 ML/day under historic climate[4].

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[4] Note: the difference in flow frequency was not assessed for 30,000 ML/day because VMFRP was not targeting flows close to without development (marked as NA in **Table 18**).

It is important to note that the number of events decrease markedly as flow thresholds increase which decreases confidence in the variability statistics presented in **Attachment 6** for the 100,000 and 170,000 ML/day thresholds.

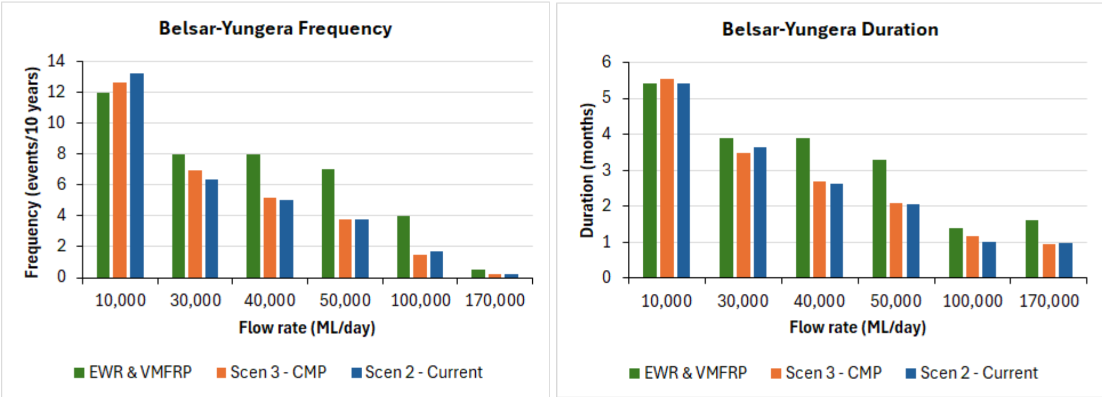


Figure 17 – Frequency and duration of events at Belsar-Yungera for 10,000, 30,000, 40,000, 50,000, 100,000 and 120,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 2 – Current

Table 18 – Significance of the potential ecological disbenefit in using CMP compared to VMFRP works at Belsar-Yungera

	EWR			Frequency			Duration		
EWRC	Flow Threshold (ML/day)	Average Frequency	Median Duration	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
Watercourses	10,000	12	5.4						
Semi-permanent Wetlands	30,000	8	3.9	NA	NA	NA	NS	S	HS
Red Gum Forest and Woodland	40,000	8	3.9	HS	HS	HS	NS	NS	NS
Lignum Shrubland and Woodland	50,000	7	3.3	HS	HS	HS	NS	S	S
Black Box Woodland	100,000	4	1.4	S	HS	HS	NS	NS	HS
Floodplain Lake	170,000	0.5	1.6	NS	NS	NS	NS	HS	HS

4.6.4 How might relaxing constraints affect the operation of VMFRP works?

Figure 17 shows that the CMP (Scen 3 – CMP) results in a small increase in the frequency of flows above Current (Scen 2 – Current) at the 30,000 and 40,000 ML/day thresholds at Belsar-Yungera. The frequency of flows at other thresholds is lower than current conditions. The CMP has little effect on the duration of spells at the higher ecological flow thresholds.

Implementation of the CMP will have little, if any, effect on the operation of VMFRP works at Belsar-Yungera.

4.6.5 How resilient are the projects under a changing climate?

Section 4.1 demonstrated that VMFRP can meet ecological objectives and EWRs at the eight floodplain sites under climate change and that it is highly resilient to climate change.

Figure 18 shows that the frequency and duration of events under the CMP declines under the Medium (Scen 4 – Med CC) and High (Scen 5 – High CC) CC scenarios compared to the CMP under historic climate (Scen 3 - CMP) at all flow thresholds except 10,000 and 100,000 ML/day.

Under the Medium CC scenario (with CMP), event frequencies are reduced from the CMP Scenario 3 (historic climate) by 19% at 30,000 ML/day, and by almost 40% at 40,000 and 50,000 ML/day, and by 66% at the 100,000 ML/day scenario. Events of 170,000 ML/day did not occur under Scenario 4 – Medium 2070 CC. Under Scenario 4 the frequency of in-channel flows (10,000 ML/day) increases.

Under the High CC scenario (with CMP), event frequency is similar to Scenario 3 – CMP (historic climate) for events of 10,000 ML/day, but less than half the CMP (Scenario 3) at higher flows. Events of 100,000 and 170,000 ML/day did not occur under the High CC scenario.

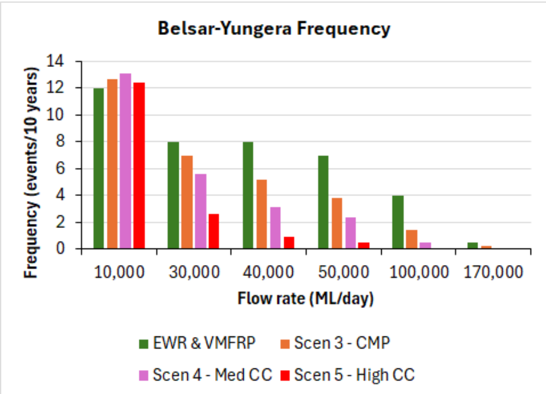
Under the Medium CC scenario, the median duration of events declines by approximately 20 to 30% at all flow thresholds compared to Scenario 3 – CMP (historic climate) except for the 100,000 ML/day threshold where longer durations occur for very rare events.

Under the High CC scenario (with CMP) event duration is reduced from Scenario 3 – CMP (historic climate) by between approximately 30 and 50% for thresholds from 10,000 to 50,000 ML/day.

Table 18 shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant for flow frequency at all flow thresholds from 40,000 to 100,00 ML/day under Medium and High CC.

The decline in flood frequency at intermediate flood levels (40,000 ML/day and greater) to less than 4 events in 10 years under both scenarios is insufficient to maintain the Red Gum and Lignum Shrubland communities. These areas would transition to Black Box Woodlands or Alluvial Plains dominated by terrestrial shrubs and grasses.

Under Medium and High 2070 CC VMFRP objectives at Belsar-Yungera would not be met by implementing the CMP. The CMP is less resilient to climate change than VMFRP at Belsar-Yungera.



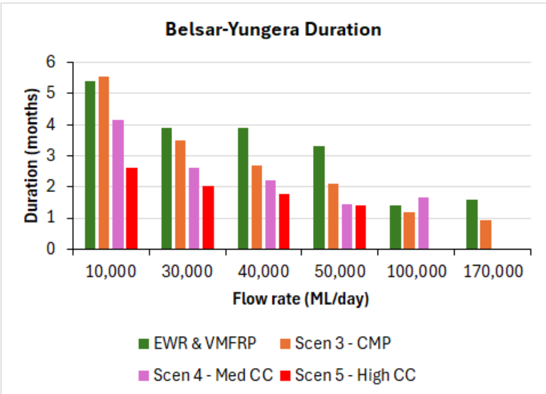


Figure 18 – Frequency and duration of inundation events at Belsar-Yungera for 10,000, 30,000, 40,000, 50,000, 100,000 and 170,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 – CMP; iii) Scenario 4 – Medium 2070 climate change; iv) Scenario 5 – High 2070 climate change

4.7 Hattah Lakes North

4.7.1 Site characteristics

The Hattah Lakes North area is part of the broader Hattah Lakes floodplain system, located 75 km south-east of Mildura. The floodplain system extends over 13,000 ha. The Hattah Lakes North project area extends northwards from the 6,000 ha floodplain area already managed under Living Murray.

The Hattah North VMFRP project proposes to manage environmental water in two areas over a total area of 1,130 ha (**Figure 19**):

- Chalka North area (417 ha) which comprises mainly River Red Gum Woodland
- Lake Boolca area (713 ha) which comprises mainly Black Box Woodland and ephemeral lakes.

Flows at this location reference the Euston downstream gauge.

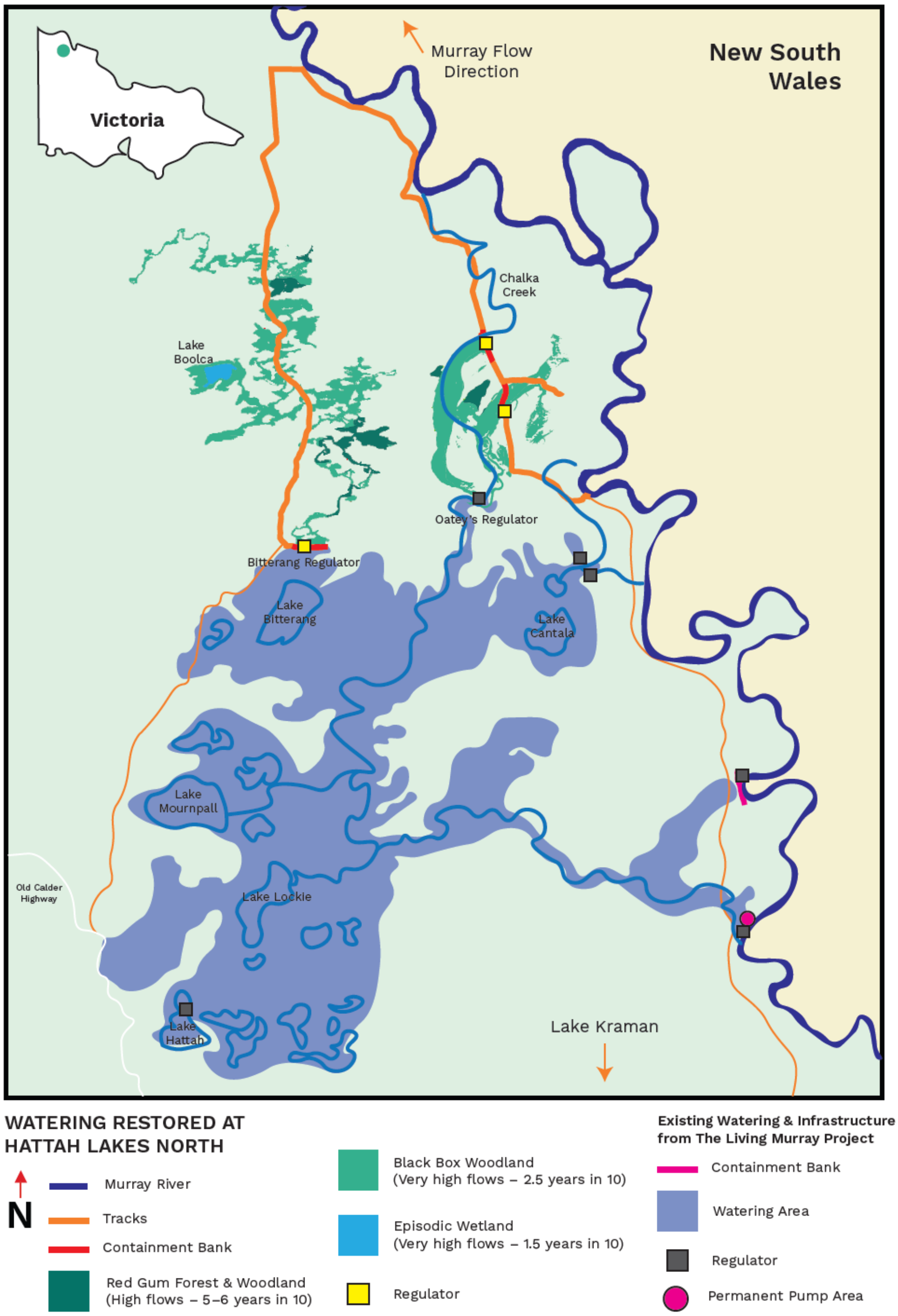


Figure 19 – Schematic of Hattah Lakes North (Source: Hattah Lakes North Fact Sheet, https://media.caapp.com.au/pdf/rs1z2k/2be9fa35-248a-417e-a702-7b425782a5bb/Site%20Map.pdf)

4.7.2 Environmental Water Requirements

Chalka Creek North provides a flow path for water between Hattah Lakes to the Murray River. VMFRP will provide a regulator on Chalka Creek North which will detain water over the adjacent Chalka North floodplain, providing inundation to Red Gum and Black Box Woodland. The Red Gum areas are inundated at flows exceeding 80,000 ML/day and Black Box vegetation is inundated by flows of 120,000 ML/day. The EWR aims to maintain the productivity and habitat value of woodland vegetation, particularly for floodplain birds (bush birds) between flood events.

The Lake Boolca area is a network of high-level wetlands and channels set within a landscape of mallee dunes. The area is connected to the main Hattah Lakes area by a channel north of Lake Bitterang. Inundation of the lakes commences at flows greater than 120,000 ML/day with the outermost episodic wetlands inundated by flows exceeding 140,000 ML/day. The EWR aims to intermittently flood the wetlands to provide opportunistic feeding and breeding habitat for waterbirds. Flooding of woodland areas aims to maintain vegetation health and productivity and to support floodplain bird (bush bird) abundance and diversity.

The ecological objectives for the EWRCs at Hattah Lakes North are shown in **Table 19**. The EWRs for the EWRCs at Hattah Lakes North are shown in **Table 20**.

Table 19 – Ecological objectives for EWRCs at Hattah Lakes North (MCMA (2014d))

Specific Objective	**Water Regime Class**
Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, lace monitor and bats	• Red Gum Woodland • Black Box Woodland
Provide occasional breeding habitat for waterbirds	• Red Gum Woodland • Episodic Wetlands
Maintain the health and age structure of Red Gum and Black Box trees	• Red Gum Woodland • Black Box Woodland
Maintain a plant community of drought-tolerant wetland species in frequently inundated areas	• Episodic Wetlands
Contribute to the carbon requirements of the River Murray channel ecosystem	• Red Gum Woodland • Black Box Woodland

Table 20 – EWRCs and EWRs at Hattah Lakes North (VMFRP (2022b))

Ecological Water Regime Class (EWRC)	Flow Threshold	Environmental Water Requirement (EWR)
Red Gum Forest and Woodland	80,000 ML/day	• Frequency – 6 events in 10 years average • Duration – 1.6 months median peak duration
Black Box Woodland	120,000 ML/day	• Frequency – 2.5 events in 10 years average • Duration – 1 month median peak duration
Episodic Wetlands	140,000 ML/day	• Frequency – 1.5 events in 10 years average • Duration – 1 month median peak duration

4.7.3 Can VMFRP ecological objectives be met by CMP?

Figure 20 shows median duration and average frequency of flows for three flow thresholds at Hattah Lakes North corresponding to the recommended EWRs (and VMFRP), CMP flows with constraints relaxed (Scen 3 – CMP) and Current flows with existing constraints in place (Scen 2 – Current).

The frequency of the CMP inundation events at Hattah Lakes North are less than half the EWR frequencies at all EWR flow thresholds. The duration of these events is similar to the EWR.

The low frequency of the CMP events at the 80,000 and 120,000 ML/day thresholds is similar to Current and will result in the continued decline in tree health and ongoing low rates of ecosystem productivity and habitat value the area currently experiences.

The floodplain lakes, watered by events exceeding 140,000 ML/day, are adapted to infrequent flooding and long dry spells. The lower frequency of inundation under the CMP is similar to the depleted current flood regime and is not likely to lead to further change in the ecosystem. However, failure to meet the EWR will result in fewer opportunities for aquatic fauna to use the system, particularly waterbirds.

VMFRP ecological objectives at the Hattah Lakes North will not be met by implementation of the CMP.

Data on the variability in flow frequency and duration largely supports these results which are based on average frequency and median duration. The frequency and duration plots in **Attachment 7** show that:

- the median frequency of events under the CMP at the 80,000 ML/day EWR threshold lies outside the central 50% range of Without Development flow frequencies

- the median frequency of events under the CMP at 120,000 ML/day is equal to the 25th percentile frequency of Without Development flows indicating that the differences aren't significant. However, because the percentiles are based on very few events the results are uncertain
- the median frequency and duration of events for EWR (and VMFRP) flows lie within or above the central 50% of range of Without Development flows.

This indicates that the differences in EWRs and the CMP flows are likely to be ecologically significant at 80,000 ML/day and may be significant at 120,000 ML/day when the natural underlying variability of flows is considered. This is further illustrated in **Table 21** which shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Significant for flow frequency at 80,000 ML/day.

It is important to note that the number of events decrease markedly as flow thresholds increase which decreases confidence in the variability statistics presented in **Attachment 7** and **Table 21**.

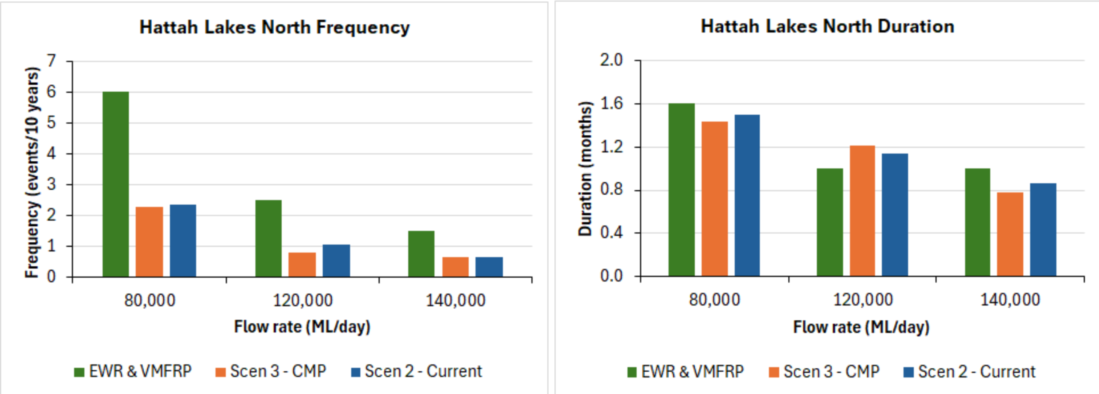


Figure 20 – Frequency and duration of events at Hattah Lakes North for 80,000, 120,000 and 140,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWR and VMFRP; ii) Scenario 3 – CMP; iii) Scenario 2 – Current

Table 21 – Significance of the potential ecological disbenefit in using CMP compared to VMFRP works at Hattah Lakes North

	EWR			Frequency			Duration		
EWRC	Flow Threshold (ML/day)	Average Frequency	Median Duration	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
Red Gum Forest and Woodland (Chalka North Water Management Area)	80,000	6	1.6	S	HS	HS	NS	NS	HS
Black Box Woodland (Chalka North and Lake Boolca Water Management Areas)	120,000	2.5	1	NS	S	HS	NS	NS	HS
Episodic Wetlands (Lake Boolca Water Management Area)	140,000	1.5	1	NS	NS	NS	NS	HS	HS

4.7.4 How might relaxing constraints affect the operation of VMFRP works?

Figure 20 shows that the duration and frequency of the CMP (Scen 3 – CMP) inundation events exceeding 80,000, 120,000 and 140,000 ML/day are similar to current conditions (Scen 2 – Current).

The implementation of CMP will have little, if any, effect on the operation of VMFRP works at Hattah Lakes North.

4.7.5 How resilient are the projects under a changing climate?

Section 4.1 demonstrated that VMFRP can meet ecological objectives and EWRs at the eight floodplain sites under climate change and that it is highly resilient to climate change.

Figure 21 shows that the frequency of events under the CMP declines under the Medium (Scen 4 – Med CC) and High (Scen 5 – High CC) CC scenarios compared to the CMP under historic climate (Scen 3 - CMP).

Under the Medium CC scenario, event frequencies decline substantially from the CMP scenario with historic climate. Flows exceed the 80,000 ML/day threshold one third as frequently as under the CMP with historic climate. They exceed the 120,000 ML/day threshold one half as frequently as under the CMP with historic climate. Events exceeding 140,000 ML/day did not occur in the modelled period.

The duration of events under the Medium CC scenario is similar to the CMP with historic climate conditions (Scen 3 – CMP) for the 80,000 and 120,000 ML/day thresholds. However, these medians are taken from a very small number of events (8 and 4 respectively) from a highly variable data set and do not indicate that the EWR will be met with any reliability.

In the High CC scenario, events exceeding the 80,000 ML/day threshold did not occur in the modelled period.

Table 21 shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant or Significant for flow frequency or duration at all flow thresholds under Medium and High CC.

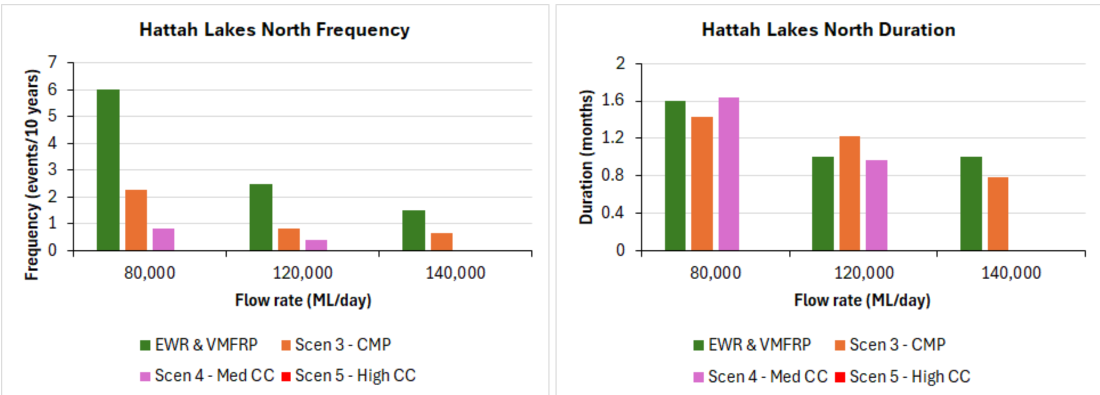


Figure 21 – Frequency and duration of inundation events at Hattah Lakes North for 80,000, 120,000 and 140,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 – CMP; iii) Scenario 4 – Medium 2070 climate change; iv) Scenario 5 – High 2070 climate change

The very low frequency (or absence) of spells exceeding EWR thresholds in the Medium and High CC scenarios would accelerate the existing decline in plant communities and aquatic habitat. Hattah Lakes North would no longer support Red Gum communities, and Black Box communities would become less productive with poor habitat value for floodplain birds (bush birds) and other vertebrate fauna. In the absence of flooding the wetlands would no longer provide aquatic habitat.

Under Medium and High 2070 CC VMFRP objectives at Hattah Lakes North would not be met by implementing the CMP. The CMP is much less resilient to climate change than VMFRP at Hattah Lakes North.

4.8 Wallpolla Island

4.8.1 Site characteristics

The Wallpolla Island floodplain system is located approximately 30 km west of Mildura, immediately downstream of the junction of the Murray and Darling Rivers. The floodplain extends over approximately 9,000 ha.

The Wallpolla Island VMFRP project proposes to deliver and manage environmental water in four areas with a combined extent of 2,682 ha (**Figure 22**):

- Upper Wallpolla area (866 ha)
- Mid Wallpolla area (1,074 ha)
- South Wallpolla area (630 ha)
- Direct Local Pumping area (112 ha).

Flows at this location reference the gauge Upstream of Lock 9.

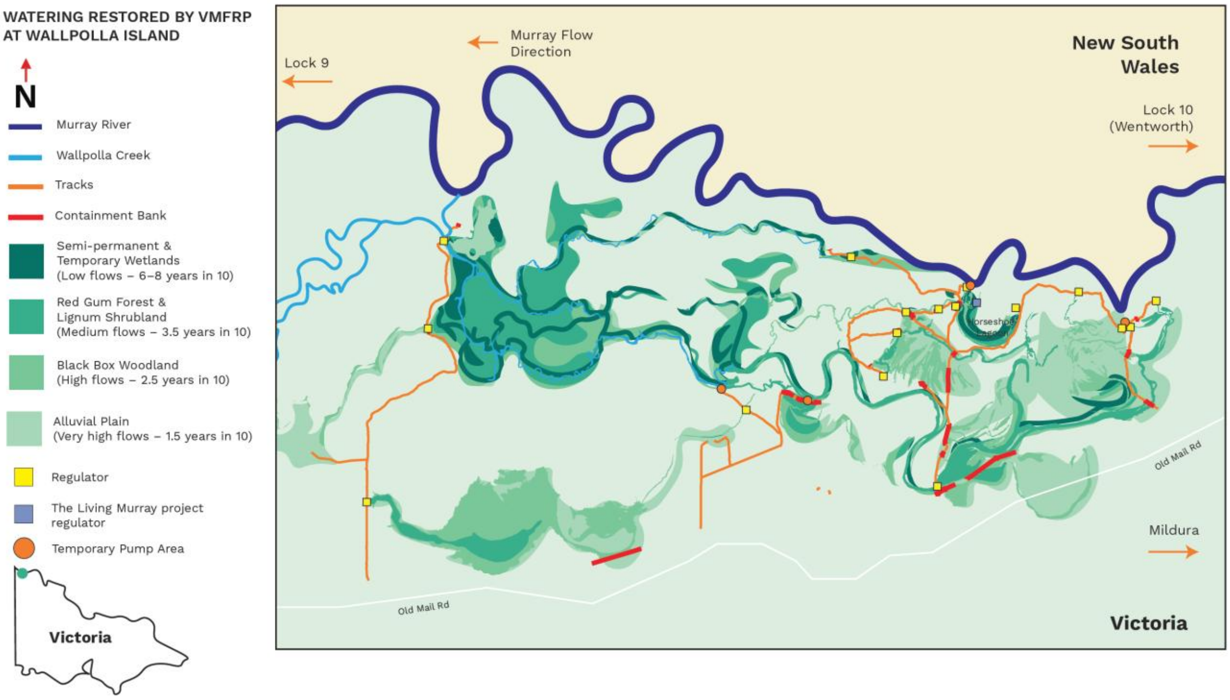


Figure 22 – Schematic of Wallpolla Island (Source: Wallpolla Island Story and FAQ, https://www.vmfrp.com.au/wp-content/uploads/2021/11/Site-story-and-FAQ-WALLPOLLA-V01.pdf)

4.8.2 Environmental Water Requirements

The floodplain is crossed by a network of anabranches. In the western part of the island the watercourses are permanently inundated by the Lock 9 weir pool. In the east, elevated river flow is required to initiate flow into creeks at their upstream connections. A river discharge of 30,000 ML/day generates substantial flow through most reaches of most watercourses. The EWRs aim to improve the habitat quality in watercourses by providing periodic inundation of riparian zones and extending flooding to high-level reaches. Environmental watering is targeted to improving the abundance and diversity of fish and frogs and improving the health and diversity of riparian vegetation.

Wallpolla Horseshoe is a Semi-permanent Wetland with a deep retention level and a low flow threshold of 40,000 ML/day. Temporary Wetlands have a relatively high flow threshold of 60,000 ML/day and are distributed across the floodplain. The EWRs aim to restore flooding to increase vegetation diversity and abundance and provide reliable foraging and breeding habitat for waterbirds, fish and frogs. Fringing trees, which benefit from wetland inundation, provide important habitat components for wetland fauna including waterbirds.

Red Gum Woodlands and Lignum Shrublands are inundated by flows exceeding 80,000 ML/day. The EWRs aim to restore flooding to improve tree and shrub cover and productivity and to increase the diversity and habitat complexity of understorey vegetation. Habitat quality will improve for floodplain birds. Improved habitat quality will increase waterbird abundance near watercourses and wetlands. Sustained flooding of healthy Lignum Shrublands will support waterbird breeding.

Black Box Woodlands are inundated by flows exceeding 100,000 ML/day. The EWRs aim to promote Black Box tree health, recruitment and survival. Higher productivity in the woodlands, and the availability of tree hollows will increase the diversity and abundance of woodland fauna.

Alluvial Plains are grassy shrublands that occur at high flow thresholds exceeding 120,000 ML/day. These areas are rarely flooded. The EWRs aim to provide opportunistic foraging habitat for waterbirds, particularly when they are breeding elsewhere on the floodplain. Following flood events, higher productivity will increase the habitat value of Alluvial Plains for ground-dwelling vertebrate fauna.

The ecological objectives for the EWRCs at Wallpolla Island are shown in **Table 22**. The EWRs for the EWRCs at Wallpolla Island are shown in

Table 23.

Table 22 – Ecological objectives for EWRCs at Wallpolla Island (Source: MCMA (2014e))

Specific Objective	**Water Regime Class**
Increase resident population of frogs, waterbirds and small fish in wetlands	• Semi-permanent Wetlands • Temporary Wetlands • Watercourses
Provide reliable breeding habitat for waterbirds, including colonial nesting species	• Semi-permanent Wetlands • Temporary Wetlands • Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Alluvial Plain
Enhance local populations of channel-specialist fish by augmenting anabranch habitat and improving the	• Semi-permanent Wetlands • Temporary Wetlands

productivity of connected riparian zones and wetlands	• Watercourses
Frequently provide habitat for thousands of waterbirds	• Lignum Shrubland and Woodland • Alluvial Plain
Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and Giles Planigale	• Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Black Box Woodland
Contributing to the carbon requirements of the River Murray channel ecosystem	• Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Black Box Woodland

Table 23 – EWRCs and EWRs at Wallpolla Island

Ecological Water Regime Class (EWRC)	**Flow Threshold**	**Environmental Water Requirement (EWR)**
Watercourses	30,000 ML/day	• Frequency – 9.5 events in 10 years average • Duration – 4.9 months median peak duration
Semi-permanent Wetlands	40,000 ML/day	• Frequency – 8.8 events in 10 years average • Duration – 3.9 months median peak duration
Temporary Wetlands	60,000 ML/day	• Frequency – 6.0 events in 10 years average • Duration – 3.0 months median peak duration
Red Gum Forest and Woodlands Lignum Shrubland and Woodlands	80,000 ML/day	• Frequency – 3.5 events in 10 years average • Duration – 1.6 months median peak duration
Black Box Woodlands	100,000 ML/day	• Frequency – 2.5 events in 10 years average • Duration – 1.4 months median peak duration
Alluvial Plains	120,000 ML/day	• Frequency – 1.5 events in 10 years average • Duration – 1.0 months median peak duration

4.8.3 Can VMFRP ecological objectives be met by CMP?

Figure 23 shows median duration and average frequency of flows for six flow thresholds at Wallpolla Island corresponding to the recommended EWRs (and VMFRP), CMP flows with constraints relaxed (Scen 3 – CMP) and Current flows with existing constraints in place (Scen 2 – Current).

The CMP does not meet the EWRs of Wallpolla Island. Flow event frequency and/or duration is similar to current conditions and less than the environmental targets.

Event frequency is similar to current conditions and less than the EWRs at all flow thresholds. The duration of events is similar to current. At the 30,000, 40,000 and 60,000 ML/day thresholds event durations under the CMP and current scenarios are similar and substantially lower than the EWRs. At thresholds of 80,000 ML/day and above current and CMP event durations are similar to the EWR but fail to meet the water requirement due to low event frequencies.

Under the CMP:

- Wetlands will be flooded too infrequently and too briefly to support resident populations of frogs, waterbirds and fish or to provide reliable breeding habitat for waterbirds
- Red Gum Woodlands and Lignum Shrublands will be flooded too infrequently and to briefly to restore productivity and habitat for terrestrial fauna and floodplain birds. Infrequent shrubland flooding will rarely contribute to breeding habitat for waterbirds
- Black Box Woodlands and Alluvial Plains will be flooded too infrequently to restore vegetation productivity and to restore habitat for terrestrial fauna and floodplain birds.

Data on the variability in flow frequency reinforces these results which are based on average frequency and median duration. The plots in **Attachment 8** show that:

- the median frequency of events at all flow thresholds under the CMP lies below the central 50% range of natural variability (Scen 1 – W/O Dev)
- the median frequency and duration of EWR flows, which will be achieved by VMFRP, lie within the central 50% range of Without Development flow durations at all flow thresholds.

This indicates that the differences in EWRs and the CMP flows are likely to be ecologically significant when the natural underlying variability of flows is considered. This is further illustrated in **Table 24** which shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Significant or Highly Significant for flow frequency at all flow thresholds under historic climate.

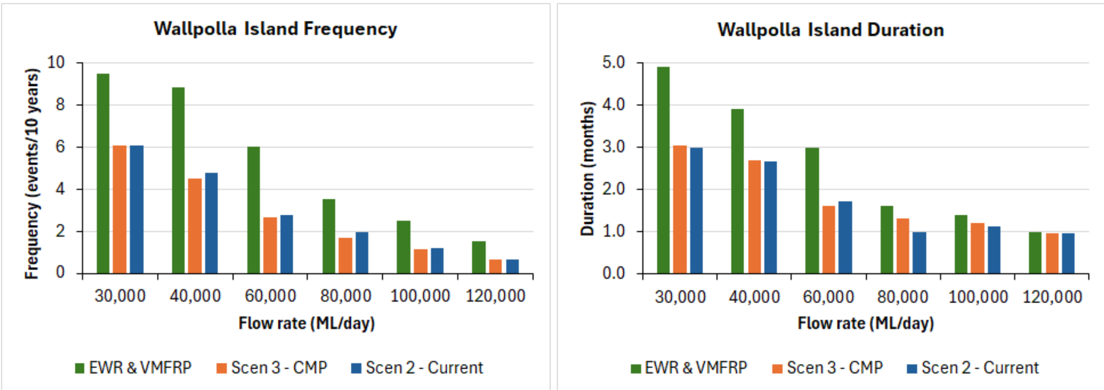


Figure 23 – Frequency and duration of events at Wallpolla Island for 30,000, 40,000, 60,000, 80,000, 100,000 and 120,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 2 – Current

Table 24 – Significance of the potential ecological disbenefit in using CMP compared to VMFRP works at Wallpolla Island

		Frequency			Duration		
EWRC	Flow Threshold (ML/day)	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
Watercourses	30,000	HS	HS	HS	S	S	HS
Semi-permanent Wetlands	40,000	HS	HS	HS	NS	S	NS
Temporary Wetlands	60,000	S	HS	HS	S	S	NS
Red Gum Forest and Woodlands and Lignum Shrubland and Woodlands	80,000	HS	HS	HS	NS	NS	HS
Black Box Woodland	100,000	S	HS	HS	NS	NS	HS
Alluvial Plain	120,000	S	HS	HS	NS	NS	HS

4.8.4 How might relaxing constraints affect the operation of VMFRP works?

Figure 23 shows that the CMP (Scen 3 - CMP) has little effect on any of the EWR thresholds. Implementation of the CMP will therefore not affect the operation of VMFRP works at Wallpolla Island.

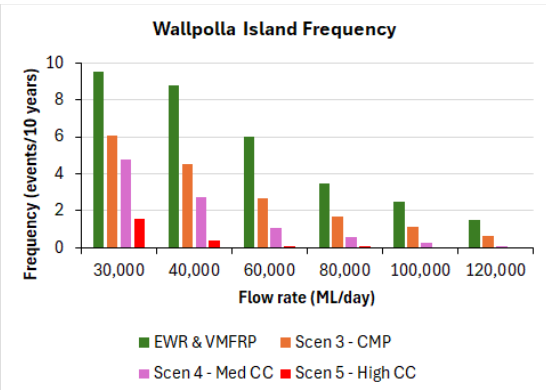
4.8.5 How resilient are the projects under a changing climate?

There is an overall trend in decreasing event frequency under the Medium and High CC scenarios. Medium CC event frequencies are less than Scenario 3 – CMP at all flow thresholds, and events rarely or never occur at flows over 60,000 ML/day. In the High CC scenario events occur less than 1 in 10 years at flows above 30,000 ML/day and not at all above 100,000 ML/day.

Median event durations are reduced with increasingly severe climate change scenarios at 30,000 ML/day. Median durations at higher flow thresholds are based on very few events from a highly variable data set and do not indicate that the EWR will be met with any reliability.

Table 24 shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant for flow frequency at all flow thresholds under Medium and High CC.

At Wallpolla Island the CMP is much less resilient to climate change than VMFRP as it would not meet VMFRP ecological objectives under a hotter drier climate and the health of the floodplain would decline.



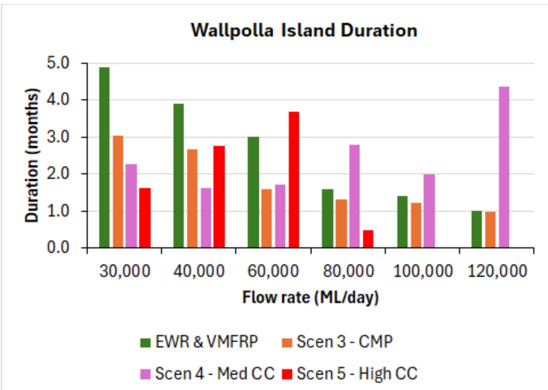


Figure 24 – Frequency and duration of events at Wallpolla Island for 30,000, 40,000, 60,000, 80,000, 100,000 and 120,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 4 - Medium 2070 climate change; iv) Scenario 5 - High 2070 climate change

4.9 Lindsay Island

4.9.1 Site characteristics

The Lindsay Island floodplain system is located 75 km north-west of Mildura and extends over approximately 18,000 ha.

The Lindsay Island VMFRP project proposes to deliver and manage environmental water in four areas with a combined extent of 5,233 ha (**Figure 25**):

- Berribee area (3,645 ha in Victoria and 519 in NSW which includes 411 ha of the Murray River)
- Crankhandle area (298 ha)
- Lindsay South area (121 ha)
- Wallawalla West area (621 ha).

Flows at this location reference the SA Border modelled gauge.

4.9.2 Environmental Water Requirements

Semi-permanent Wetlands are maintained by flows exceeding 40,000 ML/day. The EWRs aim to restore flooding to increase vegetation diversity and abundance and provide reliable foraging and breeding habitat for waterbirds, fish and frogs. Fringing trees, which benefit from wetland inundation, provide important habitat components for wetland fauna including waterbirds.

Red Gum Woodlands and Lignum Shrublands are inundated by flows exceeding 80,000 ML/day. The EWRs aim to restore flooding to improve tree and shrub cover and productivity and to increase the diversity and habitat complexity of understorey vegetation. Habitat quality will improve for floodplain birds. Improved habitat quality will increase waterbird abundance near watercourses and wetlands. Sustained flooding of healthy Lignum Shrublands will support waterbird breeding.

Black Box Woodlands are inundated by flows exceeding 85,000 ML/day. The EWRs aim to promote Black Box tree health, recruitment and survival. Higher productivity in the woodlands, and the availability of tree hollows will increase the diversity and abundance of woodland fauna.

Alluvial Plains are grassy shrublands that occur at high flow thresholds exceeding 120,000 ML/day. These areas are rarely flooded. The EWRs aim to provide opportunistic foraging habitat for waterbirds, particularly when they are breeding elsewhere on the floodplain. Following flood events, higher productivity will increase the habitat value of Alluvial Plains for ground-dwelling vertebrate fauna.

The ecological objectives for the EWRCs at Lindsay Island are shown in **Table 25**. The EWRs for the EWRCs at Lindsay Island are shown in

Table 26.

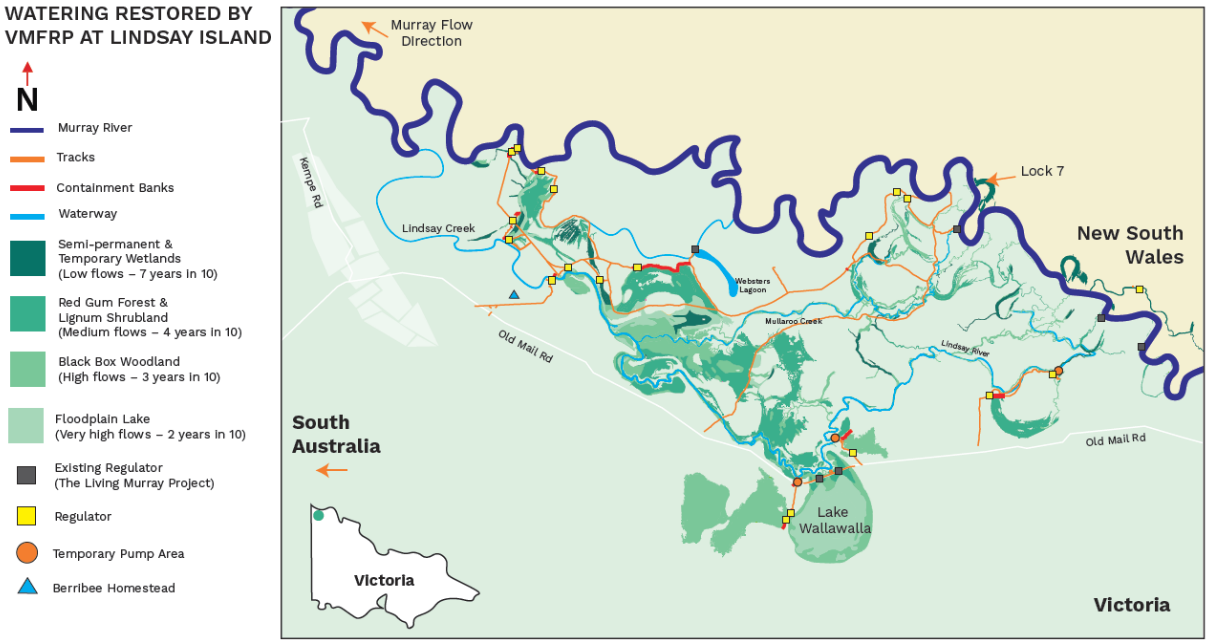


Figure 25 – Schematic of Lindsay Island (Source: Lindsay Island Story Site Map, https://www.vmfrp.com.au/wp-content/uploads/2021/11/VMFRP-Site-Map-LIND-V01.pdf)

Table 25 – Ecological objectives for EWRCs at Lindsay Island (MCMA (2014f))

Specific Objective	Water Regime Class
Enhance Murray cod habitat by improving the productivity of connected riparian zones and wetlands while maintaining fast-flowing water	• Semi-permanent Wetlands
Maintain resident populations of frogs and small fish in wetlands	• Semi-permanent Wetlands
Provide reliable breeding habitat for waterbirds, including colonial nesting species	• Semi-permanent Wetlands • River Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Alluvial Plain
Frequently provide habitat for thousands of waterbirds	• Semi-permanent Wetlands • River Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Alluvial Plain
Protect and restore floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, insectivorous bats and Giles planigale	• River Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Black Box Woodland

Contribute to the carbon requirements of the River Murray channel ecosystem	• Temporary Wetlands • River Red Gum Forest and Woodland • Lignum Shrubland and Woodland • Black Box Woodland

Table 26 – EWRCs and EWRs at Lindsay Island (VMFRP (Draft))

Ecological Water Regime Class (EWRC)	Flow Threshold	Environmental Water Requirement
Semi-permanent Wetlands	40,000 ML/day	• Frequency – 9 events in 10 years average • Duration – 4 months median peak duration
Temporary Wetlands	60,000 ML/day	• Frequency – 6.6 events in 10 years average • Duration – 4 months median peak duration
Red Gum Forest and Woodlands Lignum Shrubland and Woodlands	75,000 ML/day	• Frequency – 4.3 events in 10 years average • Duration – 2 months median peak duration
Black Box Woodlands	85,000 ML/day	• Frequency – 2.1 events in 10 years average • Duration – 1 month median peak duration
Alluvial Plain	120,000 ML/day	• Frequency – 2.1 events in 10 years average • Duration – 1 month median peak duration

4.9.3 Can VMFRP ecological objectives be met by CMP?

Figure 26 shows median duration and average frequency of flows for five flow thresholds at Lindsay Island corresponding to the recommended EWRs (and VMFRP), CMP flows with constraints relaxed (Scen 3 – CMP) and Current flows with existing constraints in place (Scen 2 – Current).

The CMP does not meet EWRs at Lindsay Island. Flow event frequency is similar to current conditions and less than the environmental targets.

CMP event frequency is similar to current conditions and less than the EWRs at all flow thresholds. The duration of events is similar to current at the 40,000 and 60,000 ML/day thresholds but substantially less than the watering target. There is a high variability in duration among the few events that occur at the 85,000 and 120,000 ML/day thresholds but the frequency of these events is less than the watering target.

Under the CMP:

- Semi-permanent and Temporary Wetlands will be inundated too infrequently and too briefly to support resident populations of frogs, waterbirds and fish or to provide reliable breeding habitat for waterbirds
- Red Gum Woodlands and Lignum Shrublands will be flooded too infrequently and too briefly to restore productivity and habitat for terrestrial fauna and floodplain birds. Infrequent shrubland flooding will rarely contribute to breeding habitat for waterbirds
- Black Box Woodlands and Alluvial Plains will be flooded too infrequently to restore vegetation productivity and to restore habitat for terrestrial fauna and floodplain birds.

Data on the variability in flow frequency reinforces these results which are based on average frequency and median duration. The plots in **Attachment 9** show that:

- the median frequency of events at all flow thresholds under the CMP lie below the central 50% range of natural variability (Scen 1 – W/O Dev)
- the median frequency and duration of EWR flows, which will be achieved by VMFRP, lie within the central 50% of Without Development flow durations at all flow thresholds.

This indicates that the differences in EWRs and the CMP flows are likely to be ecologically significant when the natural underlying variability of flows is considered. This is further illustrated in **Table 27** which shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Significant or Highly Significant for flow frequency at all flow thresholds under historic climate.

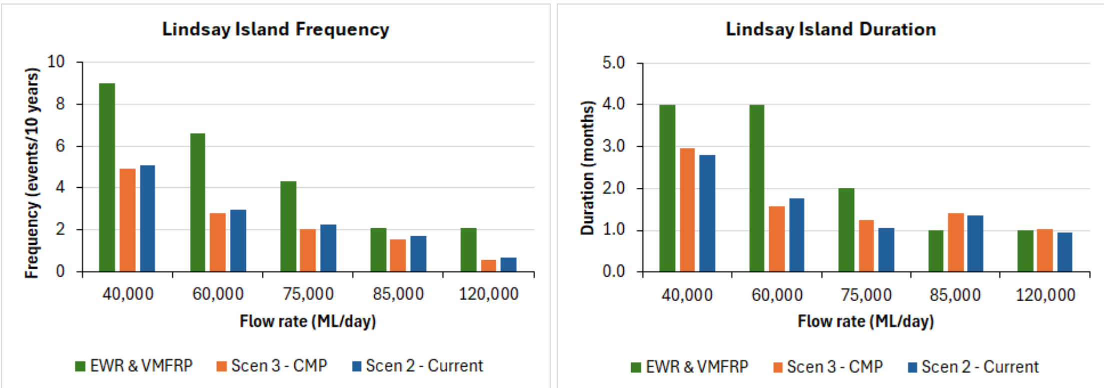


Figure 26 – Frequency and duration of events at Lindsay Island for 40,000, 60,000, 75,000, 85,000 and 120,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 2 – Current

Table 27 – Significance of the potential ecological disbenefit in using CMP compared to VMFRP works at Lindsay Island

		Frequency			Duration		
EWRC	Flow Threshold (ML/day)	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
Semi-permanent Wetlands	40,000	HS	HS	HS	NS	NS	S
Temporary Wetlands	60,000	S	HS	HS	S	S	NS
Red Gum Forest and Woodlands and Lignum Shrubland and Woodlands	75,000	S	HS	HS	NS	NS	NS
Black Box Woodlands	85,000	S	HS	HS	NS	NS	HS
Alluvial Plain	120,000	S	HS	HS	NS	NS	HS

4.9.4 How might relaxing constraints affect the operation of VMFRP works?

Figure 26 shows that the CMP (Scen 3 - CMP) has little effect on any of the EWR flow thresholds. Implementation of the CMP will therefore not affect the operation of VMFRP works at Lindsay Island.

4.9.5 How resilient are the projects under a changing climate?

Section 4.1 demonstrated that VMFRP can meet ecological objectives and EWRs at the eight floodplain sites under climate change and that it is highly resilient to climate change.

Figure 27 shows that there is an overall trend in decreasing event frequency under the Medium and High CC scenarios. Medium CC event frequencies are less than Scenario 3 – CMS at all flow thresholds, and events rarely or never occur at flows over 60,000 ML/day. In the High CC scenario events occur less than 1 in 10 years at the 40,000, 60,000 and 75,000 ML/day flow thresholds and not at all at the 85,000 and 120,000 ML/day thresholds.

Median event durations are reduced with increasingly severe climate change for the 40,000 ML/day flow threshold. Median durations at higher flow thresholds are based on very few events from a highly variable data set and do not indicate that the EWR will be met with any reliability.

Table 27 shows that the significance of the potential ecological disbenefit of using CMP compared to VMFRP is Highly Significant for flow frequency at all flow thresholds under Medium and High CC.

At Lindsay Island the CMP is much less resilient to climate change than VMFRP as it would not meet VMFRP ecological objectives under a hotter drier climate and the health of the floodplain would decline.

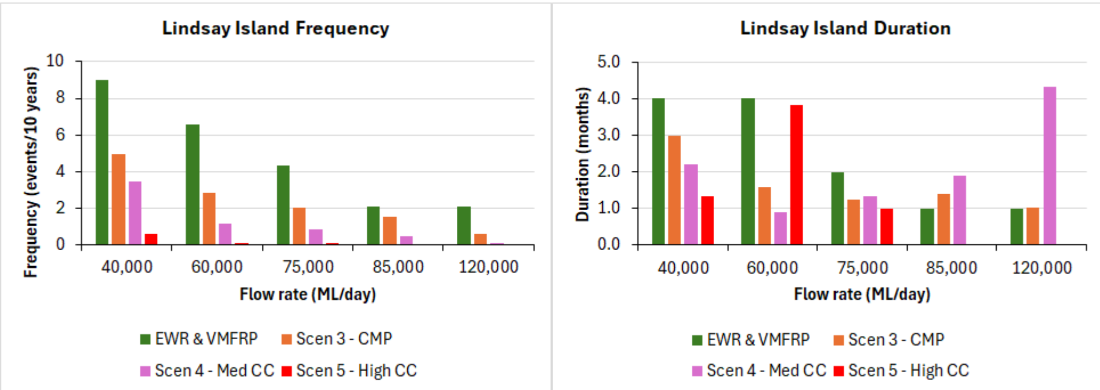


Figure 27 – Frequency and duration of events at Lindsay Island for 40,000, 60,000, 75,000, 85,000 and 120,000 ML/day EWR flow thresholds for the following scenarios: i) recommended EWRs and VMFRP; ii) Scenario 3 - CMP; iii) Scenario 4 - Medium 2070 climate change; iv) Scenario 5 - High 2070 climate change

5 Discussion

5.1 Consistency with the VCMP Feasibility Study

The environmental watering scenarios for the CMP used in this analysis used the hydrological data from modelling done by the MDBA for the Victorian CMP Feasibility Study (DEECA, 2024).

The results in this analysis should therefore be consistent with those reported in the feasibility study.

The feasibility study found that by relaxing constraints:

- short duration events extending to minor flood level can be provided
- the greatest benefits relate to the ability to water low-lying riparian vegetation and billabongs and flood runner ecosystems more frequently
- the effect on flows decreases with increasing distance from major storages as releases are attenuated through the river systems
- the peaks of higher flows are largely diminished by the time they reach the Wakool Junction due to the flat wide landscapes that water passes through when it leaves the river channel in the upstream mid-Murray and Edward-Wakool systems
- there does not appear to be a significant effect on the frequency and duration of higher flows at the South Australian border although the frequency of lower flows in the order of 10,000 to 15,000 ML/day may increase
- the effectiveness of relaxing constraints is dramatically diminished under a much drier future climate. This is mostly because of the reduced opportunities to 'piggyback' environmental releases on, and less water available to deliver 'new' environmental events when flows are low
- enables more water in the environmental water portfolio to be used more frequently. This will reduce storage levels at times, creating dam airspace which reduces the chance of spills at higher levels and the duration and frequency of more extensive floodplain inundation
- the need for environmental works projects such as The Living Murray and the proposed VMFRP are more pronounced further downstream.

These findings are consistent with results from this analysis which demonstrated that relaxing constraints:

- marginally increased the frequency of lower flows (15,000 to 20,000 ML/day) at Vinifera and Nyah but did not increase flow durations
- had little effect on flow frequency and duration of higher flow rates
- was not able to meet EWRs or maintain the current flow regime under Medium and High 2070 CC conditions.

5.2 Importance of understanding variability of flows

The ecological significance of differences between flow regimes for a natural system will vary depending on the natural range of variability that the system has adapted to cope with. A difference of 10% between frequency and/or duration of flows in a highly variable system may be of little significance, but the same difference in a less variable system might take it outside its historical range of variability making the differences ecologically significant. This concept is illustrated in **Figure 3** in **section 3.2**.

The effect of this is that the use of averages or medians to characterise the impact of differences (e.g. between VMFRP and CMP flow regimes) may not accurately reflect the ecological significance of the differences (Rory Nathan, email communication, 19 December 2024). These concepts are explored more fully in Nathan et al. (2019).

The core analysis in this report used average frequencies and median durations to quantify the differences between VMFRP flow regimes, as represented by recommended EWRs, and CMP flow regimes and to describe the ecological consequences of the differences. Flow variability data were then examined to check whether the conclusions were still likely to be valid given underlying natural variability in flow frequency and duration. These checks confirmed that at all sites the conclusions remained valid.

The variability data also allowed the significance for the potential ecological disbenefit in using CMP compared to VMFRP works to be described for flow frequency and duration. The degree of disbenefit was described as either Not Significant (NS), Significant (S) or Highly Significant. These results were presented throughout **Chapter 3.3** of this report. The results are presented in full in **Attachment 10**.

Plotting the highest ecological disbenefit for flow frequency or duration for all EWR flow thresholds shows that 29 of the 34 flow thresholds targeted by VMFRP have a Significant or Highly Significant ecological disbenefit (**Figure 28**). This means that very few of the VMFRP ecological objectives and EWRs at the eight VMFRP sites can be met by implementing the CMP under Historic climate conditions. They can be met by VMFRP.

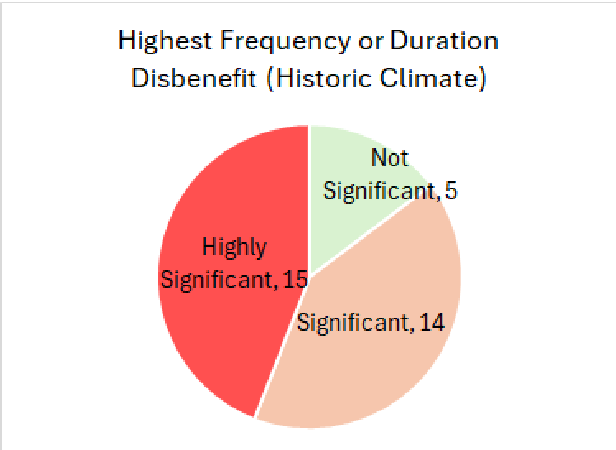
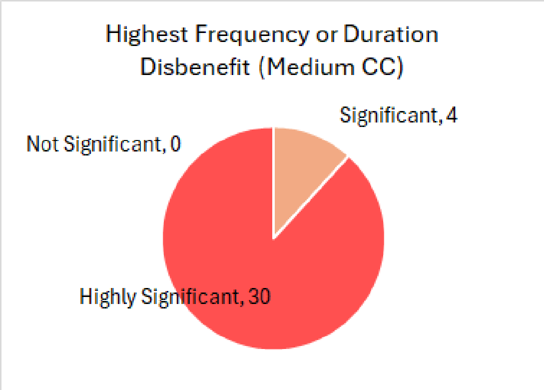


Figure 28 – Highest potential ecological disbenefit for frequency or duration associated with implementing CMP compared to VMFRP – Historic climate conditions

The ecological outcomes for the VMFRP sites worsen under climate change where the potential disbenefit for frequency or duration associated with implementing CMP compared to VMFRP:

- under Medium 2070 CC is Highly Significant for 30 of the 34 targeted flow thresholds (**Figure 29**)
- under High 2070 CC is Highly Significant for 33 of the 34 targeted flow thresholds (**Figure 29**).



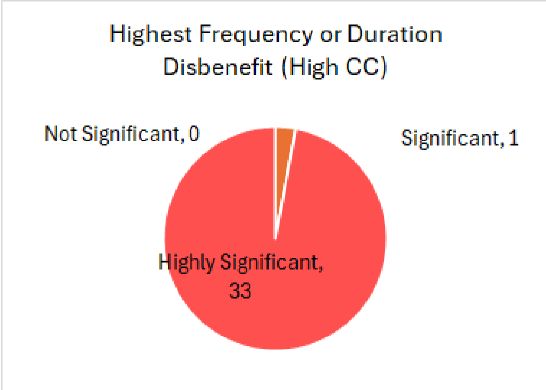


Figure 29 – Highest potential ecological disbenefit for frequency or duration associated with implementing CMP compared to VMFRP – Medium and High climate change

The increased disbenefit occurs because the frequency and/or duration of CMP flows decrease substantially under Medium and High 2070 climate change scenarios.

This means that no VMFRP ecological objectives and EWRs at the eight VMFRP sites can be met by implementing the CMP under modelled Medium and High 2070 CC conditions. VMFRP is required at all the sites to provide confidence that the ecological health of the waterway, wetland, forest and woodland systems will be restored.

5.3 Watering with works versus river flows

The VMFRP will use environmental works at eight floodplain sites to provide recommended EWRs to meet a range of ecological objectives. VMFRP will operate alongside existing Living Murray environmental works projects that to date have had over 4,000 GL of water delivered to them. Most Living Murray sites are on trajectory of improving condition, demonstrating that using environmental water and works helps to improve river health (MDBA, 2024b). VMFRP will operate within the established environmental watering program in Victoria, with coordination of environmental watering between local communities, catchment management authorities, waterway managers, storage managers, environmental water holders, land managers and State and Commonwealth government forming the foundation of the program.

There are a range of risks which are reduced with watering floodplains and wetlands with flows from the river compared to watering with works, e.g. water quality and connectivity. Brookes et al., (2014, p. 7) and Overton et al., (2014, pp. 4, 78, 143) briefly discuss these matters. Environmental watering programs consider these, and other risks associated with environmental watering, continually during long-term and annual planning, delivery and review. These risks are not limited to organisational boundaries and are often shared by two or more stakeholders. The VEWH, in collaboration with its key program partners, has developed a risk management framework that addresses inter-agency risk, respects the risk management process of each partner organisation and documents roles and responsibilities in operating arrangements. Key risks that are managed include:

- unplanned impacts on third parties (such as property damage from high water levels)
- environmental outcomes not occurring (or cannot be shown)
- unplanned negative impacts on the environment (for example, impacts to water quality)

- lack of community support
- insufficient resources within partner agencies to deliver water, mitigate risk or assess outcomes.

Risks are continuously reassessed as the season unfolds and planned watering actions are due to commence. Some risks may only eventuate at the time of delivery or there may be unintended effects from environmental flows or situations where environmental flows cannot be delivered. In these scenarios, stakeholders work together to respond to these incidents and adapt their processes and planning for the coming season.

Experience shows that there is high confidence that VMFRP will be able to deliver water to the eight floodplain sites and that associated risks can be managed.

The Constraints Relaxation Implementation Roadmap recognises that the cost and complexity of relaxing constraints was underestimated in the initial strategy in 2013 (MDBA, 2024). Relaxing constraints is seen as necessary to maximising environmental outcomes from Basin Plan water recovery. However, the Roadmap also recognises that a 10-year program is required to relax constraints and that doing so will be a complex task.

The Peer Review Report of this analysis (**Attachment 1**) also raises several risks associated with the CMP including:

- Climatic uncertainty – confidence in outcomes from relaxing constraints decreases with –
    - time as there is decreasing confidence in the rate of climate change and its impacts on stream flows
    - increasing flow threshold as there is less evidence available with which to characterise the frequency and duration of events, i.e. there are less modelled events at higher flow rates. It is noted that there is an upper limit above which this uncertainty is irrelevant as it may lie above the maximum constraint level adopted
    - uncertainty about future stream flows under climate change as estimates are based on simple factoring of historical data which are unlikely to represent future conditions
- Delivery uncertainty – delivery of environmental water via the CMP involves risks that are inherently more uncertain than watering with environmental works. Delivering water from upstream storages to lower reaches will require river operators to synchronise regulated releases with tributary flows. This is difficult given that releases may take many weeks to flow to downstream reaches and rainfall and stream flow forecasts are only accurate over a few days. Thus, river operators are likely to limit releases to reduce risks of flooding to third parties.

The author comments that these uncertainties have little impact on the operation of VMFRP environmental works.

5.4 Aspects of environmental flow modelling

During this project questions were raised about some of the assumptions and representation of aspects of environmental water management used in Victorian CMP Feasibility Study modelling. The matters discussed were important because they could influence the benefits provided by relaxed constraints flows and therefore results of this project. Matters raised included:

- representation of 'piggybacking' on unregulated flows
- coordination of environmental watering events in the Murray River and tributaries
- volume of environmental water recovery
- relaxed constraints flow thresholds.

Each matter is briefly discussed in the following sections.

5.4.1 'Piggybacking' on existing flows

The Basin Plan introduced unimplemented or prerequisite policy measures to improve the efficiency, effectiveness and flexibility of environmental water use (MDBA, 2025). 'Piggybacking' on unregulated flows was one policy measure.

Environmental water managers 'piggyback' environmental releases from storage on top of unregulated flows to enable environmental watering targets to be met using less environmental water. Environmental water not released can then be used to meet other flow objectives.

Victorian CMP Feasibility Study modelling of environmental water deliveries in the Goulburn River did 'piggyback' the release of environmental water on top of existing higher flows to meet environmental demands. This was done by setting a trigger in the GBCCL model for pre-existing flows to be 30% to 40% of the target peak flow before environmental water was released to deliver fresh events. For some flow actions (e.g. winter/early spring fresh) environmental water releases were forced at the end of the season if trigger flows had not been met (HARC, 2023, p. 51).

Source modelling for the Murray used similar approaches to piggyback environmental flow releases on top of existing flows to enhance or extend flow events. If opportunistic triggers didn't occur within specified timeframes and there was sufficient water available in environmental accounts then environmental events were created largely by releasing environmental water from storages (MDBA, 2022, p. 4). The hierarchy of scheduling was (DPE, 2022, p. 23):

1. Extending and/or raising an existing 'high' flow event
2. Raising and extending an existing 'medium' flow event
3. Delivering a 'new' event under low flow conditions.

The 'piggybacking' prerequisite policy measure was incorporated into Victorian CMP modelling. Victorian CMP reporting doesn't make comment on whether changing how 'piggybacking' is represented in the models would change relaxed constraints flows.

5.4.2 Coordination of Murray River and tributary flows

Technical modelling improvements to the Murray and Goulburn Source models improved the modelled hydrological connection between the Murray and Goulburn Rivers. Theoretically this provides for some coordination of modelled flows in the Murray and Goulburn. However, results showed only marginal improvements in environmental flows at Torrumbarry as relaxed constraints flows in the Goulburn system increased.

The marginal effect on downstream flows was attributable to:

- environmental releases to meet Goulburn environmental requirements occurring earlier in the season (August) than releases from the upper Murray to meet environmental requirements in the Murray (September-October)
- how downstream Murray environmental demands are called from the Goulburn system.

MDBA (2022, p. 23) notes there is scope to improve coordination of environmental watering events from the Goulburn, Murrumbidgee and Lower Darling to the Murray. It is inferred, although not explicitly stated, that better coordination would lead to modelling showing enhanced downstream environmental outcomes in the Murray River from relaxing constraints. Whether these improvements could be operationalised is being investigated as part of the Enhanced Environmental Water Delivery project.

5.4.3 Volume of water recovery

Victorian CMP Feasibility study modelling assumed 2,100 GL of Basin Plan water recovery. This was the volume of recovered water when the modelling was done and was supported by the project Consultative Committee.

The volume of Basin Plan water recovery is likely to increase because of current rounds of water tender purchases for the 450 GL Efficiency Measures component of the Sustainable Diversion Limit Adjustment Mechanism (SDLAM). What the final water recovery volume will be is unclear as it depends on the final volume of water purchase and the final volume of the Supply Measures component of the SDLAM.

Can VMFRP ecological objectives be met by CMP if more environmental water is recovered?

Increased Basin Plan water recovery will not mean the CMP can meet VMFRP ecological objectives. This is because factors other than just water availability limit CMP's ability to meet Environmental Watering Requirements (EWRs) at VMFRP sites.

The CMP environmental flow recommendations on the Murray River targeted short duration (mostly 7 to 14 days, occasionally up to 30 days) overbank flows below minor flood level along the river. They were designed to prevent a decline in vegetation condition in lower lying areas of the floodplain (DEECA, 2024, p. 118). The flow recommendations aimed to maximise outcomes from the use of environmental water whilst recognising and effectively managing the risks and minimising and addressing the impacts on landowners (DEECA, 2024, p. 25).

These flow objectives align with the Victorian CMP Feasibility Study findings that, typically, relaxing constraints provides short duration events extending to the minor flood level with most benefits arising from more frequent watering of low-lying riparian vegetation and billabongs and flood runner ecosystems.

VMFRP environmental flow recommendations and corresponding inundation events targeted optimal inundation frequencies and durations up to major flood level. They sort to restore ecological condition at the eight sites.

The analysis in this report is consistent with the different project objectives, i.e. it confirms that VMFRP sites generally require more frequent and/or longer duration inundation at higher flowrates than those provided by the CMP.

The different objectives of environmental flow recommendations for the two projects mean that additional environmental water recovery through the Basin Plan will not result in the CMP meeting VMFRP ecological objectives. More environmental water would allow the CMP to deliver additional shorter duration lower flow events, but these would not meet the generally longer duration higher flow events being targeted by VMFRP. Thus, increasing environmental water holdings alone will not produce the fundamental changes required for the CMP to meet VMFRP ecological objectives. Modelling results from the Victorian CMP Feasibility Study support this conclusion.

Figure 30 shows that modelled average annual environmental water use with relaxed constraints was significantly less than the volume of environmental water available. This demonstrates that environmental water availability did not limit the modelled CMP flow outcomes. The Y40D40 scenario represents the level of relaxed constraints notified by BOC and used in this project.

Further refinement of the Murray River modelling could improve environmental flow outcomes and utilise more environmental water, but these results indicate that in most years water availability wasn't limiting environmental releases under the CMP.

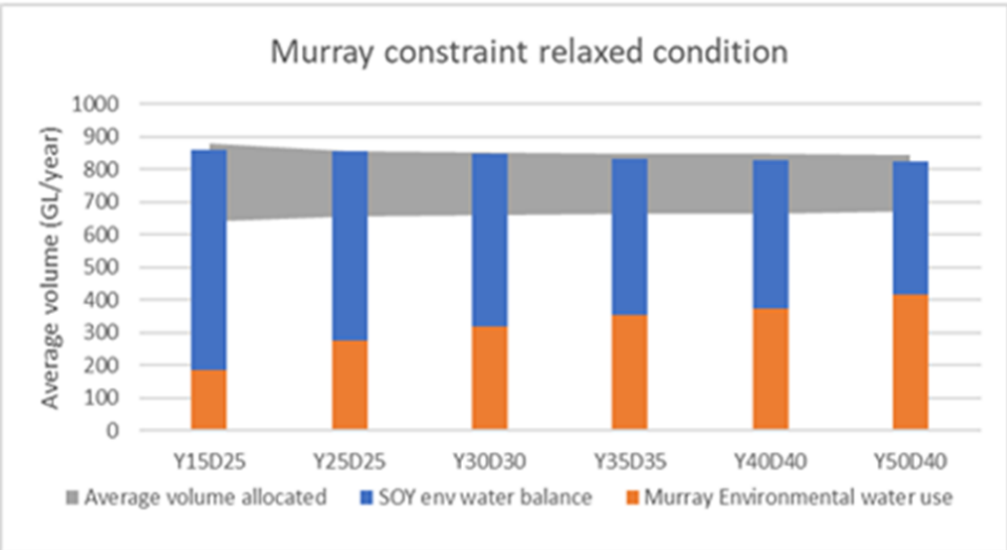


Figure 30 – Average annual environmental water use (Orange columns), average environmental water allocations at the start and end of the year (Grey shading) and average environmental water account balance at the start of the year (SOY) (Blue columns) in the Murray system for different levels of constraints relaxation (Source: Figure 6 of MDBA (2022)).

5.4.4 Level of relaxed constraints

The level of relaxed constraints used in this project is based on the flows in project business cases notified to, and approved by, BOC. The recently released Constraints Roadmap (MDBA, 2024, p. 35), notes that relaxed constraints flowrates in the 2013 Constraints Management Strategy (MDBA, 2013) were conceptual and lacked community support.

Contemporary work is exploring flow rates that are considered more reasonable and practical to implement. These flow rates are generally lower than the notified flowrates assumed for this study. The final magnitude of relaxed constraints flowrates is not known. If the flowrates are less than those notified, then the frequency and duration of some of the low to medium magnitude flow events modelled by the Victorian CMP Feasibility Study will be less than those in this study.

6 Conclusions

Can VMFRP ecological objectives be met by CMP?

The majority of VMFRP ecological objectives and EWRs at VMFRP sites cannot be met by implementing the CMP under historic climate conditions. They can be met by VMFRP. This means that the CMP will provide significantly less ecological benefits at VMFRP sites. VMFRP is required at all sites to provide confidence that the ecological health of the waterway, wetland, forest and woodland systems will be restored.

How might relaxing constraints affect the operation of VMFRP works?

At Vinifera and Nyah, because the CMP may increase the frequency of events at the three lower EWR threshold flows compared to current river flows, its implementation may reduce the work required by VMFRP to meet the EWRs. A higher frequency of events will reduce the times that pumping is required to fill the areas within environmental works. Regulators will be able to detain flood water and prolong floods efficiently, mitigating the effects of shorter flood durations under the CMP.

The CMP will not influence the operation of VMFRP works at Gunbower National Park, Guttrum and Benwell Forests, Belsar-Yungera, Hattah Lakes North, Wallpolla Island and Lindsay Island.

How resilient are VMFRP and relaxing constraints under a changing climate?

Treadwell (2022) found that under long-term average and climate change conditions there is high confidence that there will be sufficient water to meet the water demands at VMFRP sites and sufficient capacity in the Murray River and its tributaries to deliver the water to the sites when needed.

Based on this analysis it is concluded that VMFRP's ability to meet ecological objectives at the eight floodplain sites is highly resilient to climate change because there is high confidence that the operation of VMFRP environmental works will enable recommended EWRs to be delivered under historic and climate change conditions.

The frequency and/or duration of CMP flows decrease substantially under Medium and High 2070 CC scenarios meaning no VMFRP ecological objectives will be met at VMFRP sites. The effect of decreased frequencies and durations will exacerbate impacts at all floodplain sites compared to outcomes under historic climate conditions.

The CMP at VMFRP sites is less resilient to climate change than VMFRP.

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Attachment 1 – Peer Review Report

Please refer to accompanying report.

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Linda Tremewen
Senior Project Manager – Victorian Murray Floodplain Restoration Project
Department of Energy, Environment and Climate Action
Via email: linda.tremewen@deeca.vic.gov.au

c.c. Mark Wood, Principal Consultant, Woodwater

16 April 2025

Dear Ms Tremewen,

Peer Review of interface with Constraints Management Plan

I am writing to provide a review of the draft report (hereafter referred to as "the draft Report") prepared by Marcus Cooling, Mark Wood and Simon Lang entitled "VMFRP Ecological Objectives and Relaxed Constraints Flows", Version 2.0, dated 28th January 2025. This review is based on information provided in the draft report, noting that I attended three meetings via videoconference with the report authors and representatives reporting to the Department of Energy, Environment and Climate Action (on 19th December 2024,10th February 2025, and 21st March 2025) in which the proposed methodology and context for the work was broadly discussed.

Overall comments

The draft Report details investigations undertaken to compare the ecological benefits that could be obtained under different environmental watering arrangements and climatic conditions. Of key interest is the relative efficacy of the proposed VMFRP works compared to those that might be obtained through "relaxed constraints" (ie by managing enhanced natural river flows, sometimes delivered by 'piggybacking' on small flood pulses, whilst actively managing risks to third parties). In essence, the report tackles the question "can relaxing constraints provide the same benefits at selected VMFRP sites as can be achieved using VMFRP works and measures, both now and into the future?"

Overall, the authors present a compelling case to conclude that the majority of environmental watering objectives at the four sites of interest (Vinifera, Nyah, Hattah

Lakes North and Belsar-Yungera) cannot be met through relaxed constraints. Compared to VMFRP works, the comparative disbenefits of relying on relaxed constraints at the VFMRP sites increases with increasing flow threshold, and also increases with the length of the planning horizon of interest. Furthermore, the efficacy of relaxed constraints is vulnerable to expected changes in natural streamflow regime, a source of considerable uncertainty to which the operation of VMFRP works is largely immune.

The nature of the evidence used to support the conclusions is clearly presented in the report. Nonetheless, some additional commentary is provided below that characterises the significance of the disbenefits that would be involved in relying solely on constraints management to deliver the environmental watering. Further, some additional points are provided on the sources of key uncertainties that impact differentially on the two water delivery approaches, and this is followed by some brief conclusions.

Significance of disbenefits

The figures in the main body of the Report illustrate the average differences (over a 124-year period) in the frequency and duration of watering events when actively delivered under relaxed constraints and using the VMFRP works. This provides an easily understood summary of behaviour, though a comparison of averages does not capture well the ecological significance of the differences. As discussed in the draft Report, a difference of 10% in the average frequency and/or duration of flows in a highly variable system may be of little significance, but the same difference in a less variable system might take it outside its historical range of variability making the differences ecologically significant. Information on the range of outcomes associated with natural variability is provided in Attachment 1 of the draft Report.

There are some small differences between the frequency results shown in Attachment 1 and those shown in the main body of the Report, and it is understood that this is because the results shown in Attachment 1 are based on the distribution of outcomes over non-overlapping ten-year sequences, whereas those shown in the main body of the Report are based on all 124 years of available record. That is, the frequency results shown in the main body of the Report are based on averaged behaviour over 124 years of historical climatic sequences (over the period 1/7/1895 to 30/6/2019), whereas those in Attachment 1 examine the distribution of behaviour over successive ten-year sequences within the same 124-year period.

Given the wide range of differences in outcomes, it is considered useful to summarise the results in terms of their ecological significance, where here emphasis is given to characterising differences as being "not significant", "significant" and "highly significant". The basis of this categorisation is shown in Figure 1, where:

- **"Not significant" disbenefits** denote results where the use of relaxed constraints yields average (or median) ecological outcomes that lie *within* the 50% range of natural variability found under "baseline" conditions. The baseline adopted in the report relates to the outcomes over the 124 years of historical climate corresponding to "without development" (ie Scenario 1 in Table 3).
- **"Significant" disbenefits** denote results where the average (or median) ecological outcome of using relaxed constraints lies *below* the 50% range of natural variability found under "baseline" conditions. Attention is given here only to results where the outcomes are worse, as it is assumed that opportunities to provide watering events more frequently or longer than found under the pre-development scenario will not be prioritised.
- **"Highly significant" disbenefits** denote results where the *full 50% range of outcomes* under the scenario of interest lies *below* the 50% range of natural variability found under "baseline" conditions; that is, where the distribution of outcomes for a given scenario are largely worse than the range of conditions that the ecology is assumed to have adapted to.

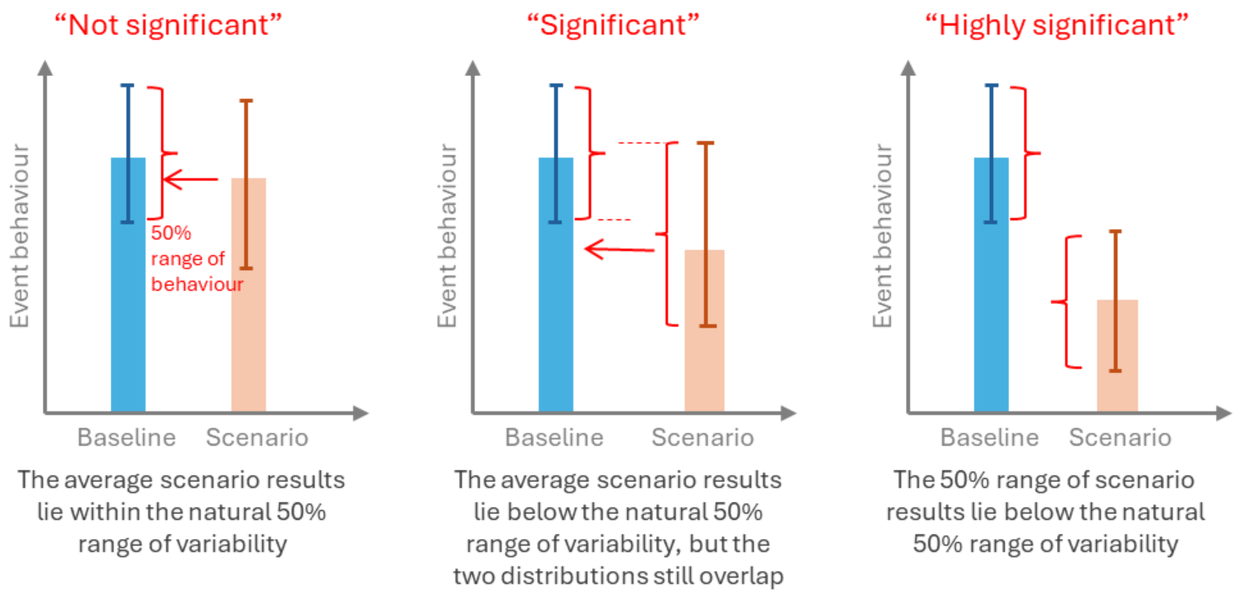

Figure 1. Definition of the degree of ecological significance for the potential disbenefit in using relaxed constraints compared to VMFRP works.

The above categorisation was applied to the results presented in the Report, which yields the summary for individual sites shown in Table 1. This summary highlights that in almost all cases the use of relaxed constraints fails to deliver on the required *frequency* of watering events, and that the required *duration* of the watering events is not achieved most of the time.

Table 1. Summary of ecological disbenefits for using relaxed constraints compared to VMFRP works on the frequency and duration of environmental watering, by individual site, where the results are grouped into three bands of watering event magnitude.

Site	**Climate change**	**Frequency of watering** Magnitude of watering event			**Duration of watering** Magnitude of watering event		
		Small	Medium	Large	Small	Medium	Large
Vinifer	Current	NS	S	HS	S	S	S
	Medium	HS	HS	HS	S	S	S
	High	HS	HS	HS	HS	HS	HS
Nyah	Current	NS	HS	HS	S	S	S
	Medium	HS	HS	HS	S	S	S
	High	HS	HS	HS	HS	HS	HS
Hattah Lakes	Current	S	S	S	NS	NS	NS
	Medium	HS	HS	HS	NS	NS	HS
	High	HS	HS	HS	HS	HS	HS
Belsar-Yungara	Current	S	HS	S	S	NS	NS
	Medium	S	HS	HS	S	S	NS
	High	S	HS	HS	HS	S	HS

NS - "not significant", S - "significant", and HS "highly significant"

An alternative high-level summary is provided in Figure 2, where here the disbenefits involved are aggregated across all four sites and all watering event magnitudes. This view of results highlights the vulnerability of the system to climate change, because reduced water availability for environmental water holders means that there will be fewer opportunities to take advantage of relaxed constraints.

One point that is not entirely clear from the Report is whether the distribution of the duration of watering events is based on a conditional sample of those events that were identified from spells over a given threshold magnitude with a specific independence criterion, or whether they were identified independently. The identification of spell events according to different criteria can yield quite different distributions, so one way of revealing whether this is an issue is to simply summarise the total number of days that flows exceed a given threshold for comparison purposes. The inclusion of this simple statistic would be readily understood and interpreted, and would help ensure that the independence criterion used to identify events is not obscuring inferences that could be made about possible differences between the two methods.

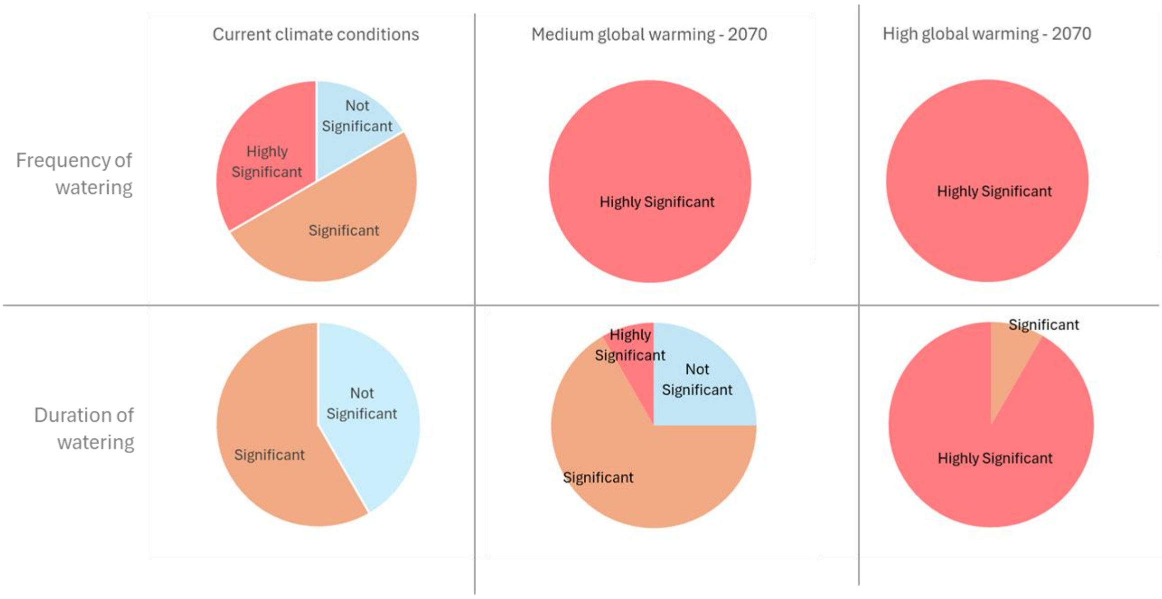

Figure 2. Significance of ecological disbenefit for using relaxed constraints compared to VMFRP works on the frequency and duration of environmental watering across all four sites and watering thresholds under current and future climate conditions.

Sources of Uncertainty

While the Report gives consideration to aleatory sources of uncertainty (ie the influence of natural variability on management outcomes), little mention is made of other sources of uncertainty which need to be considered when using the outcomes for decision-making. It could be reasonably argued that the treatment of these sources of uncertainty lies outside the scope of the work described in the Report, but they nevertheless relate to the defensibility of the conclusions drawn.

There are three key sources of uncertainty which are worth mentioning here, namely those relating to the base hydrological information on which the analyses are based, the basis of the selected climate scenario, and the "deliverability" uncertainties associated with operational active management.

Hydrological uncertainty

The hydrological data used in the draft Report was provided by the relevant State agencies. There are several assumptions underpinning this data set which are mostly acknowledged in the background documents cited in the Report, but of particular interest here it is noted that these data sets are derived assuming that:

i. Catchment conditions influencing water availability are unchanging

ii. The models used to simulate the hydrological processes and management of the regulated river system are fit for purpose

The first assumption is at odds with historical observations and with the published literature (eg Peterson et al, 2021), noting that such changes can influence hydrological projections (eg Fowler et al, 2016; John et al, 2022). Our understanding of future water availability is also subject to changes in catchment land use, both natural and agricultural, and these will impact on runoff behaviour and on the timing and magnitude of demands for irrigation and water supply. However, given the intrinsic uncertainty in such factors it is not practical to speculate on such changes in such planning investigations as these, though they remain as sources of uncertainty in our understanding of future changes to water availability.

The daily flow sequences relied upon for the Report are derived using hydrological models to simulate catchment runoff, and on the Source model to simulate operation of the river system. The hydrological models are subject to the non-stationary uncertainties discussed in the previous paragraph, though perhaps of more specific relevance to this project is the fact that the models have been calibrated for water resource management purposes rather than the investigation of ecologically important flow components. While the calibration objective for water management purposes generally attempts to reproduce the overall flow regime and seasonal yield water availability (ie the flow duration curve and associated statistics of central tendency), these metrics are generally not sufficient to reproduce the spell characteristics (ie the distribution and frequency of spells above or below a range of thresholds of ecological importance) that might occur as frequently as several times per year, or as rarely as several times per 100 years. Specific calibration approaches are required to reproduce the statistical behaviour of such events (eg Wasko et al 2023), and without specific attention it unknown how well the hydrological models faithfully reproduce the frequency-duration-magnitude characteristics of the high flow spells of most interest here.

Any uncertainties and deficiencies in the hydrological modelling propagate directly through to the river system (Source) models, though of course the river system modelling also includes additional assumptions related to how the system is managed. It is noted that this data set is the first time that it has been possible to include daily (Source model) outputs from the Goulburn system. There are various different aspects of water management that are potentially relevant to the uncertainty in deliverability of the environmental water, which is discussed below. But first, it is appropriate to discuss the impact of the deep uncertainty associated with the rate and nature of global warming.

Climatic uncertainty

The results presented in the Report indicate that the watering events of ecological value typically range in frequency from around 1 to 10 times in a ten-year period, though at three of the sites under climate change, (Nyah, Hattah Lakes, and Belsar-Yungara), the largest events of interest may only be achieved a few times in a hundred-year period. This point is worth making as our confidence in the distribution of watering events is heavily dependent on the threshold of interest, and how far into the future we are projecting. For example, if a particular threshold is only exceeded on average a few times in a 100-year period, then under a stationary climate assumption there will be some 100-year periods where we don't observe any occurrences, and others where we might observe two or three times the average number of events. Conversely, with low thresholds that are exceeded many times in a decade, then we can expect to have good confidence in our ability to characterise the distribution using data from a single 100-year period. Additionally, our confidence in the impacts of global warming on streamflows decreases the further we project into the future; the key (and largely irreducible) uncertainties here being the rate at which can reduce our carbon emissions, and the associated hydroclimatic assumptions relating to runoff generation in a warmer world.

The influence of these factors on our confidence in water delivered by relaxed constraints is notionally illustrated in Figure 3. This figure illustrates that our confidence in the ability of relaxed constraints decreases with increasing planning horizon as we have decreasing confidence in the rate of climate change and its impacts on natural streamflows. It also decreases with increasing flow threshold as there is less evidence available with which to characterise the frequency and duration of spells above these thresholds. There is an upper limit beyond which this uncertainty is irrelevant as it may lie above the maximum constraint level adopted, but the uncertainty associated with frequent events delivered by relaxed constraints continues to increase into the future due to increasing hydroclimatic uncertainty under global warming.

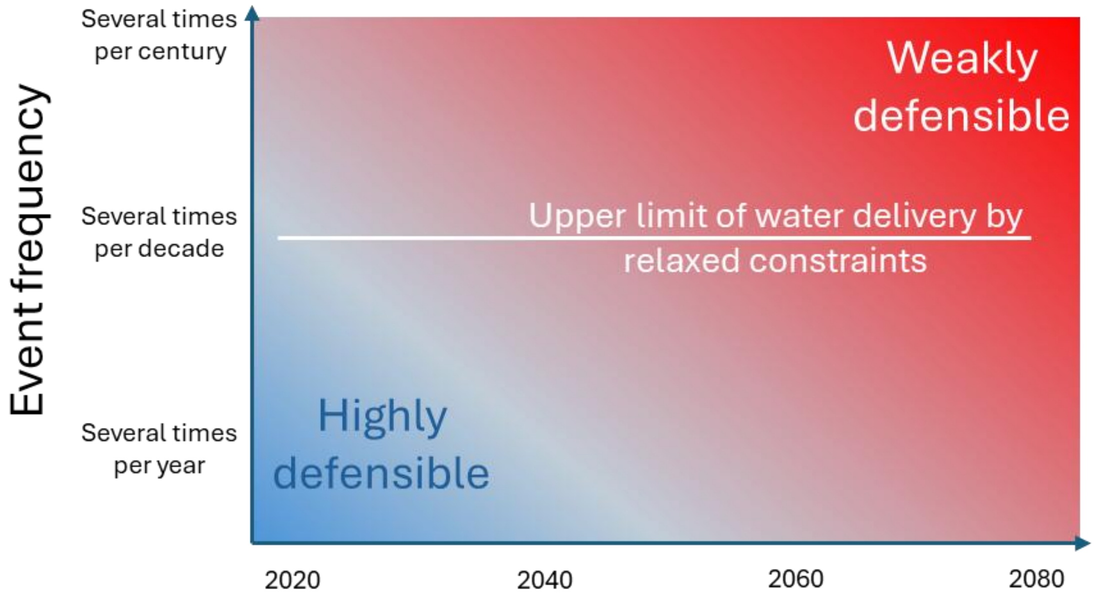

Figure 3. Notional illustration of how confidence in the relaxed constraints results depends on event frequency and the planning period of interest.

It is to be noted that the estimates of future streamflows used in the draft Report are based on the simple factoring on historical data, which is a commonly used approach in these kinds of planning investigations. With this approach it is implicitly assumed that the future sequence of wet and dry periods is identical to the past, generally just shifted down a little (in seasonal magnitude terms) to represent conditions associated with global warming. This "groundhog day" approach largely ignores the changing mix of rainfall intensities over different time scales (Wasko et al, 2023) and the changing mixes of weather systems (Pepler et al, 2021). Such factors can be expected to impact on the distribution of flow pulses and thus to annual flows (Dykman et al, 2023), and to freshwater ecology (John et al, 2022). The nature of these "groundhog day" assumptions is partly responsible for the slanted nature of the coloured regions in Figure 3, as the fixed nature of the sequencing of wet and dry periods severely constrains the sampling variability relevant to rarer events. Stochastic simulation approaches can be used to address this problem (as illustrated by John et al, 2024), however, such approaches are computationally demanding and not well suited for use with the adopted Source models. A discussion about the trade-offs involved in using complex versus simple surrogate models to simulate the deep uncertainty of hydrologic projections is beyond the scope of this paper, but suffice to state here that climate change impacts differentially on different aspects of the hydrologic regime, and the defensibility of using scaled historic data decreases with event magnitude and with increasing planning horizon. Such uncertainties undermine our confidence in the results obtained for the relaxed constraints approach as they rely heavily on the defensibility of the projected frequency and duration of naturally occurring flow pulses.

In contrast, it is considered that these uncertainties have little impact on the performance of the VMFRP works. While the target watering frequency is subject to increasing uncertainty as the threshold of interest increases, it can be expected that with monitoring our understanding of watering requirements will adapt over time as climatic conditions change, and that the VMFRP operating regime will be altered as required.

Delivery benefit uncertainty

The delivery of environmental water using relaxed constraints represents distinctly different risks to those associated with VMFRP works. The operation of the VMFRP works relies on the use of engineering infrastructure to pump and/or control river levels for diversion, and with appropriate maintenance and testing procedures it is reasonable to expect that these works will be able to reliably deliver water on demand.

In contrast, the delivery of environmental water via relaxed constraints involves risks that are inherently more uncertain. To ensure that relaxing constraints in the upper reaches of the system will provide environmental benefits in the lower reaches, it will be necessary for river operators to carefully synchronise regulated releases from dams and weir storages on the Murray and Goulburn systems using agreed procedures. Given the time taken for water to flow from upstream sources to targeted delivery sites it is necessary to rely heavily on streamflow forecasts. The reliability of such forecasts has improved over time with investment in additional gauging and improvements in weather models, but streamflow forecasts that depend heavily on rain that has not yet fallen on the catchment involve large and largely irreducible uncertainties which increase with the distance downstream. To avoid adverse outcomes to third parties it would be expected that releases will be biased low relevant to forecasts, and this increases the likelihood that the environmental water targets may not be met for any given event.

With the information to hand, it is considered that our understanding of the deliverability of environmental water using relaxed constraints is subject to considerably larger uncertainty than water delivered by VMFRP works. While such a view implies that the likely actual benefits of environmental water delivered via relaxed constraints are likely to be less than that estimated from hindcast modelling, it is to be noted that relaxed constraints offer benefits beyond the identified VMFRP sites in terms of in-stream aquatic benefits and inundation of upstream and downstream riparian reaches.

Conclusions

On the basis of the available information and the above considerations, it is concluded that:

- The frequency and duration of environmental watering provided by relaxed constraints is of significantly less ecological benefit than VMFRP at the VMFRP sites – this is especially true for high magnitude watering events, but it is also generally the case for smaller flow thresholds.

- The efficacy of using relaxed constraints for delivery of environmental water to the VMFRP sites is expected to decrease under climate change, though our ability to estimate the behaviour of the underlying natural streamflow sequences is subject to increasing uncertainty with longer planning horizons.

- The delivery of environmental water by relaxed constraints is operationally more uncertain than that by the VMFRP works due to the inherent difficulties in forecasting rainfalls (and hence streamflows) at long lead times.

- VMFRP works represent a compelling solution to managing the uncertainty surrounding future water availability.

Overall, it is considered that relaxed constraints have the potential to provide a valuable complement to VMFRP works for small watering events (and for in-stream and riparian reaches upstream and downstream of VMFRP sites), but they do not represent a credible alternative under either current or future climate conditions.

I would be happy to discuss any of the above points as needed.

Yours sincerely,

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M: 0438 586 095

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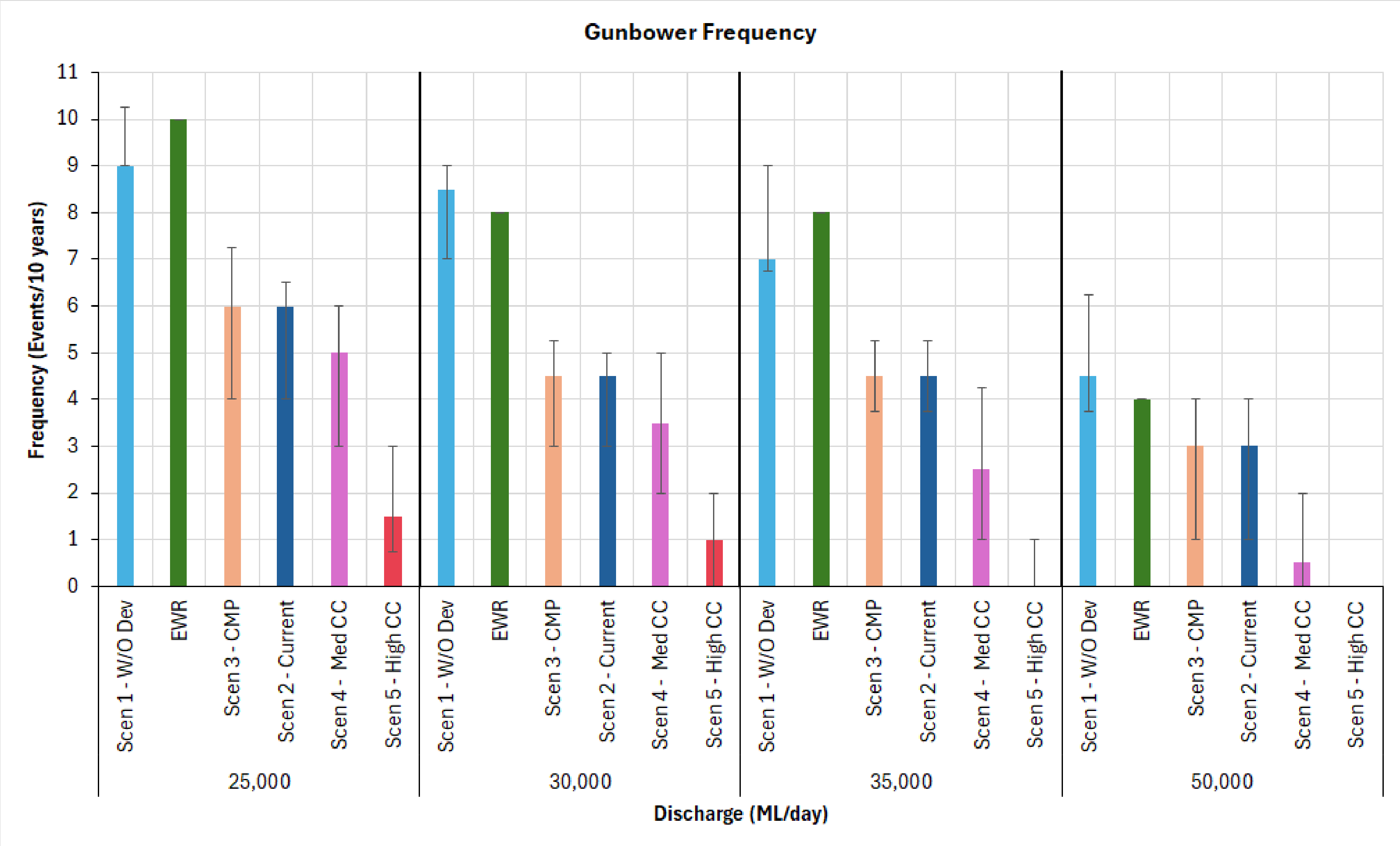
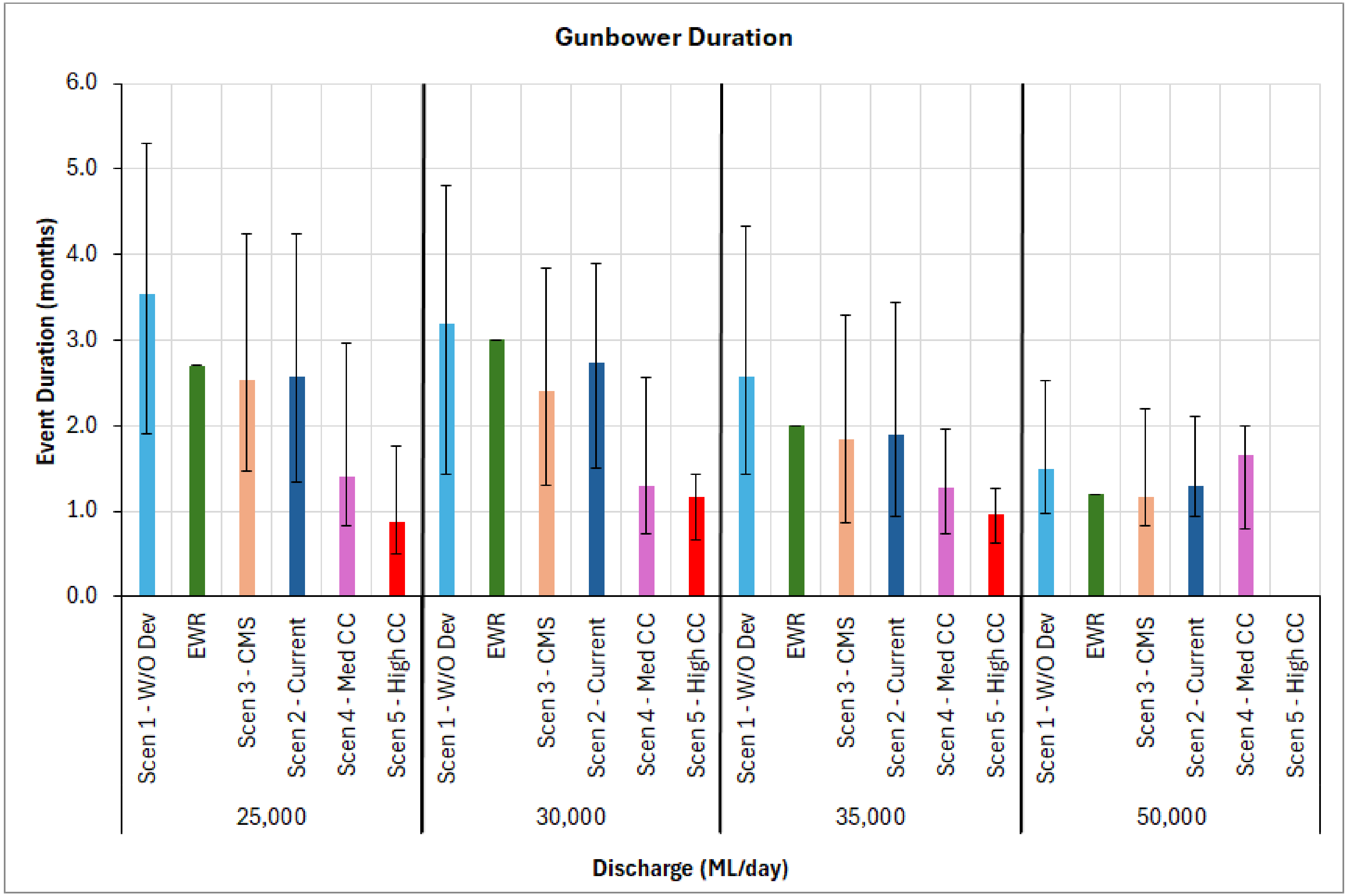
Attachment 2 – Gunbower frequency and duration variability

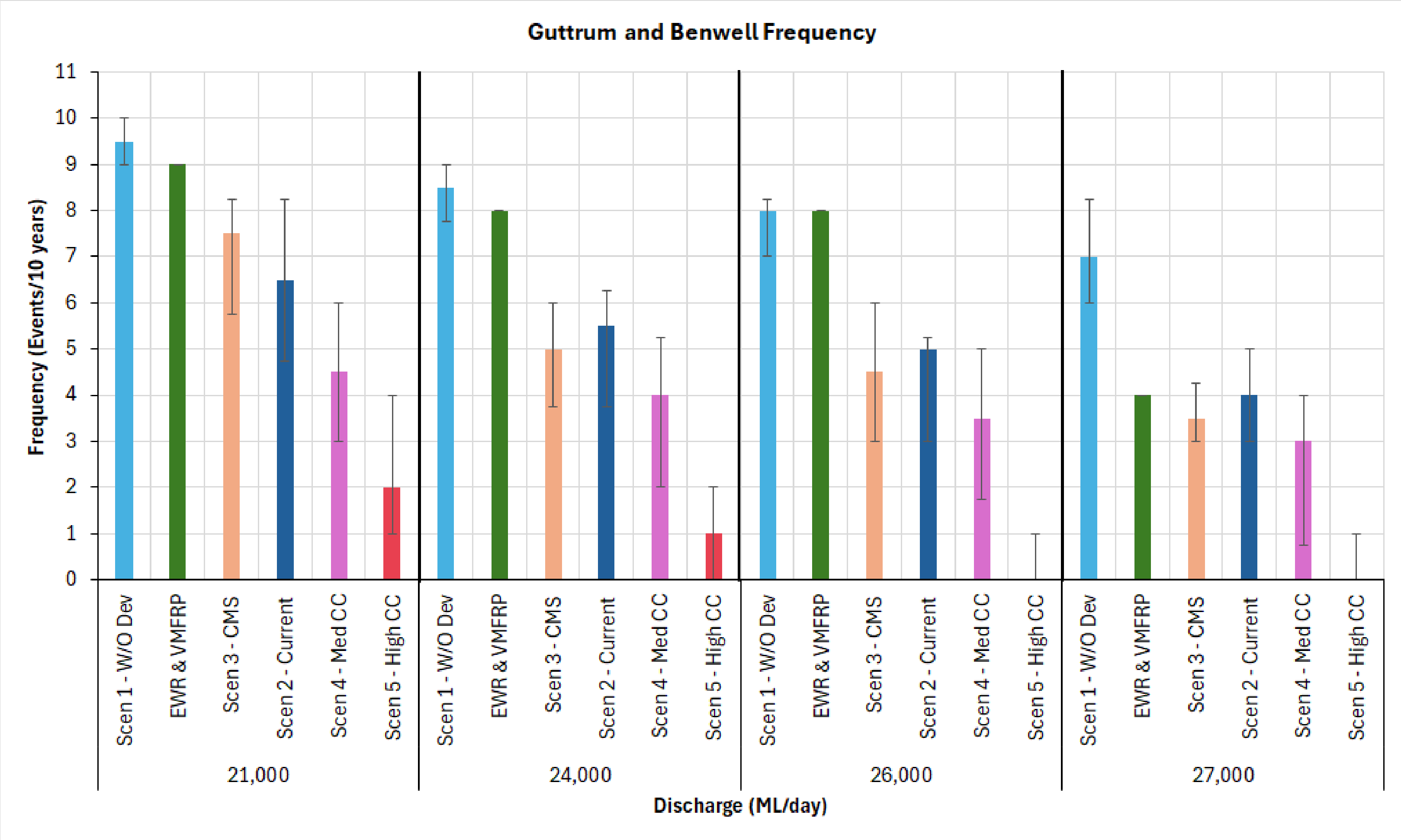
In the charts the columns represent the median frequency and duration (50th percentile), the error bars the 25th and 75th percentile frequencies and durations. EWRs were defined using average frequencies (events/10 years) and median durations only. There will be significant variability in flows using VMFRP works, but what these are will be subject to adaptive operations and management.

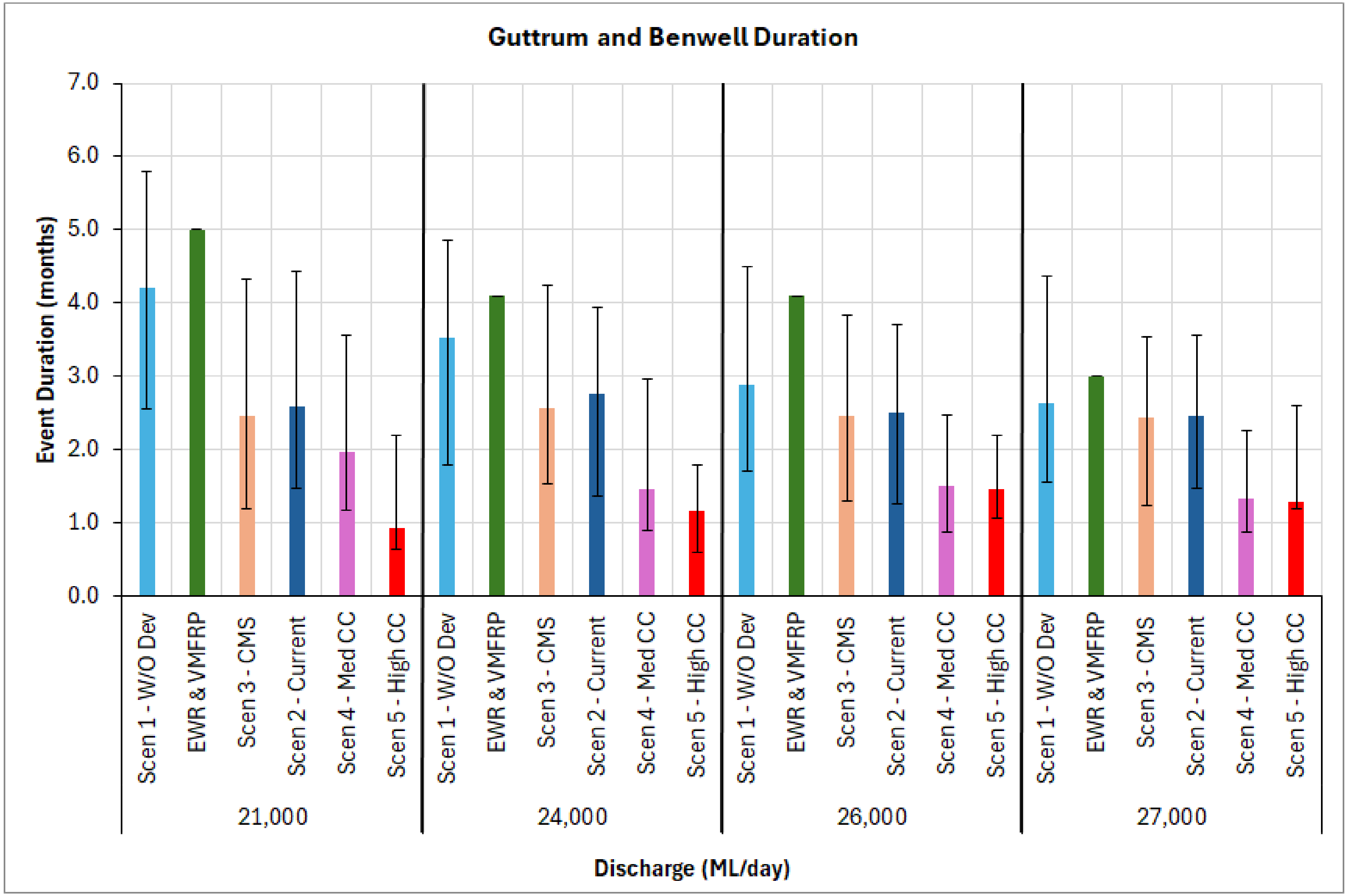



Gunbower Duration
Event Duration (months)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Scen 1 - W/O Dev
EWR
Scen 3 - CMS
Scen 2 - Current
Scen 4 - Med CC
Scen 5 - High CC
25,000
30,000
35,000
50,000
Discharge (ML/day)

Attachment 3 – Guttrum and Benwell Forest frequency and duration variability

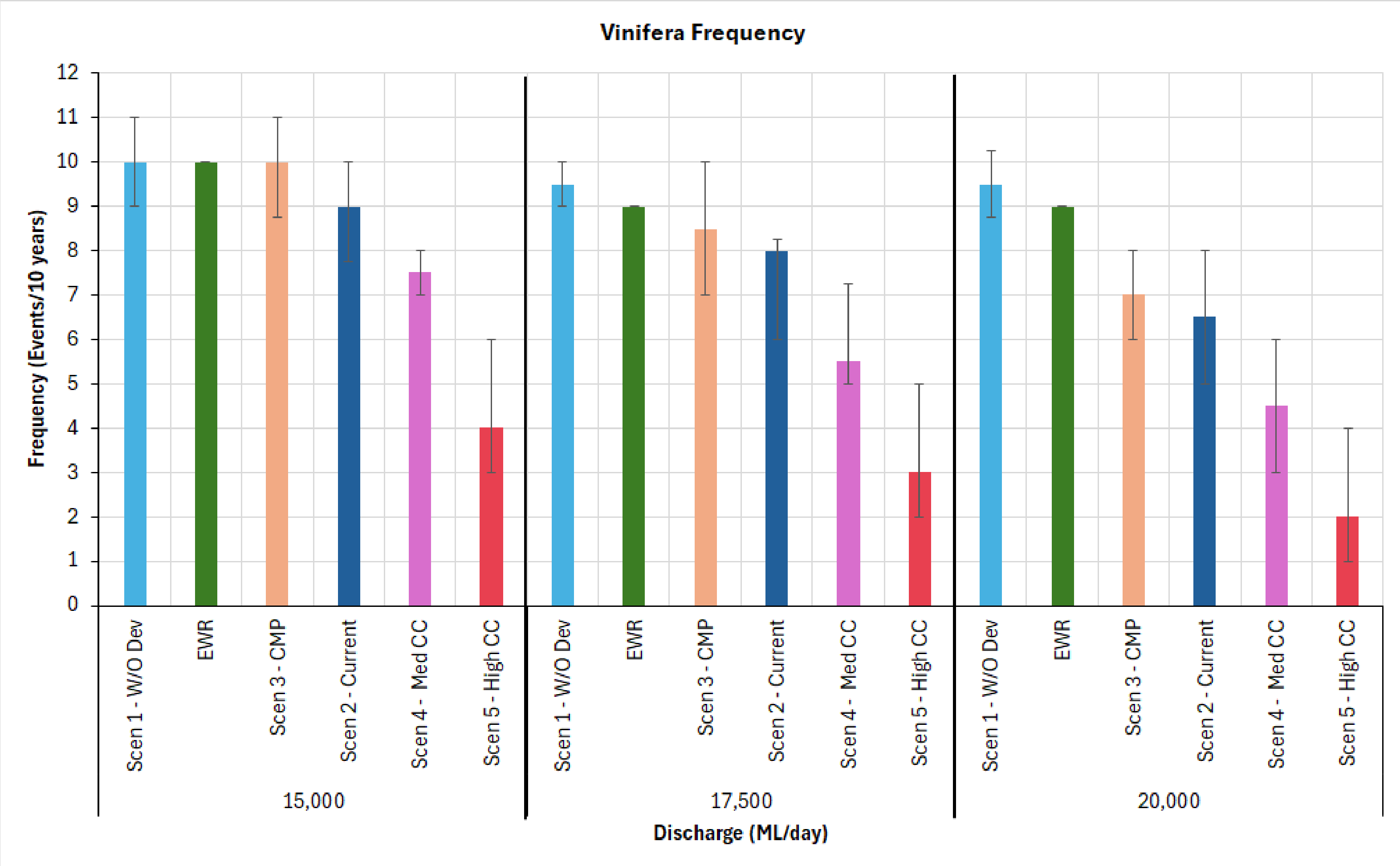
In the charts the columns represent the median frequency and duration (50th percentile), the error bars the 25th and 75th percentile frequencies and durations. EWRs were defined using average frequencies (events/10 years) and median durations only. There will be significant variability in flows using VMFRP works, but what these are will be subject to adaptive operations and management.

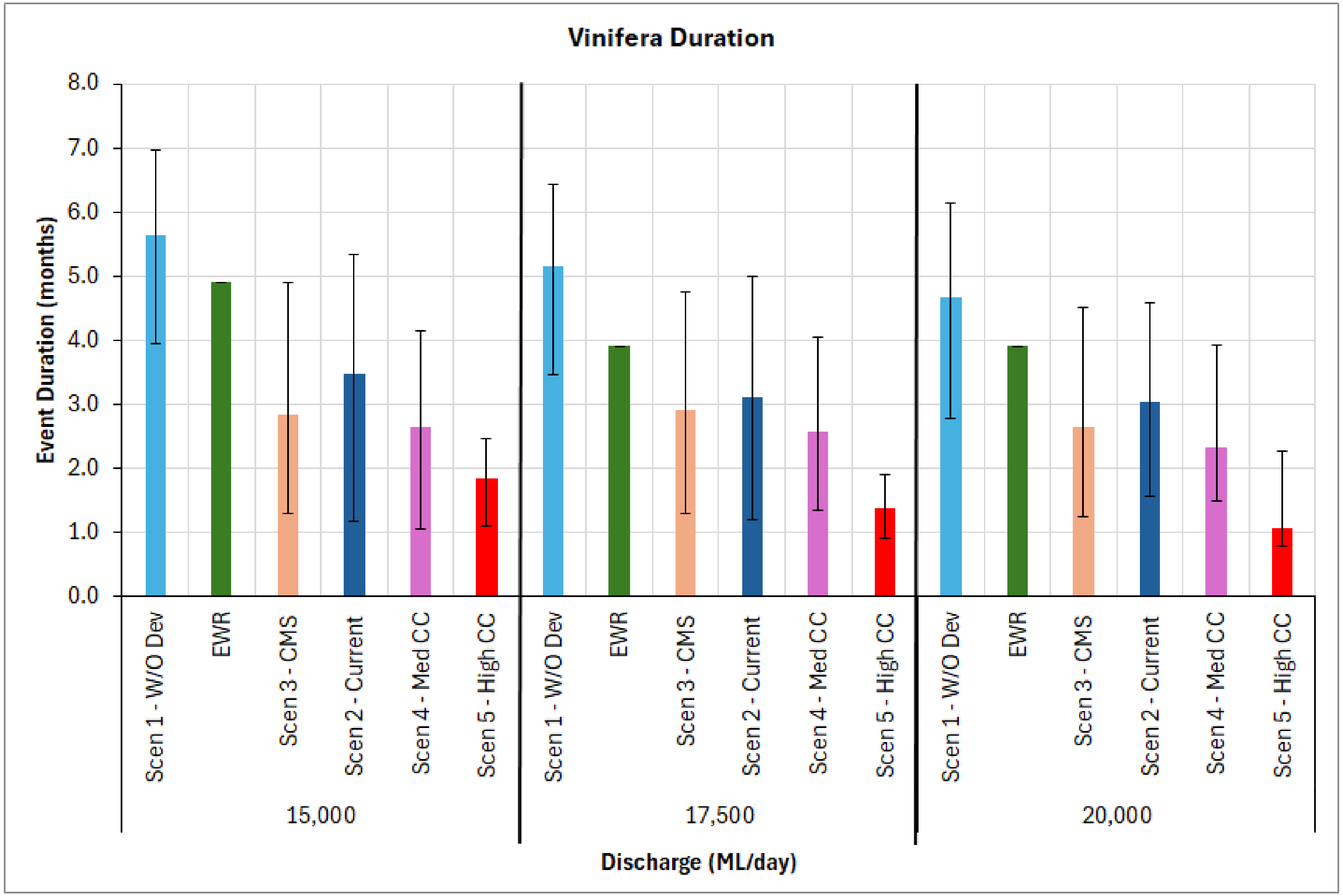



Guttrum and Benwell Duration
Event Duration (months)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Scen 1 - W/O Dev
EWR & VMFRP
Scen 3 - CMS
Scen 2 - Current
Scen 4 - Med CC
Scen 5 - High CC
21,000
24,000
26,000
27,000
Discharge (ML/day)

Attachment 4 – Vinifera frequency and duration variability

In the charts the columns represent the median frequency and duration (50th percentile), the error bars the 25th and 75th percentile frequencies and durations. EWRs were defined using average frequencies (events/10 years) and median durations only. There will be significant variability in flows using VMFRP works, but what these are will be subject to adaptive operations and management.

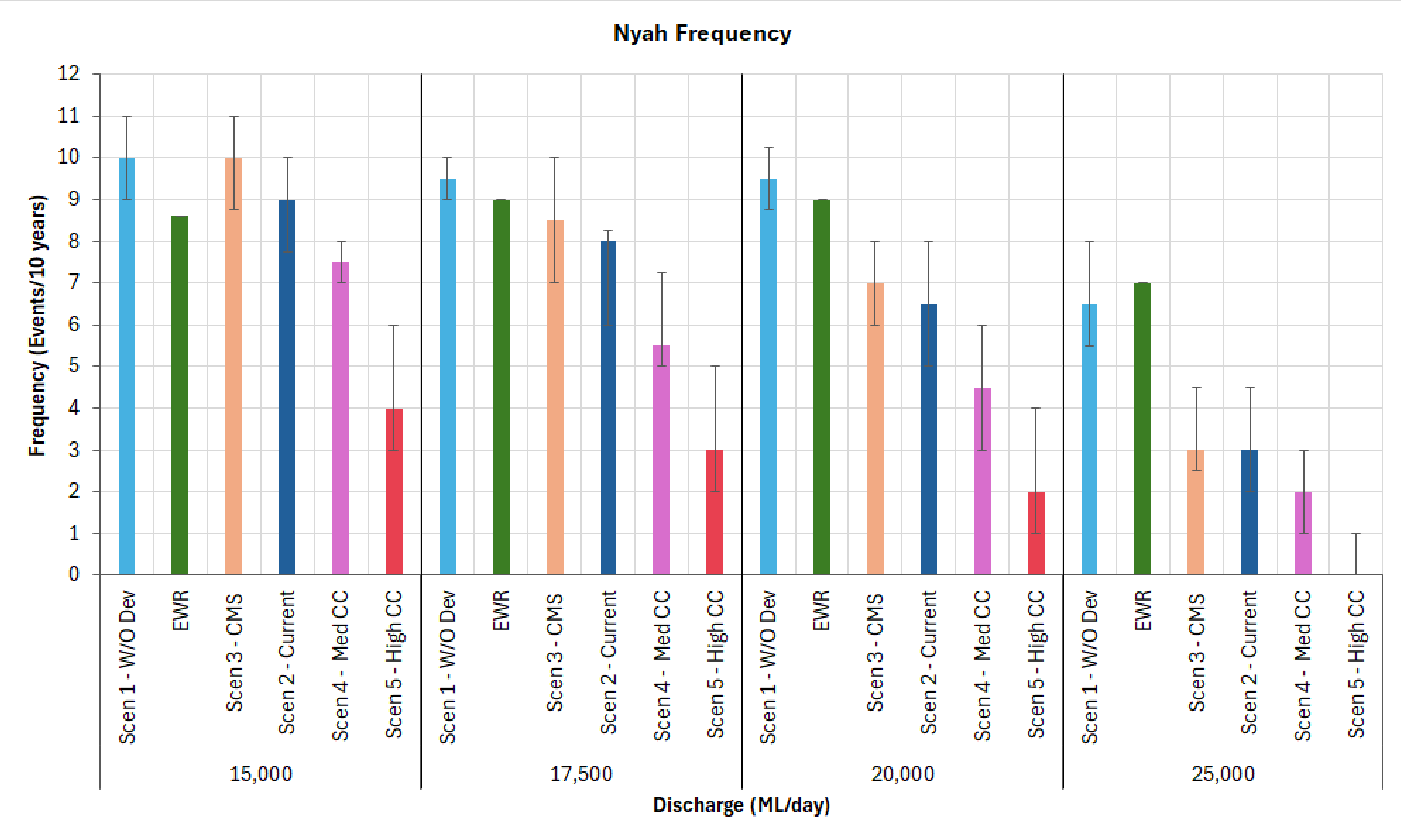


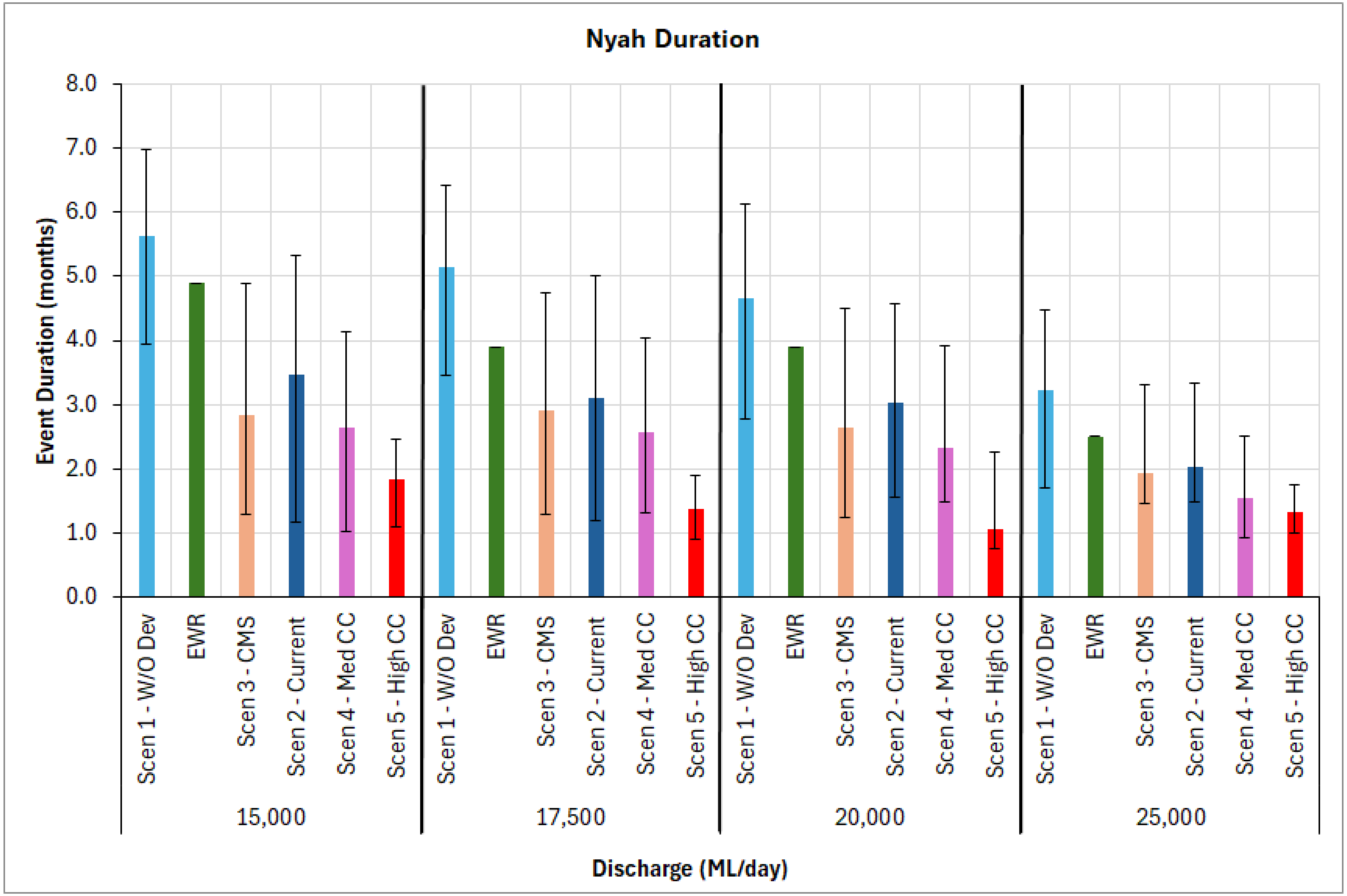


Vinifera Duration
Event Duration (months)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Scen 1 - W/O Dev
EWR
Scen 3 - CMS
Scen 2 - Current
Scen 4 - Med CC
Scen 5 - High CC
15,000
17,500
20,000
Discharge (ML/day)

Attachment 5 – Nyah frequency and duration variability

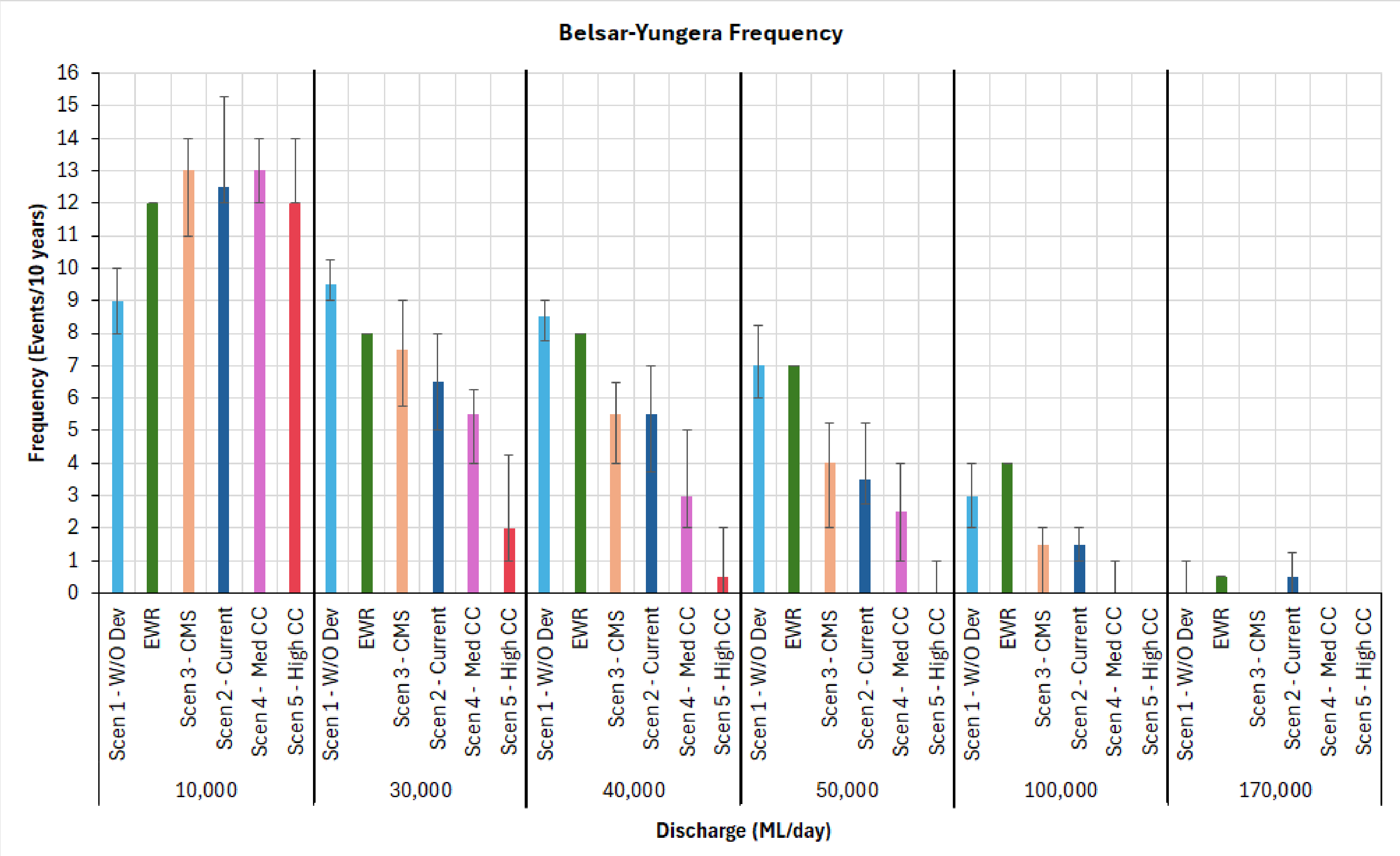
In the charts the columns represent the median frequency and duration (50th percentile), the error bars the 25th and 75th percentile frequencies and durations. EWRs were defined using average frequencies (events/10 years) and median durations only. There will be significant variability in flows using VMFRP works, but what these are will be subject to adaptive operations and management.

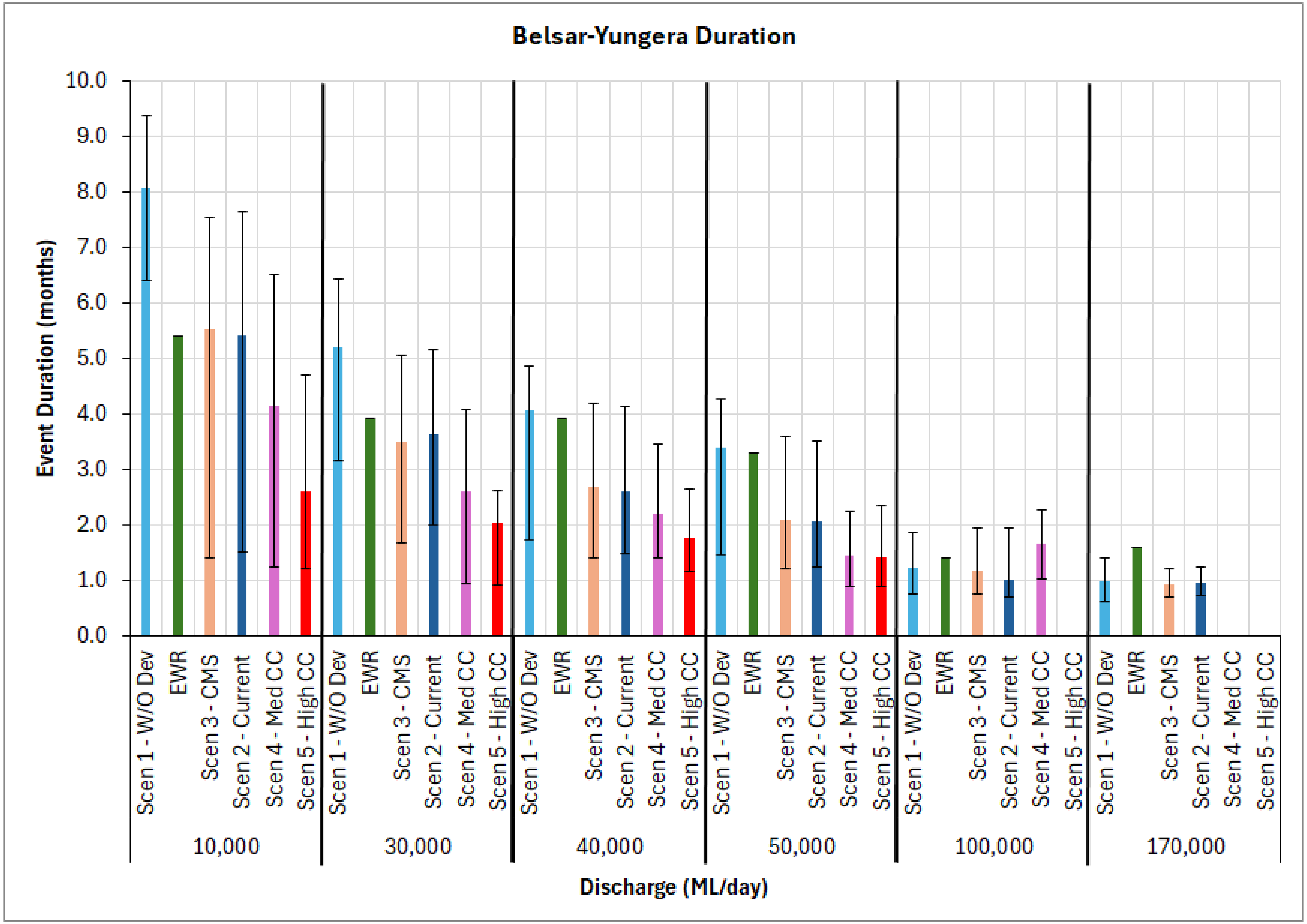



Nyah Duration
Event Duration (months)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Scen 1 - W/O Dev
EWR
Scen 3 - CMS
Scen 2 - Current
Scen 4 - Med CC
Scen 5 - High CC
15,000
17,500
20,000
25,000
Discharge (ML/day)

Attachment 6 – Belsar-Yungera frequency and duration variability

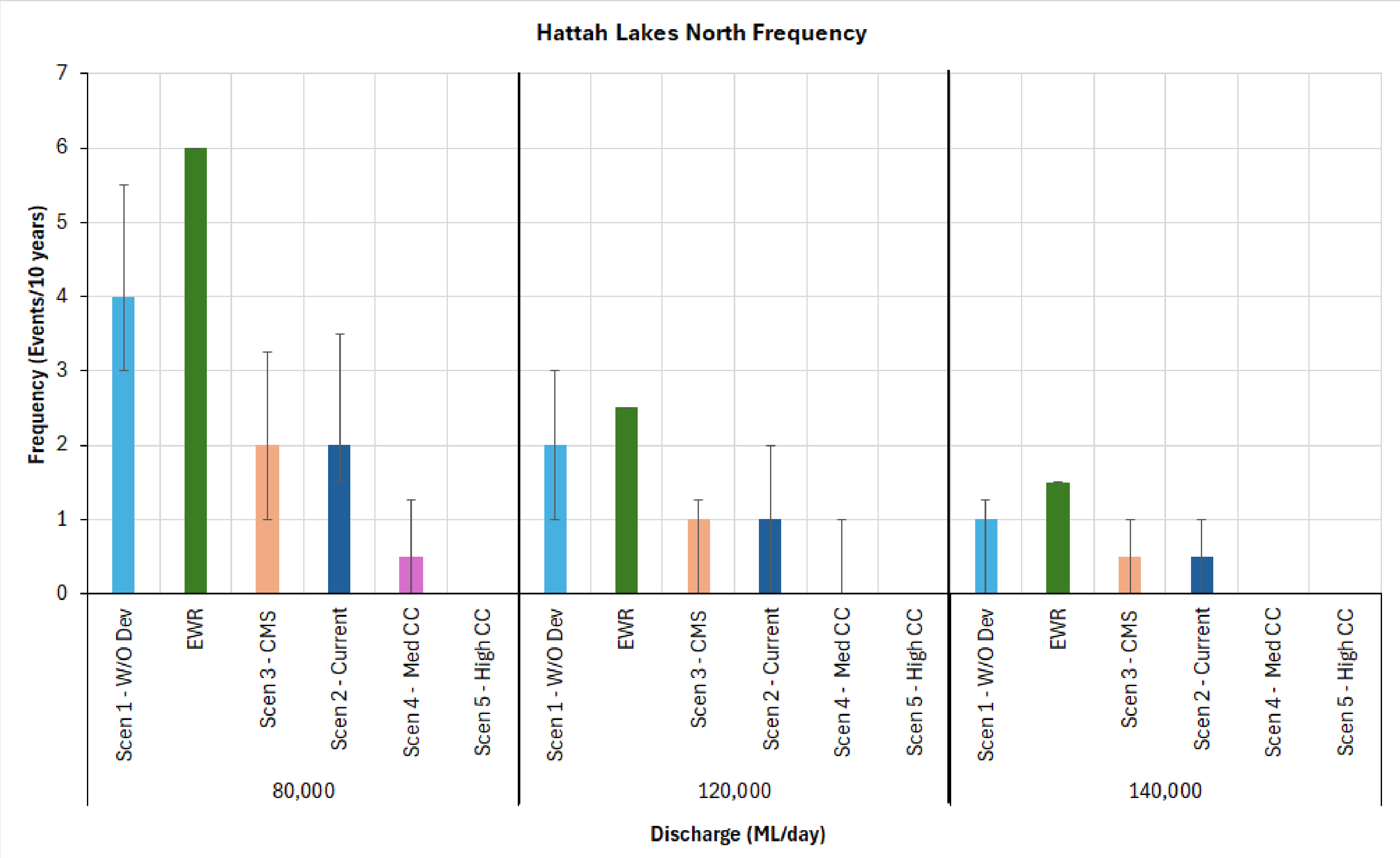
In the charts the columns represent the median frequency and duration (50th percentile), the error bars the 25th and 75th percentile frequencies and durations. EWRs were defined using average frequencies (events/10 years) and median durations only. There will be significant variability in flows using VMFRP works, but what these are will be subject to adaptive operations and management.

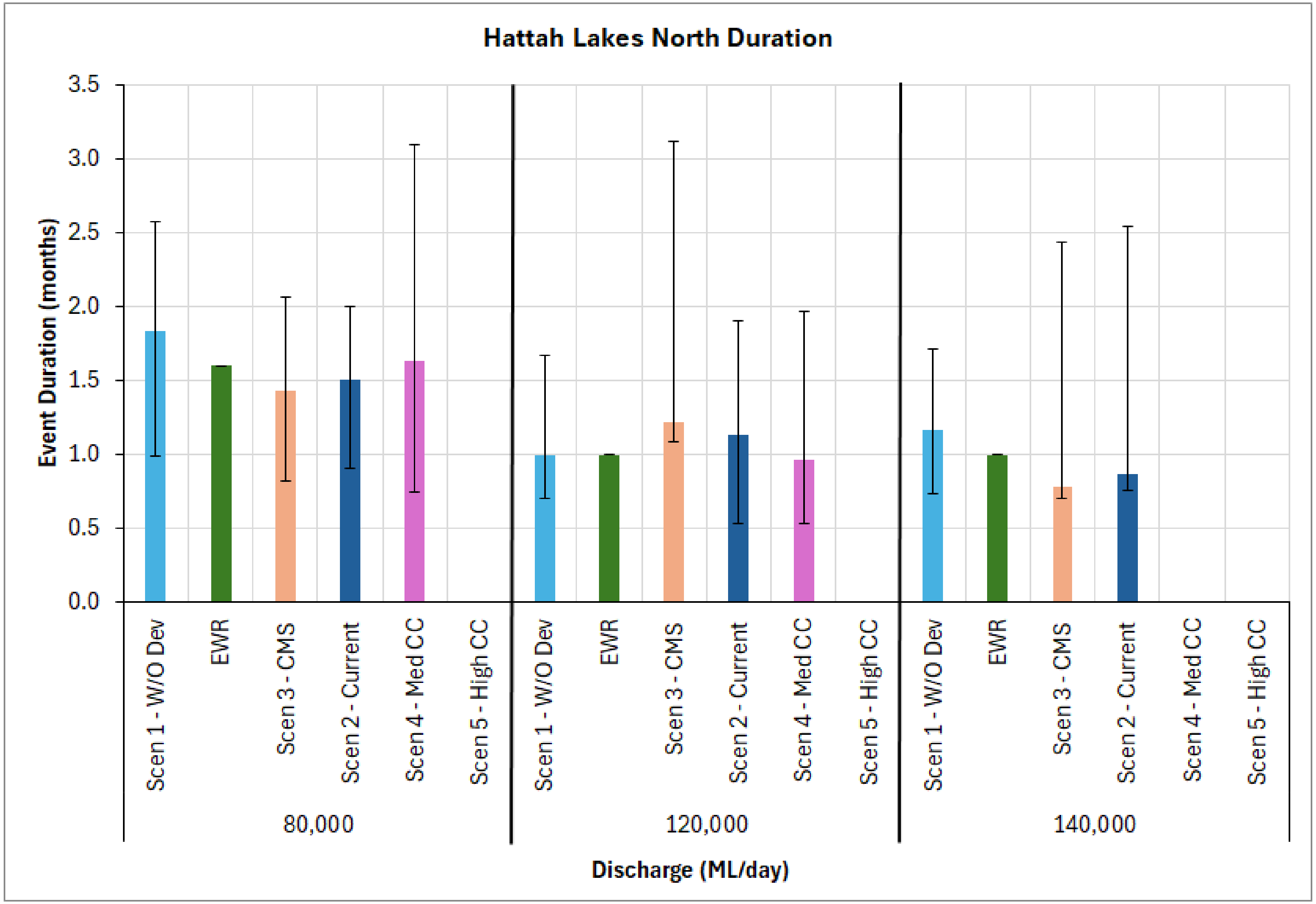



Belsar-Yungera Duration
Event Duration (months)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Scen 1 - W/O Dev
EWR
Scen 3 - CMS
Scen 2 - Current
Scen 4 - Med CC
Scen 5 - High CC
10,000
30,000
40,000
50,000
100,000
170,000
Discharge (ML/day)

Attachment 7 – Hattah Lakes North frequency and duration variability

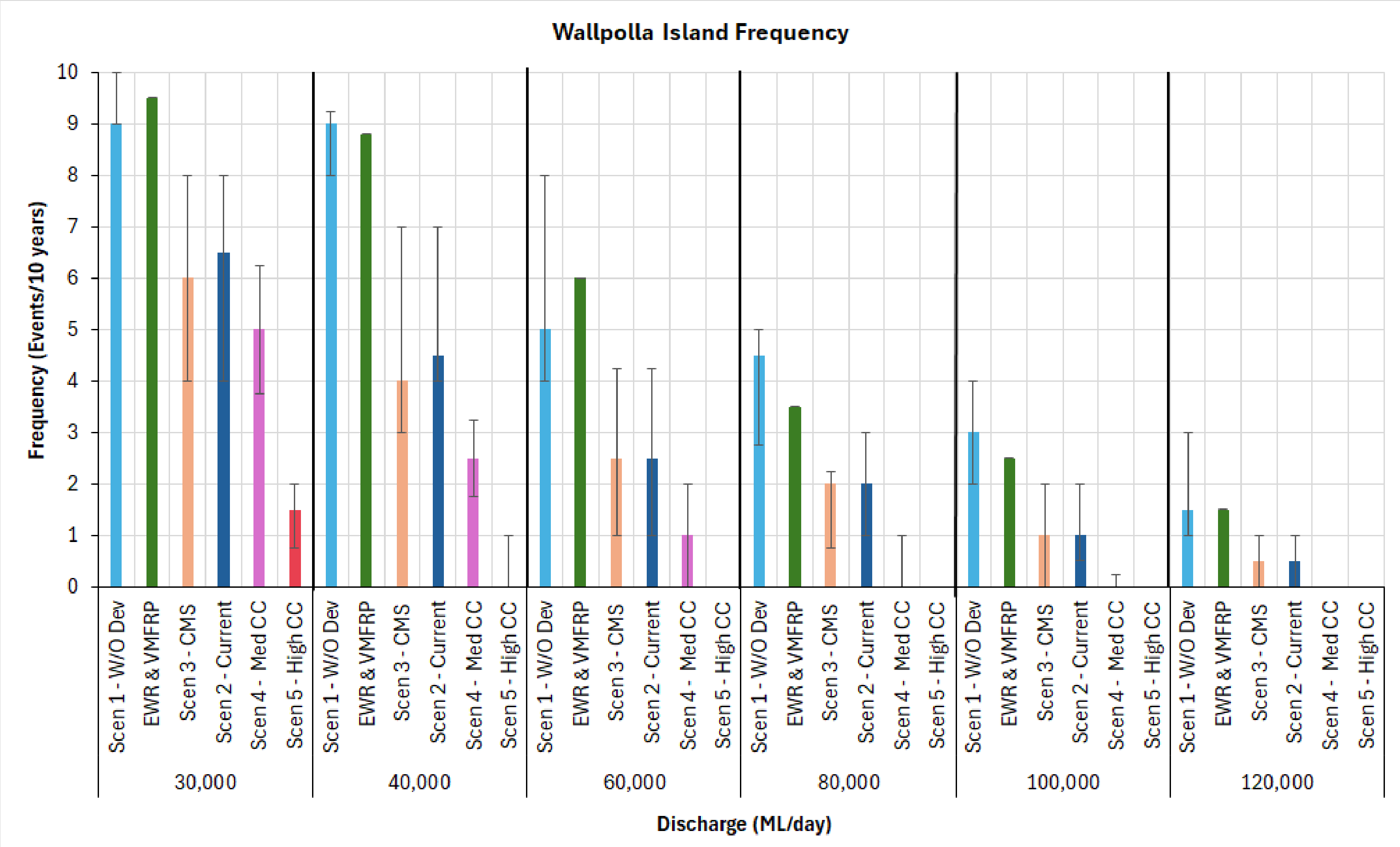
In the charts the columns represent the median frequency and duration (50th percentile), the error bars the 25th and 75th percentile frequencies and durations. EWRs were defined using average frequencies (events/10 years) and median durations only. There will be significant variability in flows using VMFRP works, but what these are will be subject to adaptive operations and management.

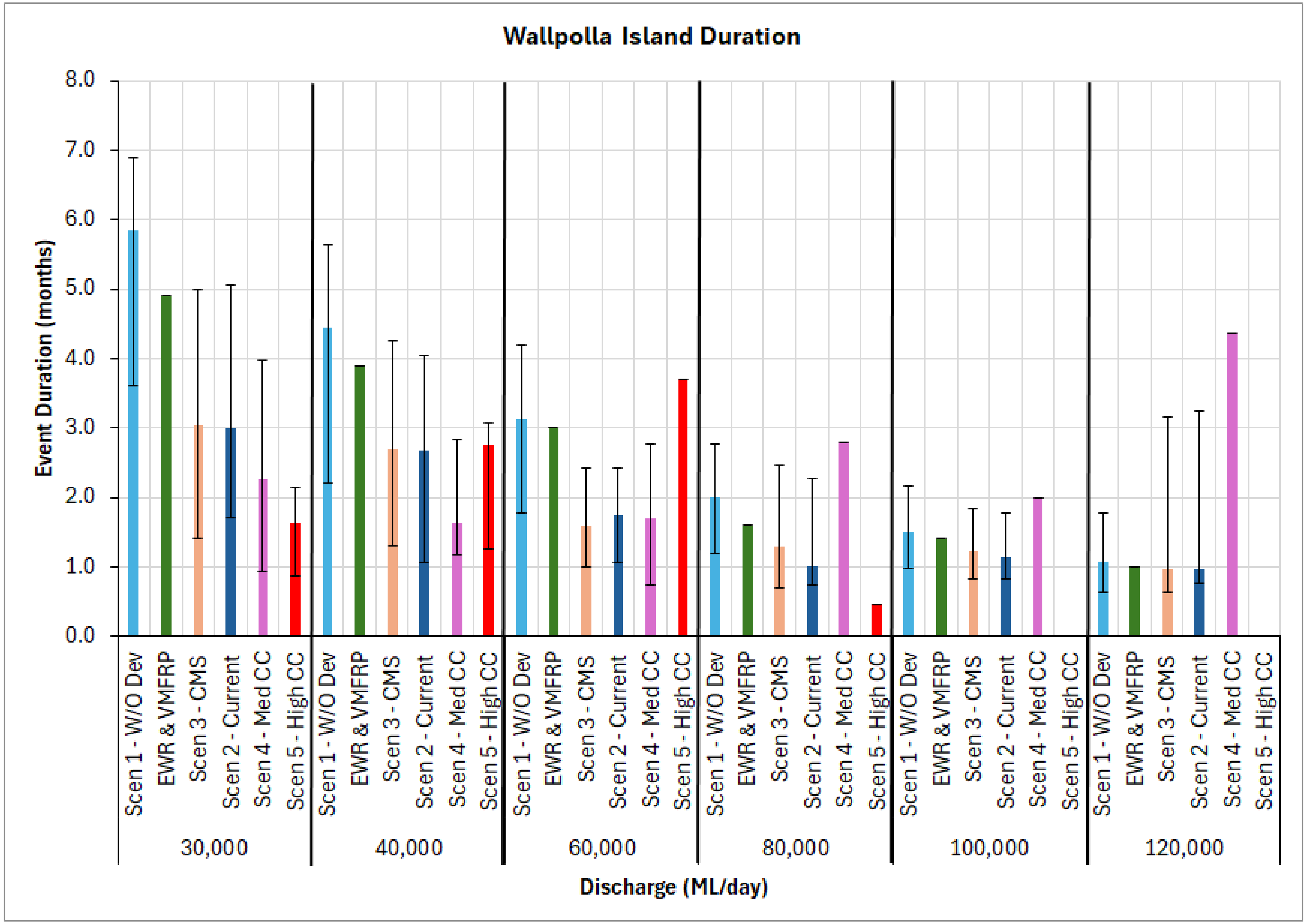



Hattah Lakes North Duration
Event Duration (months)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Scen 1 - W/O Dev
EWR
Scen 3 - CMS
Scen 2 - Current
Scen 4 - Med CC
Scen 5 - High CC
80,000
120,000
140,000
Discharge (ML/day)

Attachment 8 – Wallpolla Island frequency and duration variability

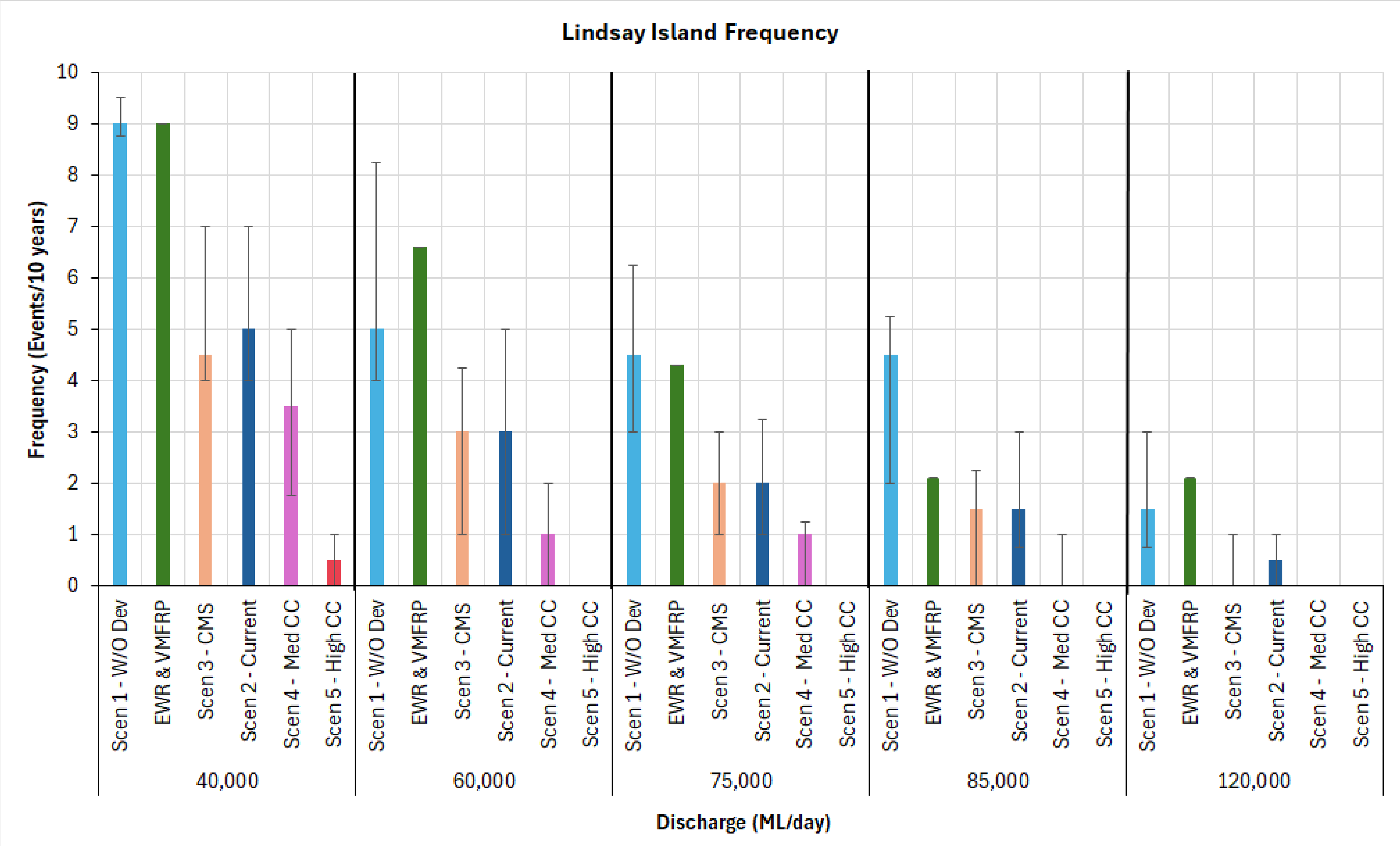
In the charts the columns represent the median frequency and duration (50th percentile), the error bars the 25th and 75th percentile frequencies and durations. EWRs were defined using average frequencies (events/10 years) and median durations only. There will be significant variability in flows using VMFRP works, but what these are will be subject to adaptive operations and management.

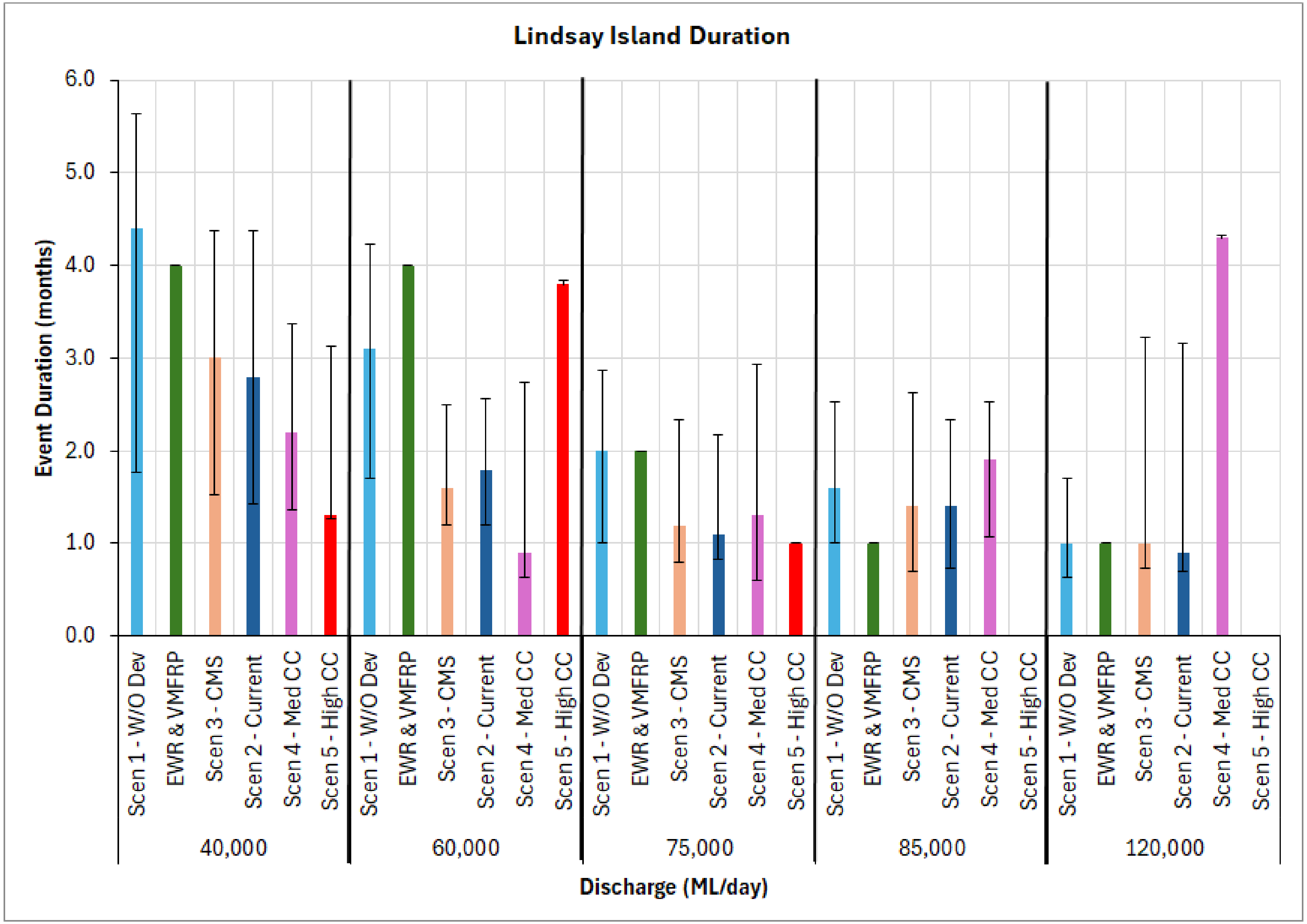



Wallpolla Island Duration
Event Duration (months)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Scen 1 - W/O Dev
EWR & VMFRP
Scen 3 - CMS
Scen 2 - Current
Scen 4 - Med CC
Scen 5 - High CC
30,000
40,000
60,000
80,000
100,000
120,000
Discharge (ML/day)

Attachment 9 – Lindsay Island frequency and duration variability

In the charts the columns represent the median frequency and duration (50th percentile), the error bars the 25th and 75th percentile frequencies and durations. EWRs were defined using average frequencies (events/10 years) and median durations only. There will be significant variability in flows using VMFRP works, but what these are will be subject to adaptive operations and management.




Lindsay Island Duration
Event Duration (months)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Scen 1 - W/O Dev
EWR & VMFRP
Scen 3 - CMS
Scen 2 - Current
Scen 4 - Med CC
Scen 5 - High CC
40,000
60,000
75,000
85,000
120,000
Discharge (ML/day)

Attachment 10 – Ecological significance of differences in flow regimes

Significance of the potential ecological disbenefit in using CMP compared to VMFRP works: Highly Significant (HS) is shaded red; Significant (S) is shaded orange; Not Significant (NS) is shaded green.

The disbenefit is not assessed if the recommended EWR (and VMFRP) median or average frequency and duration of flows are less than the central 50% range of without development flows, i.e. VMFRP is not targeting frequency or duration of flows that are close to natural. These are marked as Not Assessed (NA) in the table below.

			EWR			Frequency			Duration		
No.	Site	EWRC	Flow Threshold (ML/day)	Average Frequency	Median Duration	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change	CMP Historical Climate	CMP Median Climate Change	CMP High Climate Change
1	Gunbower	Permanent Wetland	25,000	10	2.7	HS	HS	HS	NS	S	HS
2	Gunbower	Semi-Permanent Wetland	30,000	8	3	HS	HS	HS	NS	S	S
3	Gunbower	Red Gum Forest and Temporary Wetlands	35,000	8	2	HS	HS	HS	NS	S	HS
4	Gunbower	Red Gum Forest and Woodland	50,000	4	1.2	S	HS	HS	NS	NS	HS
5	Guttrum and Benwell Forests	Semi-Permanent Wetland	21,000	9	5	HS	HS	HS	S	S	HS
6	Guttrum and Benwell Forests	Red Gum Forest (Benwell)	24,000	8	4.1	HS	HS	HS	NS	S	S
7	Guttrum and Benwell Forests	Red Gum Forest (Guttrum)	26,000	8	4.1	HS	HS	HS	NS	S	S
8	Guttrum and Benwell Forests	Red Gum Forest and Woodland	27,000	4	3	NA	NA	NA	NS	S	S
9	Vinifera	Seasonal Wetland	15,000	10	4.9	NS	HS	HS	S	S	HS
10	Vinifera	Red Gum Swamp Forest	17,500	9	3.9	S	HS	HS	S	S	HS
11	Vinifera	Red Gum Forest and Woodland	20,000	9	3.9	HS	HS	HS	S	S	HS
12	Nyah	Seasonal Anabranch and Billabong	15,000	10	4.9	NA	NA	NA	S	S	HS
13	Nyah	Seasonal Wetland	17,500	9	3.9	S	HS	HS	S	S	HS
14	Nyah	Red Gum Swamp Forest	20,000	9	3.9	HS	HS	HS	S	S	HS
15	Nyah	Red Gum Forest and Woodland	25,000	7	2.5	HS	HS	HS	NS	S	S
16	Belsar-Yungera	Watercourses	10,000	12	5.4						
17	Belsar-Yungera	Semi-permanent Wetlands	30,000	8	3.9	NA	NA	NA	NS	S	HS
18	Belsar-Yungera	Red Gum Forest and Woodland	40,000	8	3.9	HS	HS	HS	NS	NS	NS
19	Belsar-Yungera	Lignum Shrubland and Woodland	50,000	7	3.3	HS	HS	HS	NS	S	S
20	Belsar-Yungera	Black Box Woodland	100,000	4	1.4	S	HS	HS	NS	NS	HS
21	Belsar-Yungera	Floodplain Lake	170,000	0.5	1.6	NS	NS	NS	NS	HS	HS
22	Hattah Lakes North	Red Gum Forest and Woodland (Chalka North Water Management Area)	80,000	6	1.6	S	HS	HS	NS	NS	HS
23	Hattah Lakes North	Black Box Woodland (Chalka North and Lake Boolca Water Management Areas)	120,000	2.5	1	NS	S	HS	NS	NS	HS
24	Hattah Lakes North	Episodic Wetlands (Lake Boolca Water Management Area)	140,000	1.5	1	NS	NS	NS	NS	HS	HS
25	Wallpolla Island	Watercourses	30,000	9.5	4.9	HS	HS	HS	S	S	HS
26	Wallpolla Island	Semi-permanent Wetlands	40,000	8.8	3.9	HS	HS	HS	NS	S	NS
27	Wallpolla Island	Temporary Wetlands	60,000	6	3	S	HS	HS	S	S	NS
28	Wallpolla Island	Red Gum Forest and Woodlands and Lignum Shrubland and Woodlands	80,000	3.5	1.6	HS	HS	HS	NS	NS	HS
29	Wallpolla Island	Black Box Woodland	100,000	2.5	1.4	S	HS	HS	NS	NS	HS
30	Wallpolla Island	Alluvial Plain	120,000	1.5	1	S	HS	HS	NS	NS	HS
31	Lindsay Island	Semi-permanent Wetlands	40,000	9	4	HS	HS	HS	NS	NS	S
32	Lindsay Island	Temporary Wetlands	60,000	6.6	4	S	HS	HS	S	S	NS
33	Lindsay Island	Red Gum Forest and Woodlands and Lignum Shrubland and Woodlands	75,000	4.3	2	S	HS	HS	NS	NS	NS
34	Lindsay Island	Black Box Woodlands	85,000	2.1	1	S	HS	HS	NS	NS	HS
35	Lindsay Island	Alluvial Plain	120,000	2.1	1	S	HS	HS	NS	NS	HS